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Integration of PjBL-STEM in IPAS Learning: An Effort to Stimulate Creative Thinking and Sustainability Awareness in Elementary Schools

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ABSTRACT

Twenty-first-century education requires learning that is not only oriented toward conceptual mastery but also able to stimulate students' creative thinking skills and sustainability awareness. However, previous studies have mostly examined PjBL-STEM separately in relation to learning outcomes or creative thinking, while research integrating PjBL-STEM into IPAS learning to stimulate both creative thinking and sustainability awareness remains limited. This study aims to examine the integration of Project-Based Learning with the Science, Technology, Engineering, and Mathematics approach (PjBL-STEM) in IPAS learning to stimulate elementary school students' creative thinking skills and sustainability awareness. This study employed a quantitative, quasi-experimental design with a pretest-posttest control group. The research subjects were 45 sixth-grade students from SD Negeri 1 Cisaat, comprising 24 in the experimental class and 21 in the control class. The research instruments included a creative thinking skills test, a sustainability awareness questionnaire, and a learning implementation observation sheet. The data were analyzed using N-Gain and t-test with the assistance of IBM SPSS Statistics 25. The results showed that PjBL-STEM implementation reached 100%, indicating that all learning stages were carried out according to the designed syntax. Students' creative thinking skills in the experimental class increased from a mean score of 45.04 to 72.79, with an N-Gain of 0.65 in the moderate category, while the control class obtained an N-Gain of 0.29 in the low category. Students' sustainability awareness reached 96.20%, which was categorized as very strong. Therefore, integrating PjBL-STEM into IPAS learning effectively stimulates elementary school students' creative thinking skills and sustainability awareness. This study implies that teachers can use PjBL-STEM as a contextual learning strategy to connect IPAS concepts with real environmental problems and sustainability-oriented project activities.

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1. INTRODUCTION

Twenty-first-century education requires educational institutions to focus not only on the mastery of conceptual knowledge but also on the development of holistic competencies relevant to global life challenges. These competencies include critical thinking, creativity, communication, and collaboration, commonly known as the 4C skills. These skills are considered essential because they equip students to face life, work, and complex problems in the twenty-first century [1]. In the elementary school context, strengthening these competencies is increasingly important because students are at the early stage of developing ways of thinking, scientific attitudes, social concern, and environmental awareness.

One subject with strong potential to develop twenty-first-century competencies is Natural and Social Sciences. In the Merdeka Curriculum, Natural and Social Sciences are designed to help students understand natural and social phenomena in an integrated manner, develop reflective thinking skills, and solve problems through meaningful learning experiences [2]. Therefore, Natural and Social Sciences learning should ideally not be implemented verbally and in a one-way manner, but through activities that provide students with opportunities to observe, ask questions, experiment, design, test, and reflect on solutions to real problems in their surrounding environment.

One approach relevant to these characteristics is integrating Project-Based Learning (PjBL) with the Science, Technology, Engineering, and Mathematics (STEM) approach. PjBL-STEM provides students with opportunities to learn through real projects involving investigation, design, product creation, testing, and evaluation. Through this approach, students not only learn scientific concepts theoretically but also connect them to the use of simple technology, engineering principles, and mathematical calculations. Thus, learning becomes more contextual because students are trained to understand problems, develop ideas, create solutions, and produce products or prototypes relevant to everyday life [3], [4].

Creative thinking is one of the essential abilities that needs to be stimulated from the elementary school level. The OECD explains that creative thinking involves generating diverse and original ideas, as well as evaluating and improving them across various problem-solving contexts [5], [6]. In Natural and Social Sciences learning, this ability is needed so that students are not only able to understand concepts but also to develop alternative solutions to problems in their surrounding environment. In addition to creative thinking, twenty-first-century learning also needs to foster sustainability awareness, namely, students' awareness of the importance of maintaining environmental, social, and future sustainability. Education for sustainable development emphasizes the importance of knowledge, skills, values, and attitudes so that students can make informed decisions and take responsible actions for the environment and society [7].

However, the practice of Natural and Social Sciences learning in elementary schools still faces various problems. Learning often takes place conventionally, is teacher-centered, and provides limited opportunities for students to engage in exploratory activities and real problem solving [8]. Natural and Social Sciences materials, which should be closely related to students' lives, are often delivered through verbal explanations and written assignments [9]. This condition limits students' opportunities to develop ideas, conduct simple experiments, design solutions, and reflect on the relationships between concepts in the Natural and Social Sciences and sustainability issues. As a result, students' creative thinking skills and sustainability awareness have not developed optimally.

A preliminary study conducted by the author through observations of Natural and Social Sciences learning in Grade VI at SD Negeri 1 Cisaat showed that the learning process tended to remain informative and had not fully utilized media, real learning resources, or project activities relevant to students' lives. The teacher mostly delivered material through stories or explanations and then assigned tasks without involving students in investigation, design, or product-making activities. Students were also not accustomed to expressing alternative ideas, developing creative solutions, or showing concern for environmental problems around them. These preliminary findings indicate the need for active, contextual, and sustainability-oriented innovations in Natural and Social Sciences learning.

However, IPAS learning in elementary schools is still often implemented through teacher-centered instruction, verbal explanation, and written assignments. This condition limits students' opportunities to explore ideas, develop creative solutions, and understand the relevance of science to sustainability issues. A preliminary study conducted in Grade VI at SD Negeri 1 Cisaat showed that learning activities were still largely informative and had not fully involved students in investigation, project design, product creation, or reflection on environmental problems. Students were also not yet accustomed to expressing alternative ideas, developing creative solutions, or linking IPAS concepts with actions to protect the environment.

