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IMPLEMENTING STEAM–PROJECT BASED LEARNING IN SOLID GEOMETRY LEARNING: A DESCRIPTIVE STUDY OF ELEMENTARY STUDENTS' CRITICAL THINKING SKILLS

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Abstract: This study aims to examine the implementation of mathematics instruction on 3D shapes using the STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach combined with Project-Based Learning (PjBL) to enhance the critical thinking skills of elementary school students. The study was motivated by the students' initially low critical thinking skills, a result of instructional practices that prioritized rote memorization and lacked contextual learning experiences. A quantitative method with a descriptive approach was employed, utilizing project-based learning in which students actively designed and created eco-friendly plant pots using repurposed materials. The study was conducted at SDN Dukuh Kupang V Surabaya, involving all 18 students from class V-B (10 boys and 8 girls) as subjects; total sampling was used. Data collected during the study indicated an improvement in students' critical thinking skills following the implementation of STEAM-PjBL. Pre-test results showed that the majority of students fell into the low-ability category, with an initial class average of 26.6%. Following the intervention, post-test results showed a significant increase, with the class average reaching 82.2% and all 18 students meeting the Minimum Mastery Criteria (KKM). Observations during the learning process demonstrated that this instructional method fostered greater student engagement, creativity, and critical thinking in solving real-world problems. Consequently, instruction utilizing the STEAM approach and the PjBL model shows potential for developing students' critical thinking skills while simultaneously cultivating awareness regarding food security and sustainability.

Keywords: Steam Approach; Project Based Learning; Mathematics; Critical Thinking, Solid Geometry

Abstrak: Penelitian ini bertujuan mengkaji implementasi pembelajaran matematika materi bangun ruang berbasis pendekatan *Sciene, Technology, Engineering, Arts, and Mathematics* (STEAM) melalui *Project Based Learning* (PjBL) dalam meningkatkan kemampuan berpikir kritis muri SD. Penelitian ini dilandasi oleh kondisi kemampuan berpikir kritis siswa yang masih rendah, akibat praktik pembelajaran yang masih berorientasi pada hafalan dan kurang memberikan pengalaman belajar kontekstual. Metode penelitian ini menggunakan kuantitatif dengan pendekatan deskriptif melalui penerapan pembelajaran berbasis proyek, di mana siswa

terlibat secara aktif dalam merancang dan membuat produk berupa pot tanaman ramah lingkungan yang memanfaatkan bahan bekas pakai. Penelitian dilaksanakan di SDN Dukuh Kupang V Surabaya. Penelitian ini melibatkan seluruh siswa kelas V B sebagai subjek, yaitu sebanyak 18 siswa yang terdiri atas 10 siswa laki-laki dan 8 siswa perempuan. Teknik pengambilan sampel menggunakan sampling total. Penerapan pembelajaran STEAM-PjBL menunjukkan adanya perkembangan kemampuan berpikir kritis siswa berdasarkan hasil data yang dikumpulkan selama penelitian. Hasil pre-test menunjukkan bahwa sebagian besar siswa berada pada kategori kemampuan rendah dengan rata-rata kelas awal 26,6%. Setelah penerapan, terjadi peningkatan signifikan pada hasil post-test dengan rata-rata kelas mencapai 82,2%, di mana 18 siswa telah memenuhi Kriteria Ketuntasan Minimal (KKM). Pembelajaran ini terbukti mendorong peningkatan keaktifan, kreativitas, dan kemampuan berpikir kritis siswa dalam menyelesaikan permasalahan nyata berdasarkan hasil observasi selama proses pembelajaran. Oleh karena itu, pembelajaran dengan pendekatan STEAM dan model PjBL menunjukkan potensi dalam mengembangkan kemampuan berpikir kritis siswa serta menumbuhkan kesadaran terhadap ketahanan pangan dan keberlanjutan.

Kata kunci: Pendekatan STEAM; Pembelajaran Berbasis Proyek; Matematika; Berpikir Kritis, Bangun Ruang

INTRODUCTION

Technological advancements and the use of artificial intelligence (AI) require students to possess critical thinking skills, enabling them to assess information, consider diverse sources, and solve problems effectively. Critical thinking has the potential to enhance analytical capabilities; thus, honing this skill is a crucial step toward improving student learning outcomes (Hasanah et al., 2023). However, critical thinking skills among elementary school students remain low, as instruction often prioritizes rote memorization over active engagement in finding solutions to real-world problems. While the use of gadgets and AI in education facilitates information access and supports the learning process, it must be accompanied by guidance and the strengthening of digital literacy. This ensures that students do not merely receive information instantly but are also capable of verifying, analyzing, and evaluating the information they obtain (Putri, 2026). This issue is underscored by observations of fifth-grade students at SDN Dukuh Kupang V, which revealed low interest in mathematics; the subject is perceived as difficult, and instruction tends to rely on memorization. Without proper oversight, students are likely to seek answers without engaging in a deep thinking process. This situation warrants serious attention amidst the increasingly widespread use of technology in education.