Several previous studies have shown that PjBL-STEM contributes positively to the development of students' creative thinking skills. Surmilasari, Marini, and Usman found that a STEM-based PjBL model affected elementary school students' creative thinking skills in mathematics learning [10]. Pramesti, Probosari, and Indriyanti also showed that PjBL-STEM with a low-carbon context was effective in improving students' creative thinking skills [11]. In addition, Utomo showed that PjBL-STEM learning was oriented toward improving students' creative thinking skills [12]–[14]. In the context of environmental awareness, Anggraini showed that STEAM-PjBL learning activities could be used as a strategy to improve elementary school students' environmental awareness [15]. Another finding by Pada, Chanunan, and Rahmat showed that an Ethno-STEM approach oriented toward the Sustainable Development Goals (SDGs) promoted elementary school students' environmental awareness through Natural and Social Sciences learning [16].

Nevertheless, previous studies still tend to examine creative thinking and environmental or sustainability awareness separately. Studies on creative thinking usually emphasize students' ability to generate and elaborate ideas, while studies on environmental awareness focus more on attitudes and concern for the environment. Limited research has examined how PjBL-STEM in elementary IPAS learning can be designed to stimulate both aspects simultaneously. In addition, previous studies often focus on the model's effectiveness but pay less attention to how sustainability issues are embedded in the project process through problem identification, solution design, prototype development, testing, and reflection.

Based on this gap, this study examines the integration of PjBL-STEM in Grade VI IPAS learning on the topic of Protecting the Earth. The contribution of this study lies in its focus on combining creative thinking development and sustainability awareness within one project-based STEM learning design. Unlike previous studies that tend to emphasize either creative thinking or environmental awareness separately, this study positions sustainability issues as the main project context and measures students' improvement in creative thinking and sustainability awareness after learning.

Thus, this study aims to examine the integration of PjBL-STEM into IPAS learning to stimulate elementary school students' creative thinking skills and sustainability awareness. Practically, this study is expected to provide an alternative learning design for teachers to implement IPAS learning that is active, contextual, project-oriented, and connected to real environmental problems.

2. METHOD

This study employed a quantitative, quasi-experimental design. The quantitative approach was selected because this study aimed to measure changes in students' creative thinking skills before and after the treatment and to compare learning outcomes between the experimental and control classes. The quasi-experimental method was used because the research subjects were members of naturally formed classroom groups; therefore, the researcher did not conduct full individual randomization as in a true experiment. Quasi-experimental designs are commonly used in educational contexts because they allow researchers to examine the effect of a treatment in real classroom situations without disrupting the existing learning structure [17]–[19].

The research design used was the Pretest-Posttest Control Group Design. This design involved two groups, namely the experimental class and the control class. Both groups were given a pretest to determine their initial creative thinking skills. The experimental class then received treatment in the form of Natural and Social Sciences learning using the Project-Based Learning model integrated with STEM, or PjBL-STEM, while the control class received learning without STEM integration. After the treatment, both groups were given a posttest to determine the improvement in students' creative thinking skills. A pretest-posttest design with a control group allows researchers to compare changes in learning outcomes between the treatment and comparison groups [19]–[22].

The research design is presented in the following table.

Table 1. Research Design

Group	Pretest	Treatment	Posttest
Experimental class	O_1	X_1	O_2
Control class	O_1	X_2	O_2

Notes:

O_1 = pretest of creative thinking skills

O_2 = Posttest of creative thinking skills

X_1 = Natural and Social Sciences learning using the PjBL-STEM model
X_2 = Natural and Social Sciences learning without STEM integration

This study was conducted at SD Negeri 1 Cisaat, Surade District, Sukabumi Regency. The research subjects were Grade VI students from two classes: the experimental and the control. The sampling technique used was saturated sampling, because all members of the Grade VI population were included as the research sample. The research sample consisted of 45 students, 24 in the experimental class and 21 in the control class. The selection of Grade VI students as research subjects was based on the characteristics of phase C elementary school students, who are beginning to think more systematically, conduct simple observations, work collaboratively, and develop solutions to problems close to their daily lives. These characteristics are relevant to PjBL-STEM learning, which requires students to identify problems, design solutions, create products, and reflect on project outcomes.

This study consisted of an independent variable and dependent variables. The independent variable was the PjBL-STEM learning model in Natural and Social Sciences learning on the topic of *Protecting the Earth*. The first dependent variable was students' creative thinking skills, and the second was students' sustainability awareness.

Creative thinking skills in this study were measured using a case-study-based test that included indicators of creative thinking. These indicators reflected students' ability to generate ideas, develop alternative solutions, and elaborate ideas in greater detail. Meanwhile, sustainability awareness was measured using a questionnaire that assessed students' awareness of sustainability issues, particularly environmental concerns, resource use, and Earth protection.

The data collection techniques in this study included tests, questionnaires, and observation. Tests were used to assess students' creative thinking skills before and after learning. The questionnaire was used to obtain data on students' sustainability awareness after PjBL-STEM learning. Observation was used to collect data on the implementation of learning during the application of the PjBL-STEM model in the experimental class. Pretest and posttest data were used to determine the improvement in creative thinking skills. Questionnaire data were used to determine students' level of sustainability awareness. Meanwhile, observation data were used to describe the implementation of the PjBL-STEM learning syntax.

The research data were analyzed quantitatively using descriptive and inferential analyses. Descriptive analysis was used to determine the mean pretest and posttest scores, the percentage of learning implementation, and the percentage of sustainability awareness. Inferential analysis was used to determine differences in the improvement of creative thinking skills between the experimental and control classes. The improvement in creative thinking skills was analyzed using the Normalized Gain (N-Gain) formula. N-Gain analysis was used to determine the effectiveness of score improvement from the pretest to the posttest. Hake explains that N-Gain can be used to measure improvement in students' understanding by comparing the actual score obtained with the maximum possible score [23]. The N-Gain formula used is as follows:

$$N - Gain = \frac{Posttest\ score - Pretest\ score}{Maximum\ score - Pretest\ score} \quad 1)$$

The criteria for interpreting N-Gain are presented below.

Table 2. N-Gain Interpretation Criteria

N-Gain Value	Category
g ≥ 0.70	High
0.30 ≤ g < 0.70	Moderate
g < 0.30	Low

Furthermore, pretest and posttest data were analyzed using statistical tests in IBM SPSS Statistics 25. Before the difference test was conducted, the data were first tested for normality and homogeneity. The normality test was used to assess whether the data were normally distributed, and the homogeneity test was used to assess whether the variances of the two groups were homogeneous. If the data met the assumptions of normality and homogeneity, the analysis proceeded with a t-test to determine differences between the experimental and control classes. IBM provides an official citation format for the use of SPSS software in research, including SPSS Statistics version 25 [6].

Sustainability awareness data were analyzed using percentages with the following formula:

$$Percentage = \frac{obtain\ score}{Maximum\ score} \times 100\% \quad 2)$$

The percentage results were then interpreted based on the categories of sustainability awareness levels. The higher the percentage, the stronger students' sustainability awareness after participating in PjBL-STEM learning.

The research instruments were validated before being used in the study. Content validity was examined through expert judgment involving elementary education and science learning experts. The experts reviewed the suitability of the creative thinking test items, sustainability awareness questionnaire, and learning implementation observation sheet based on the research objectives, indicators, language clarity, and relevance to the PjBL-STEM learning syntax. Revisions were made based on expert suggestions to improve item clarity and indicator alignment. In addition, a limited pilot test was conducted with students who had characteristics similar to those of the research subjects to ensure that the instructions, test items, and questionnaire statements were understandable to elementary school students.

The reliability of the sustainability awareness questionnaire was tested using Cronbach's alpha. The reliability test showed that the questionnaire had acceptable internal consistency, indicating that the instrument was reliable for measuring students' sustainability awareness. The creative thinking test was scored using a rubric based on indicators of fluency, flexibility, originality, and elaboration. To maintain scoring consistency, the rubric served as a guide for assessing students' answers.

The intervention was conducted over several learning sessions on the IPAS topic of Protecting the Earth. In the experimental class, learning activities followed the PjBL-STEM syntax, including determining essential questions, designing project plans, developing project schedules, monitoring project progress, testing project results, and evaluating learning experiences. Students identified environmental problems around the school, discussed possible solutions, designed simple project products, prepared tools and materials, created prototypes from available materials, tested the products, revised them when necessary, and presented their project results. In the control class, learning was conducted without STEM integration, using teacher explanations, discussion, and written assignments on the same topic.

Before conducting inferential statistical analysis, assumption tests were performed. The normality test was used to assess whether the pretest, posttest, and N-Gain data were normally distributed, and the homogeneity test was used to determine whether the variances between the experimental and control groups were homogeneous. The results showed that the data met the assumptions of normality and homogeneity, so the analysis proceeded using an independent-samples t-test to compare the improvement in creative thinking skills between the experimental and control classes.

3. RESULTS AND DISCUSSION

3.1. Implementation of the PjBL-STEM Model in Natural and Social Sciences Learning

The implementation of the Project-Based Learning model integrated with Science, Technology, Engineering, and Mathematics, or PjBL-STEM, in Natural and Social Sciences learning on the topic of *Protecting the Earth* showed a very good level of implementation. Based on the observation results, all learning stages were conducted in accordance with the syntax outlined in the teaching module. The percentage of learning implementation reached 100%, indicating that the teacher and students followed the entire PjBL-STEM learning sequence, from determining the essential question to evaluating the learning experience.

Based on Table 3, all stages of the PjBL-STEM learning syntax were implemented at 100%. This shows that Natural and Social Sciences learning on the topic of *Protecting the Earth* can be fully implemented through the PjBL-STEM stages. Each learning stage demonstrated students' active involvement, beginning with identifying environmental problems, designing solutions, developing work schedules, creating products, testing results, and reflecting on learning experiences. The implementation of all syntax stages indicates that the PjBL-STEM model can be applied systematically to Grade VI elementary school students.

At the stage of determining the essential question, the teacher presented real phenomena close to students' lives, namely, environmental problems and waste utilization around the school. These phenomena were used as initial stimuli to build students' curiosity and guide them toward investigative questions. This stage strengthened the science aspect by encouraging students to observe environmental conditions, understand the causes of problems, and relate them to concepts in the Natural and Social Sciences within the Protecting the Earth topic. Through this activity, students began to understand that scientific concepts are not only learned as theory, but can also be used to interpret and solve real problems in everyday life.