Mathematics instruction in elementary schools often fails to engage students because it is perceived as difficult and abstract, and tends to rely on rote memorization (Hidayanthi & Siregar, 2024). Consequently, student learning outcomes struggle to improve, and teachers often lack knowledge regarding diverse teaching methods—such as STEAM, which has been shown to enhance cognitive, affective, and psychomotor domains (Salwa, 2022). This situation underscores the need for innovation in mathematics instruction to make it more contextual and capable of fostering students' higher-order thinking skills. One relevant approach is STEAM-based learning integrated with Project-Based Learning (PjBL). STEAM is an interdisciplinary learning approach that combines various fields of knowledge to cultivate critical thinking and creativity (Suryanti et al., 2024). PjBL actively engages students in problem-solving through real-world projects, enabling them to develop skills in thinking, research, and analysis, as well as the ability to

create learning products (Satria et al., 2025). Integrating these two approaches aims to create a meaningful learning process aligned with 21st-century skills. PjBL-STEAM instruction has proven effective in enhancing critical thinking skills compared to conventional methods (Almarwah et al., 2025). The instruction goes beyond mere mastery of mathematical concepts, actively training students to think critically through projects relevant to their daily lives.

Project-based STEAM implementation has been proven to enhance mathematics learning outcomes. This approach boosts student motivation, creativity, and understanding while fostering active engagement, collaborative skills, and critical thinking; consequently, its implementation warrants expansion in primary schools (Wulandari et al., 2025). Integrating STEAM into mathematics instruction—particularly regarding geometry—significantly stimulates students' creativity and innovative capabilities (Ajir & Ishak, 2025). STEAM possesses characteristics aligned with the need to develop 21st-century skills: it is contextual, interdisciplinary, and project-based, while also integrating aesthetic elements into mathematics learning. STEAM implementation has demonstrated effectiveness in improving the understanding of mathematical concepts, critical and creative thinking abilities, and problem-solving skills, as well as enhancing student interest and motivation regarding mathematics (Bariyah & Hamimi, 2025). In this study, the STEAM (Science, Technology, Engineering, Arts, Mathematics) approach combined with Project-Based Learning (PjBL) serves as an innovative solution for creating a meaningful, relevant learning experience focused on developing 21st-century skills. The theme of food security was selected because food security and healthy consumption patterns are currently matters of public concern, particularly through school healthy meal programs and campaigns to reduce food waste. Analysis (2023) indicates that the potential for food waste in schools amounts to approximately 1.1–1.4 million tons annually, with 451,000–603,000 tons consisting of surplus food that could still be salvaged.

The identified research gap concerns teachers' limited knowledge regarding the STEAM learning process, which is believed to enhance student learning outcomes across cognitive, affective, and psychomotor domains. Mathematics instruction in elementary schools still relies on traditional methods perceived as difficult and abstract, with an emphasis on rote memorization, making it challenging to improve student learning outcomes. To date, there has been limited research integrating the theme of food security with a STEAM-PjBL (Project-Based Learning) approach in elementary mathematics education, particularly within the context of SDN Dukuh Kupang V. The novelty of this study lies in the pioneering integration of the food security theme with the STEAM-PjBL approach in elementary mathematics through a series of concrete activities: planting seeds (Science); utilizing creative digital educational applications (Technology); constructing cube nets from repurposed sacks to create planters (Engineering); decorating the planters (Art); and measuring and applying geometric net concepts to ensure the planters are proportional (Mathematics). This research gap was established by comparing the focus areas of several previous studies. Research on STEAM in primary schools has focused on its benefits for understanding and creativity in mathematics learning (Salwa, 2022; Wulandari et al., 2025), whereas PjBL-STEAM research has centered on critical thinking skills among junior high school students (Suryanti et al., 2024; Almarwah et al., 2025). However, existing literature has not specifically demonstrated the integration of spatial geometry, recycled-material pot projects, and