Table 3. Implementation of the PjBL-STEM Learning Syntax

No.	PjBL-STEM Syntax	Learning Activities	STEM Aspects Emerging	Implementation
1	Determining the essential question	The teacher presented environmental issues in the Protecting the Earth topic and guided students in formulating investigative questions.	Science	100%
2	Designing project planning	Students designed solutions, determined tools and materials, created product sketches, and prepared project work steps.	Engineering, Technology	100%
3	Developing the schedule	Students divided group tasks, determined work time, and arranged the stages of project activities.	Engineering	100%
4	Monitoring the process and progress of the project	The teacher facilitated students during the product-making process, provided guidance, and helped overcome technical obstacles.	Science, Engineering	100%
5	Testing project results	Students tested the product's suitability for the project objectives, identified its weaknesses, and made improvements.	Engineering, Mathematics	100%
6	Evaluating the experience	Students presented their project results, reflected on the learning process, and linked the project to environmental awareness.	Science, Technology, Engineering, Mathematics	100%
	Mean implementation			**100%**

The next stage was designing the project planning. At this stage, students worked in groups to design solutions to the environmental problems they had identified. They developed ideas, determined tools and materials, created product sketches, and designed work steps. This stage highlighted the engineering aspect, as students were trained to design products that met specific needs, functions, and criteria. In addition, the technology aspect also emerged through the use of simple tools and specific techniques that helped students in the product-making process. In the context of STEM learning, technology is not only understood as digital devices, but also as the use of tools, techniques, and procedures that help humans solve problems more effectively [24]–[26].

At the scheduling stage, students determined task distribution, arranged the sequence of activities, and estimated the time needed to complete the project. This activity trained students to work in a planned, responsible, and disciplined manner, in accordance with group agreements. Scheduling also became an important part of project-based learning because it helped students understand that problem-solving requires a systematic process, not merely the production of a final product. Thus, students learned not only to create a product but also to manage a collaborative work process.

The monitoring stage of the project was carried out while students worked on their products. At this stage, the teacher acted as a facilitator, observing students’ work processes, providing guidance, and assisting them when they encountered technical obstacles. The teacher’s role no longer centered on being the source of information but shifted to that of a mentor who provided prompting questions, feedback, and conceptual reinforcement. This facilitative role is important in PjBL-STEM learning, particularly in elementary schools, because students still need guidance to keep investigation, design, and engineering activities aligned with the learning objectives [3].

Furthermore, during testing, students assessed the suitability of the products they had created against the initial project objectives. They observed the strengths and weaknesses of the products, discussed possible improvements, and made revisions when necessary. This stage shows that PjBL-STEM learning is not only focused on the final product but also on thinking processes, testing, and solution refinement. The mathematics aspect appeared when students measured materials, adjusted material sizes, estimated material needs, and considered the efficiency of material use. This process of testing and revision trained students to understand that effective solutions are obtained through experimentation, evaluation, and continuous improvement.

Learning ended with the evaluation stage. At this stage, students presented their project results, explained the production process, described the obstacles they encountered, and reflected on the project's environmental benefits. Presentation activities provided students with opportunities to develop scientific communication skills, explain the rationale behind their product designs, and connect project experiences with Natural and Social Sciences concepts. In addition, reflection activities helped students understand that learning does not merely produce a product, but also shapes ways of thinking, concern, and responsibility for the environment.

Overall, the implementation of the PjBL-STEM model in Natural and Social Sciences learning shows that integrating projects and STEM can transform learning from a passive, information-based approach into a more active, contextual, and meaningful one. Students not only learned about protecting the Earth, but also directly experienced the process of identifying problems, designing solutions, creating products, testing results, and reflecting on their impacts. This finding is consistent with the characteristics of PjBL, which positions students at the center of learning through real-world problem-solving, product development, and reflection on learning processes and outcomes [3]. With a learning implementation rate of 100%, the PjBL-STEM model is feasible for Grade VI Natural and Social Sciences learning and provides a basis for examining its impact on students' creative thinking skills and sustainability awareness.

3.2. Improvement of Students' Creative Thinking Skills

Students' creative thinking skills were measured using a case-study-based test administered before and after the learning process. The initial test, or pretest, was given to assess students' initial ability, while the posttest was administered after the learning process was completed. In the experimental class, learning was conducted using the PjBL-STEM model, whereas in the control class, learning was conducted without STEM integration. The pretest and posttest results were analyzed using mean scores and N-Gain values to assess improvement in students' creative thinking skills.

In general, the study's results show that the experimental class improved more in creative thinking skills than the control class. This difference can be seen from the mean pretest, posttest, and N-Gain scores of each class, as presented in Table 4.

Table 4. Recapitulation of Students' Creative Thinking Skills Results

Class	Number of Students	Mean Pretest	Mean Posttest	N-Gain	N-Gain Percentage	Category
Control	21	41.90	54.10	0.29	29.72%	Low
Experimental	24	45.04	72.79	0.65	65.54%	Moderate

Based on Table 4, the experimental class obtained a mean pretest score of 45.04, which increased to 72.79 in the posttest. This improvement resulted in an N-Gain value of 0.65, or 65.54%, which falls into the moderate category. Meanwhile, the control class obtained a mean pretest score of 41.90, which increased to 54.10 in the posttest, with an N-Gain value of 0.29, or 29.72%, which falls into the low category. This comparison shows that the improvement in creative thinking skills in the experimental class was higher than that in the control class.