food security contexts within primary school mathematics instruction. Thus, the research gap lies in the scarcity of studies combining these three elements into a single project sequence. This study addresses this gap through activities involving water spinach cultivation (Science), the use of "Qreatif" as a technological aid (Technology), the design and construction of pots from used sacks (Engineering), pot decoration (Arts), and the application of concepts such as cubes, nets, measurement, and volume (Mathematics). Spatial geometry is a branch of mathematics examining the characteristics of three-dimensional shapes—such as cylinders, rectangular prisms, and cones—that are frequently encountered in real-world contexts. Given that plant pots are typically cylindrical, the pot-making project serves as an ideal medium for internalizing the concept of geometric nets. Through these activities, students directly build their understanding of three-dimensional shapes while honing spatial visualization and geometric reasoning skills—competencies fundamental to three-dimensional geometry. As this study does not constitute a systematic literature review, its novelty is not claimed as a completely unprecedented integration, but rather as a contribution to the limited body of research regarding the integration of STEAM-PjBL, spatial geometry, recycled materials, and food security in primary education.

METHOD

This study employs a quantitative method with a descriptive approach to evaluate critical thinking outcomes, performance, product quality, and student responses regarding a mathematics learning process on the topic of 3D shapes. This process integrates the STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach with the Project-Based Learning (PjBL) model. The study utilizes a "One-Shot Case Study" design and was conducted at SDN Dukuh Kupang V in Surabaya, focusing on the entire class of 5-B students—comprising 18 individuals (10 boys and 8 girls). The research was carried out in a single 70-minute session, equivalent to two lesson periods. A total sampling method was used, meaning the entire population served as the research subjects.

The first stage is planning, which involves developing PjBL-based instructional materials—incorporating phases such as the driving question, project planning, scheduling, monitoring, product testing, and evaluation—integrated with STEAM, alongside preparing the Qreatif educational app as a supporting digital medium. During this stage, the project problem, pot dimensions and shape, work steps, student worksheets (LKM), and assessment instruments are determined. Regarding the "Technology" component, Qreatif serves not merely as a supplementary app but as a tool to help students visualize 3D shapes and access digital information, express and communicate design ideas, and support decision-making when determining the pot's shape and size. The technology's contribution is evident in how the digital information used by students aids their understanding of shapes, comparison of designs, and selection of viable product solutions. The second stage is the implementation of project-based learning. Students are divided into two groups to create pots using cube nets adapted from used sacks, intended as planters for water spinach (*kangkung*). The "Mathematics" component focuses on introducing cubes and cube nets, understanding the relationship between nets and 2D shapes, measuring the pot's length and width, and using these measurements to consider the container's capacity or volume. STEAM integration is achieved through planting water spinach (Science); using Qreatif for visualization, planning, and idea communication (Technology); designing and constructing the pot (Engineering); sewing and decorating the pot (Arts); and performing measurements and geometric calculations (Mathematics). The third stage involves data collection and analysis. Data were collected through critical thinking tests, performance

observations, product assessments, student worksheets, response questionnaires, and documentation. Quantitative data were analyzed using descriptive statistics—specifically mean scores and learning mastery percentages—while qualitative data were analyzed through data reduction, data presentation, and conclusion drawing. Data validity was ensured through technique and source triangulation. The instruction was deemed successful if the majority of students achieved a minimum score of 75, participated actively in every stage of the project, and produced work meeting the assessment criteria. The critical thinking instrument consisted of a 10-item multiple-choice test with a maximum score of 100. The questions were developed based on seven critical thinking sub-indicators: (1) formulating questions, (2) providing examples, (3) answering "why" questions, (4) reporting observation results, (5) generalizing from data, tables, and graphs, (6) drawing conclusions, and (7) considering alternative answers (Ardiyanti, 2013). The questions were compiled based on a collection of 5th-grade elementary school problems regarding geometric solids, available at the following link: https://id.scribd.com/document/499315818/Kumpulan-Contoh-Soal-Bangun-Ruang-Kelas-5-SD-Semester-2-Lengkap-Jawabanya. Content validity was established through an assessment by an IPAS (Natural and Social Sciences) education expert, Anna Roosyanti, S.Pd., M.Pd., who reviewed the test items alongside the test blueprint, answer key, and scoring rubric. Technique and source triangulation were employed to enhance the credibility of qualitative data derived from observations and questionnaires.

RESEARCH RESULTS

The results of the research conducted at SDN Dukuh Kupang V were gathered using a critical thinking skills test, observation sheets, and student response questionnaires. The initial phase of the study began with the administration of a pretest to assess the students' baseline ability to solve contextual problems.