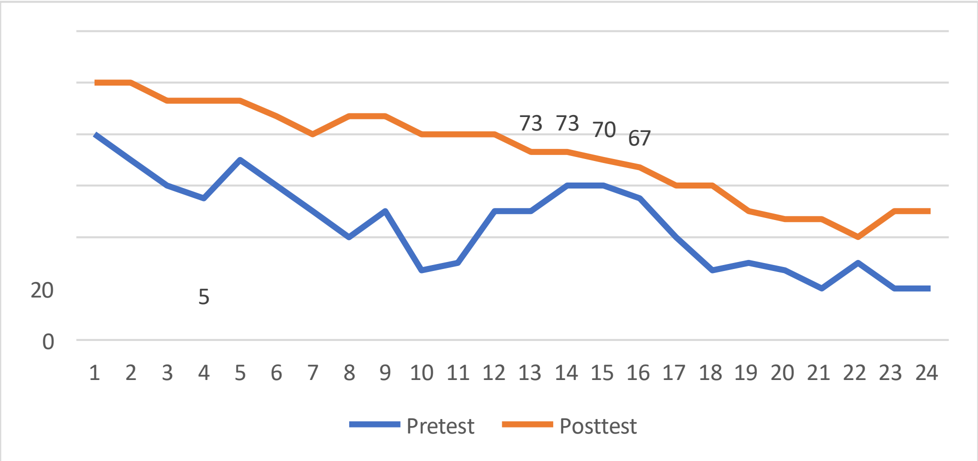

Figure 1. Improvement of Creative Thinking Skills in the Experimental Class

Figure 1 shows the comparison of pretest and posttest scores for each student's creative thinking skills in the experimental class. Based on the figure, almost all students experienced an increase in scores after participating in learning using the PjBL-STEM model. The mean score increased from 45.04 in the pretest to 72.79 in the posttest. This improvement indicates that project-based STEM learning provided students with a more active, contextual, and challenging learning experience.

The improvement in the experimental class can be explained by the characteristics of PjBL-STEM, which provide students with opportunities to engage in real-world problem-solving. In this learning process, students did not merely receive information; they also observed environmental problems, developed ideas, designed products, used tools and materials, conducted measurements, and evaluated project results. These activities encouraged students to generate ideas, develop alternative solutions, and elaborate their ideas into concrete products. This aligns with the view that project-based learning can encourage students to construct knowledge through investigation, collaboration, and the creation of meaningful products [27]–[30].

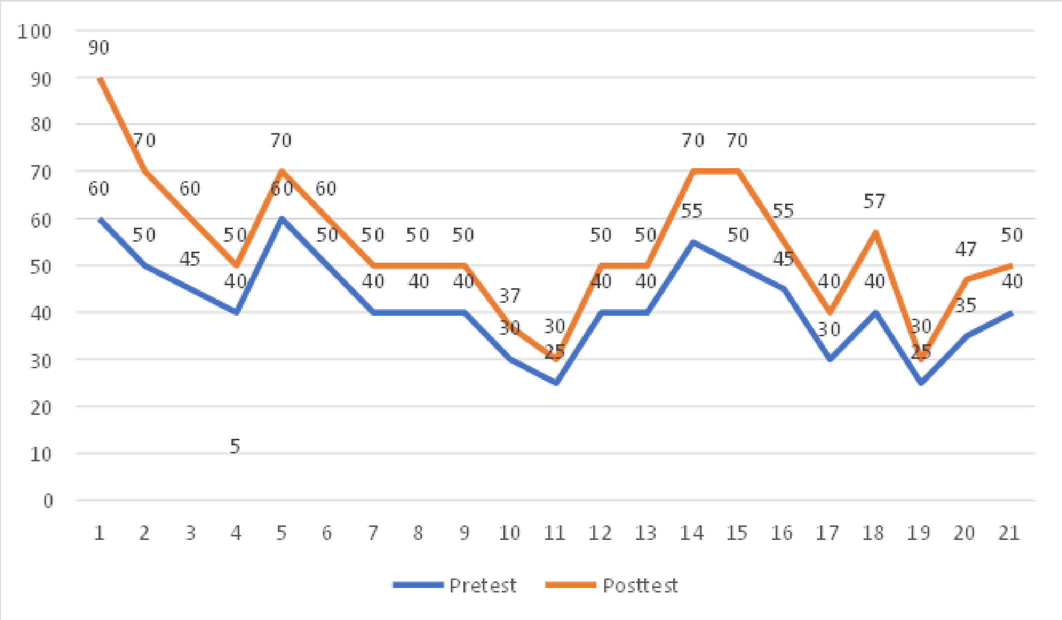

Figure 2. Improvement of Creative Thinking Skills in the Control Class

Figure 2 shows the pretest and posttest results of students' creative thinking skills in the control class. Based on the figure, the control class also experienced an increase in scores, but the improvement was not as high as that of the experimental class. The mean pretest score of the control class was 41.90, which increased to 54.10 in the posttest. Although there was an increase, the improvement remained in the low range according to the N-Gain result.

The lower improvement in the control class indicates that learning without STEM integration did not provide students with sufficient space to develop creative ideas optimally. Students were able to understand the material, but they were not extensively involved in the process of designing, testing, and improving solutions. In fact, creative thinking skills require learning activities that provide students with opportunities to explore ideas, view problems from various perspectives, and produce varied solutions. In this context, learning that emphasizes conceptual understanding alone tends to be less effective in stimulating students' flexibility and originality of thinking.

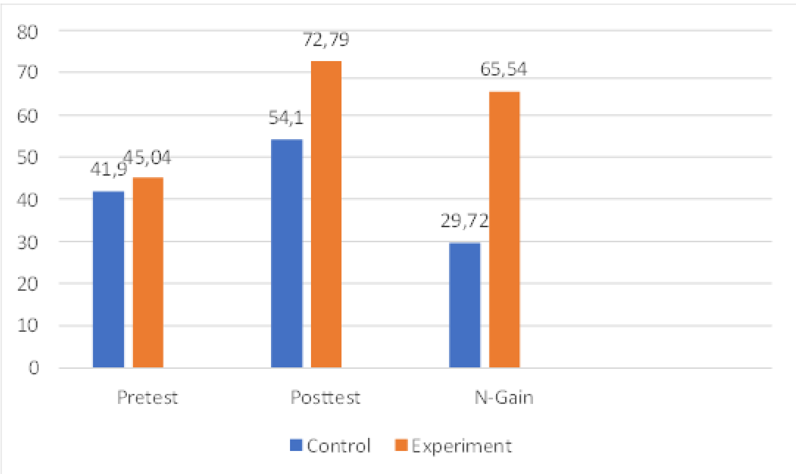

Figure 3. Percentage Results of Creative Thinking Skills

Figure 3 presents the comparison of Pretest, posttest, and N-Gain results between the control and experimental classes. Based on the figure, the experimental class achieved higher posttest scores and higher N-Gain. The N-Gain percentage of the experimental class was 65.54%, while that of the control class was 29.72%. This difference shows that the PjBL-STEM model contributed more strongly to improving students' creative thinking skills than learning without STEM integration.