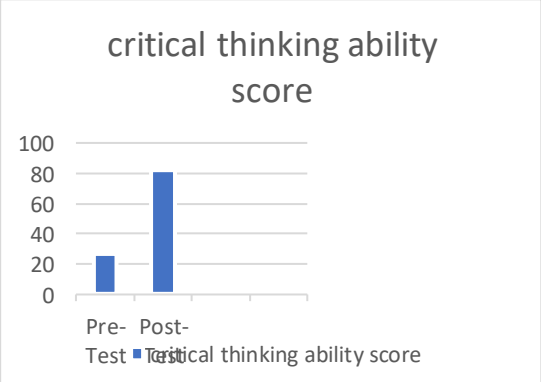


Figure 1. Diagram of the improvement in students'critical thinking skill scores.

Pre-test results indicate that students fell into the low category, with a mean score of 26.6 on a 0–100 scale. Critical thinking skills were assessed using a test comprising 10 multiple-choice questions, with a maximum possible score of 100. Figure 1 illustrates the comparison between pre-test and post-test mean scores; the values of 26.6 and 82.2 are presented as scores on a 0–100 scale. Source: research data, 2026. Initially, the majority of students struggled to comprehend HOTS (Higher-Order Thinking Skills) questions and to formulate problem-solving strategies. Preliminary observations also revealed a tendency among students to be passive and to lack confidence when expressing their ideas.



Figure 2. Pot Product Demonstration



Figure 3. Product Manufacturing

A STEAM approach based on Project-Based Learning (PjBL) was implemented in mathematics instruction, utilizing pre-tests and post-tests to describe changes in students' critical thinking skills. During the learning process, students engaged in a project themed around food security, integrating aspects of Science, Technology, Engineering, Art, and Mathematics. Learning activities were conducted in small groups and included discussions, exploration, simple product design, and presentations of group work. Observations during the intervention revealed a clear increase in student participation; students were more active in asking questions, engaging in discussions, and attempting various approaches to problem-solving. Student creativity was also evident in the variety of solution presentations, creating a more dynamic and interactive learning atmosphere. These findings indicate that the STEAM-based PjBL approach enhances both learning engagement and critical thinking skills. A post-test was administered following the intervention to measure changes in student proficiency. Post-test results showed a substantial improvement compared to the pre-test, with the class average rising to 82.2% and 18 students meeting the Minimum Mastery Criteria (KKM). Students demonstrated improved ability in comprehending Higher-Order Thinking Skills (HOTS) problems and selecting optimal solution strategies, while their confidence in presenting answers also increased. Observations conducted throughout the learning process reinforced these findings, descriptively demonstrating a shift in critical thinking scores following the implementation of STEAM-based PjBL. These findings are not intended to establish a cause-and-effect relationship, as the study did not employ a control group or inferential statistical testing.

Table 1. The Change Mean Score Critical Thinking

N	Mean pre-test	Mean post-test	Score difference	Relative improvement
18	26,6	82,2	55,6 poin	209,0%

Table 2. Student Response Questionnaire Score Results

Skor	Number Per Score Selected	Total Amount Per Score	Results
1	15	15x1	15
2	25	25x2	50
3	98	98x3	294
4	42	42x4	168
Total Score		**527**	

Information:

a. $\boldsymbol{Total\ Score}$: 527

b. $\boldsymbol{Max\ Score}$: *highest score x number of questionnaire questions x number of students*

$Max\ Score: 4x\ 10x\ 18 = 720$

c. $\boldsymbol{Percentage}: \frac{Total\ Score}{Max\ Score} x\ 100\ \%$

$Percentage: \frac{527}{720}\ x\ 100\ \% = 73{,}19\%$

Table 3. Student Response Questionnaire Criteria

Percentage	Criteria
75% ≤ SRS ≤ 100%	Very good
50% ≤ SRS < 75%	Good
25% ≤ SRS < 50%	Poor
0% ≤ SRS <25%	Very Poor

Source: (Hidayatullah 2018)

Based on the information above, the results of the student response questionnaire yielded a figure of 73.19%, placing it in the "good" category. The questionnaire consisted of 10 statements rated on a scale of 1 to 4, capturing student responses to the STEAM-PjBL learning process—specifically regarding their interest in the lessons, the level of challenge posed by the activities, and the extent to which the activities fostered engagement and critical thinking. With 18 respondents, the maximum possible score was calculated as 10 statements × 18 students × a score of 4, totaling 720. The total score obtained was 527; thus, the response percentage was 527/720 × 100% = 73.19%. These results indicate that the majority of students responded positively to the PjBL-based STEAM learning process.