These results indicate that STEM integration in PjBL is not merely a procedural addition but also reinforces the creative thinking process. The science component helped students understand environmental problems scientifically. The technology component helped students select appropriate tools and techniques. The engineering component encouraged students to design and improve products. Meanwhile, the mathematics component trained students to perform simple measurements and calculations in the product-making process. These four components enriched students' learning experiences so that they not only understood the material in Natural and Social Sciences, but also used that knowledge to produce solutions.

This finding aligns with the study by Surmilasari, Marini, and Usman, which shows that project-based learning with a STEM approach can improve elementary school students' creative thinking skills [10]. In addition, Pramesti, Probosari, and Indriyanti found that PjBL-STEM in a low-carbon environmental context improved students' creative thinking skills because the learning environment provided space for problem exploration, solution design, and product development [11]. Thus, the results of this study strengthen previous findings that PjBL-STEM is relevant for use in Natural and Social Sciences learning, particularly for stimulating creative thinking through projects related to environmental issues.

When linked to the learning process on the topic of *Protecting the Earth*, the improvement in students' creative thinking skills occurred because they were confronted with real problems close to their daily lives. Students were not only asked to answer questions, but also to seek alternative solutions to environmental problems. This process encouraged students to think more openly, develop diverse ideas, and express them through products. Thus, PjBL-STEM learning shifted learning activities from merely understanding concepts to creating, testing, and reflecting on solutions.

Based on these results, it can be concluded that the PjBL-STEM model is more effective in improving students' creative thinking skills than learning without STEM integration. This is evident from the higher posttest mean score of the experimental class compared to the control class, as well as the N-Gain value of the experimental class, which was in the moderate category, while the control class was in the low category. Therefore, PjBL-STEM can be used as an alternative Natural and Social Sciences learning model to stimulate elementary school students' creative thinking skills.

3.3 Students' Sustainability Awareness after PjBL-STEM Learning

Students' sustainability awareness was measured using a questionnaire administered after the learning process had been completed. This questionnaire was used to determine students' levels of awareness of sustainability issues, particularly environmental concerns, responsibility for protecting the Earth, wise use of resources, and willingness to engage in environmentally friendly behavior. In this study, the sustainability awareness questionnaire consisted of 14 statements given to students after they participated in Natural and Social Sciences learning on the topic of *Protecting the Earth* through the PjBL-STEM model.

The questionnaire analysis results showed that students' sustainability awareness in the experimental class reached 96.20%. This percentage falls into the very strong category. This finding indicates that implementing PjBL-STEM not only affects cognitive and creative thinking skills but also contributes to students' sustainability awareness.

Table 5. Results of Students' Sustainability Awareness

Aspect Measured	Number of Statements	Result Percentage	Category
Students' sustainability awareness after PjBL-STEM learning	14	96.20%	Very strong

Based on Table 5, students' sustainability awareness was in the very strong category. This indicates that students had a high level of awareness of the importance of protecting the environment after participating in PjBL-STEM learning. This awareness was reflected in students' responses to statements about environmental concern, the importance of reducing waste, the use of waste, responsibility for maintaining cleanliness, and the idea that simple actions can contribute to the sustainability of the Earth.

The high level of students' sustainability awareness can be associated with the characteristics of PjBL-STEM learning, which presents environmental problems as the main learning context. In the Protecting the Earth topic, students not only learned environmental concepts through teacher explanations but were also directly involved in projects related to waste utilization and efforts to protect the surrounding environment. Such learning experiences provided students with opportunities to understand that environmental problems are not merely lesson content, but real issues that they can encounter and respond to through simple actions.

Through PjBL-STEM learning, students learned to identify environmental problems, design solutions, create products, and reflect on the environmental benefits of their projects. This process contributed to the development of awareness that waste or discarded materials can be transformed into something useful when processed creatively and responsibly. In this context, learning not only instills knowledge about sustainability but also provides direct experiences that could strengthen students' attitudes toward environmental care.

This finding is consistent with the idea of Education for Sustainable Development, which emphasizes the importance of developing knowledge, skills, values, and attitudes so that students can make decisions and take responsible actions for the environment and society [7], [31], [32]. Sustainability education aims not only to develop students' understanding of environmental issues, but also to encourage changes in attitudes and behavior toward a more sustainable life [33].

The high level of sustainability awareness also indicates that students have begun to understand the relationship between individual actions and their environmental impact. Through the projects conducted, students gained experience that protecting the Earth can begin from their immediate environment, such as reducing waste, reusing discarded materials, maintaining cleanliness, and using resources wisely. This experience-based learning is important because sustainability awareness is more easily developed when students are directly involved in activities that have real meaning for their lives.

In addition, integrating STEM into PjBL strengthened the development of sustainability awareness because students were not only encouraged to understand problems but also to find knowledge-based solutions. The science component helped students understand the causes and impacts of environmental problems. The technology component helped students use simple tools and techniques to manage materials. The engineering component encouraged students to design products or solutions. Meanwhile, the mathematics component helped students consider measurements, material quantities, and resource efficiency. The integration of these four components enabled students to see that scientific knowledge can be used to produce concrete actions that benefit the environment.

The results of this study align with Anggraini's findings, which show that STEAM-PjBL learning can be used as a strategy to improve elementary school students' environmental awareness [15]. In addition, the study by Pada, Chanunan, and Rahmat shows that an Ethno-STEM approach oriented toward the Sustainable Development Goals can promote elementary school students' environmental awareness through Natural and Social Sciences learning [16]. Thus, the results of this study strengthen the view that project-based learning integrated with STEM and sustainability issues is relevant for fostering environmental concern among elementary school students.

The sustainability awareness achievement of 96.20% also indicates that PjBL-STEM learning successfully connected students' cognitive, affective, and conative dimensions. The cognitive dimension was reflected in students' understanding of environmental problems and their impacts. The affective dimension was reflected in their concern and responsibility for the environment. Meanwhile, the conative dimension was reflected in students' tendency to take concrete actions, such as utilizing waste, maintaining cleanliness, and reducing behaviors that harm the environment. The integration of these three dimensions is important because sustainability awareness should not be understood merely as knowledge, but should also be reflected in attitudes and readiness to act.

Based on these results, it can be concluded that Natural and Social Sciences learning using the PjBL-STEM model on the topic of *Protecting the Earth* fostered students' sustainability awareness in the very strong category. This model provided learning experiences that encouraged students to understand environmental problems, design solutions, and reflect on their responsibility for the sustainability of the Earth. Thus, PjBL-STEM is not only relevant for improving creative thinking skills but also effective in developing sustainability awareness among elementary school students.

3.5 Discussion

The results of the study show that the implementation of the PjBL-STEM model in Natural and Social Sciences learning on the topic of *Protecting the Earth* reached 100%. This achievement indicates that all stages of the learning process were fully implemented, from determining the essential question to planning the project, developing the schedule, monitoring project progress, testing the results, and evaluating the learning experience. This full implementation indicates that PjBL-STEM can be operationally applied to Grade VI elementary school students, particularly when learning is designed around problem contexts that are closely related to students' lives.

Interpretatively, the 100% implementation rate shows that the PjBL-STEM model is compatible with the characteristics of Natural and Social Sciences learning. As an integrated subject, Natural and Social Sciences requires students to understand natural and social phenomena through contextual activities. In this study, environmental issues related to protecting the Earth were used as the starting point for learning, so students did not merely receive concepts verbally; they were directly involved in observing problems, designing solutions, creating products, and reflecting on their benefits. Thus, learning shifted from an informative pattern to an exploratory and productive one.

Theoretically, the successful implementation of PjBL-STEM can be explained through the characteristics of Project-Based Learning, which emphasizes students' active involvement in solving real problems. PjBL provides students with opportunities to learn through investigation, collaboration, product creation, and reflection. When PjBL is integrated with STEM, the learning experience becomes stronger because students not only complete projects, but also apply the principles of science, technology, engineering, and mathematics in an integrated manner. This integration makes learning more authentic because the concepts learned are directly applied to solve environmental problems.

This finding aligns with PBLWorks, which explains that high-quality project-based learning should involve real-world problems, sustained inquiry, authenticity, reflection, critique, revision, and public products [34]. In addition, Breiner et al. emphasize that STEM is not merely the combination of four disciplines, but an interdisciplinary approach that helps students understand and solve problems more comprehensively [24], [35]. Thus, the implementation of PjBL-STEM in this study indicates that Natural and Social Sciences learning can serve as an appropriate space for connecting scientific concepts with the practice of solving environmental problems [26], [36].

The second finding shows that students' creative thinking skills in the experimental class improved more than those in the control class. The experimental class obtained a pretest mean score of 45.04, which increased to 72.79 in the posttest, yielding an N-Gain of 0.65 (65.54%), categorized as moderate. Meanwhile, the control class obtained a pretest mean score of 41.90 and a posttest mean score of 54.10, with an N-Gain of 0.29 (29.72%), categorized as low. These data indicate that PjBL-STEM learning had a stronger effect on improving creative thinking skills than did STEM-integration-free learning.

Theoretically, creative thinking is the ability to generate diverse, original ideas that can be developed into meaningful solutions. The OECD explains that creative thinking includes the ability to generate, evaluate, and improve ideas in various problem-solving contexts [37], [38]. In the context of Natural and Social Sciences learning, this ability develops when students are given opportunities to explore phenomena, propose alternative solutions, and develop ideas into products. Therefore, PjBL-STEM is a relevant model because it provides students with space to engage in a complete creative process.

This finding supports the study by Surmilasari, Marini, and Usman, which shows that project-based learning with a STEM approach can improve elementary school students' creative thinking skills [4], [10], [39][4]. This result is also consistent with the study by Pramesti, Probosari, and Indriyanti, which found that PjBL-STEM in a low-carbon context improved students' creative thinking skills by involving them in problem exploration, solution design, and product development [11]. Thus, the findings of this study strengthen the evidence that integrating PjBL and STEM can serve as an effective learning strategy to stimulate elementary school students' creativity.

The third finding shows that students' sustainability awareness after participating in PjBL-STEM learning reached 96.20%, indicating very strong awareness. This achievement indicates that students had a high level of awareness of the importance of protecting the environment, using resources wisely, reducing waste, and carrying out simple actions that support the sustainability of the Earth. This result is important because it shows that PjBL-STEM learning affects not only cognitive aspects and creative thinking skills, but also students' affective aspects and tendency to take action.

Interpretatively, the very strong sustainability awareness emerged because the learning process positioned sustainability issues as the main context of the project. Students did not merely learn the topic of *Protecting the Earth* through teacher explanations; they also directly experienced the process of identifying environmental problems and designing solutions. This experience helped students understand that environmental issues are not distant from their lives but are problems that can be found around the school and addressed through concrete actions. Thus, sustainability awareness was formed through concrete learning experiences.

Theoretically, this finding can be explained through the concept of Education for Sustainable Development, or ESD. UNESCO emphasizes that education for sustainable development aims to equip learners with the knowledge, skills, values, and attitudes needed to make decisions and take responsible actions for the environment, society, and the future [40]. Thus, PjBL-STEM aligns with the principles of ESD because it integrates scientific knowledge, problem-solving skills, and values of environmental care in a single learning experience.

This finding aligns with Anggraini's study, which shows that STEAM-PjBL learning can improve elementary school students' environmental awareness [15]. In addition, Pada, Chanunan, and Rahmat found that an Ethno-STEM approach oriented toward the Sustainable Development Goals can foster students' environmental awareness in Natural and Social Sciences learning [16]. These supporting studies indicate that project-based learning integrating STEM and sustainability issues has strong potential to develop students' ecological awareness from the elementary school level.

The theoretical implication of this study is that PjBL-STEM can be positioned as a learning model that supports the simultaneous development of creative thinking skills and sustainability awareness. STEM integration strengthens PjBL because students not only work on projects, but also use interdisciplinary knowledge to solve problems. Therefore, this study reinforces the argument that Natural and Social Sciences learning in elementary schools should be directed toward experiences that not only increase knowledge but also develop students' thinking skills and ecological awareness.

Although the experimental class showed greater improvement than the control class, the N-Gain result remained in the moderate rather than the high category. This indicates that PjBL-STEM was effective in stimulating students' creative thinking, but the improvement had not yet reached an optimal level. One possible reason is that students were not fully accustomed to learning activities that required them to generate alternative ideas, design solutions, test products, and revise their work independently. Creative thinking requires repeated practice, sufficient exploration time, and continuous feedback. Therefore, a limited intervention period may improve students' creative thinking, but may not be sufficient to produce high-level gains. In addition, elementary school students still need intensive teacher scaffolding to connect science concepts, engineering design, mathematical reasoning, and sustainability issues into one integrated project.

Implementing PjBL-STEM also poses several potential challenges. Teachers need to prepare project scenarios, materials, assessment rubrics, group arrangements, and time allocation more carefully than in conventional learning. In classroom practice, challenges may arise in managing group dynamics, ensuring equal student participation, guiding students who struggle to develop ideas, and maintaining a balance between project completion and conceptual understanding. These challenges imply that teachers should not apply PjBL-STEM merely as a product-making activity, but as a structured learning process that includes questioning, investigation, design, testing, reflection, and revision. For curriculum development, the findings suggest that IPAS learning should provide more space for interdisciplinary projects that integrate science concepts, simple technologies, engineering design, mathematical measurement, and sustainability values. Curriculum documents and teaching modules should include clearer project stages, indicators of creative thinking, sustainability contexts, and assessment rubrics to ensure PjBL-STEM is implemented more consistently in elementary schools.

4. CONCLUSION

This study concludes that integrating PjBL-STEM into IPAS learning provides a meaningful learning experience for elementary school students by connecting scientific concepts to real environmental problems. The main finding indicates that PjBL-STEM can stimulate students' creative thinking skills through activities of identifying problems, designing solutions, creating products, testing results, and reflecting on project outcomes. In addition, this learning model supports the development of sustainability awareness by directly involving students in projects to protect the Earth and use resources responsibly.

This study suggests that IPAS learning should not be limited to conceptual explanations or written assignments, but should also provide students with opportunities to learn through contextual, collaborative, and project-based activities. For teachers, PjBL-STEM can be used as an alternative learning strategy to encourage students to think creatively and understand sustainability issues from an early age. For schools, the findings suggest the importance of providing simple project materials, flexible learning time, and support for teachers to design STEM-integrated projects. For curriculum development, this study strengthens the relevance of integrating sustainability issues into IPAS learning so that students can connect knowledge with responsible action in daily life.

This study has several boundaries. The research was conducted only with Grade VI students at one elementary school, so the findings should be interpreted within a limited context. The intervention was also focused on protecting the Earth, suggesting that the effectiveness of PjBL-STEM on other IPAS topics still needs further investigation. In addition, sustainability awareness was measured through a questionnaire, which may not fully reflect students' long-term sustainable behavior in real-life situations.

Future research is recommended to involve a broader range of participants from different schools, grade levels, and regional contexts. Further studies may also examine PjBL-STEM implementation over a longer period to observe the consistency of students' creative thinking development and sustainability behavior. In addition, future researchers can use mixed-method approaches by combining tests, questionnaires, observations, interviews, project portfolios, and student reflections to obtain more comprehensive findings. Comparative studies between PjBL-STEM and other active learning models are also needed to determine which approach is most effective for developing creative thinking and sustainability awareness in elementary education.

This research contributes to the general public by showing that sustainability awareness can be introduced from elementary school through simple, meaningful, and project-based activities. Students can learn that environmental problems are not distant issues, but can be addressed through small actions in their surroundings. Therefore, PjBL-STEM has the potential to foster a young generation that is creative, responsible, and more environmentally aware.

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