The integration of a STEAM method centered on Project-Based Learning (PjBL) provides students with opportunities to actively analyze and evaluate information, engage in discussions, make decisions, and reflect throughout the activities. A project creation observation sheet is used to assess students' work processes during the activity. This instrument comprises 10 aspects, each scored on a scale of 1 to 4, resulting in a maximum possible score of 40. The data indicate a descriptive difference between the two groups of students in their execution of the project.



Figure 4. Product Result

Integrating the STEAM method—with a focus on Project-Based Learning (PjBL)—offers students opportunities to actively analyze, think critically about, and evaluate the information they acquire throughout the learning process. This approach encourages students to investigate learning problems critically, particularly regarding the use of media and learning resources as tools for content delivery. Project activities—including discussion, decision-making, and reflection—help students continuously hone their higher-order thinking skills (Andriani et al., 2026). Observation sheets are used to assess students' work processes during the project. This assessment covers 10 aspects, ranging from the preparation of tools and materials to group collaboration. The data reveal a difference in capabilities between the two groups of students in executing the project. The table below presents the results of the project observation assessment:

Table 4. Project Creation Observations

Number	Group	Number of Students	Total Average	Score Final	Grade Category
1.	Group 1	9 Students	34 and 40	85%	Good (towards very good)
2.	Group 2	9 Students	32 and 40	80%	Good

Based on observations of the project creation process, Group 1 achieved a total score of 34 out of a maximum of 40 (an 85% score), while Group 2 scored 32 out of 40 (an 80% score). Both groups achieved scores in the "good" category, with a difference of only 5%. This indicates that, overall, the students successfully carried out the project creation process in accordance with the established criteria. Group 1 demonstrated greater proficiency in terms of independence, the correct use of tools, and neatness during the pot assembly and decoration stages. Meanwhile, Group 2 still showed some reliance on teacher guidance in certain areas, particularly regarding the execution phase and creativity. Nevertheless, both groups exhibited good teamwork and a solid understanding of STEAM-based learning concepts. Consequently, future project activities should aim to further enhance creativity and independence. An observation sheet was used to assess the quality of the students' final products, evaluating aspects such as functionality, durability, neatness, creativity, and alignment with environmental and STEAM concepts. The table below presents the results of the project outcome assessment:

Table 5. Project Results Observation

Number	Group	Number of Students	Total Average	Score Final	Grade Category
1.	Group 1	9 Students	37 and 40	92,5%	Very Good
2.	Group 2	9 Students	34 and 40	80%	Good

Based on the project assessment data, Group 1 achieved a score of 37 out of 40 (92.5%), placing them in the "very good" category, while Group 2 obtained a score of 34 out of 40 (85%), classified as "good." This indicates that the products created by the students generally met the established criteria. Group 1 demonstrated superior results, particularly regarding the neatness of the pot's shape, product durability, and design creativity. Meanwhile, Group 2 successfully produced a functional product, though there were shortcomings in terms of aesthetics and design innovation. Differences in product quality were most evident in shape neatness, durability, and design creativity. These differences may be attributed to factors such as adherence to the design plan, task distribution, technical skills, and group autonomy. However, as these specific factors were not formally tested, the underlying causes are discussed only as possibilities based on observations.

Table 6. Product Assessment Rubric

Aspect	Score indicator 1	Score indicator 2	Score indicator 3	Score indicator 4
Functions	Cannot be used as a pot	Pots can still be used, but their function as a planting medium is not optimal	Pots can be used well as a planting medium, but there are still some drawbacks	Works well as a planting medium
Strength	Fragile/not sturdy	The pot is not very sturdy, and some parts easily lose their shape	The pot is reasonably strong and sturdy, though a few areas lack strength	Sturdy and able to maintain its shape
Neatness	Shape and stitching are untidy	The cut is untidy, with several irregular areas	The cut is reasonably neat, with only a few minor irregularities	Shape, stitching, and finishing are neat
Creativity	Very simple design with no further development	Creativity is still limited, largely following examples	Pot shape and decoration are quite creative and attractive	Varied design demonstrating original ideas
Environmental Suitability	Does not demonstrate appropriate use of repurposed materials.	Uses materials but does not yet optimally demonstrate environmental	Uses repurposed materials effectively and demonstrates environmental	Uses used materials appropriately and functionally.

Aspect	Score indicator 1	Score indicator 2	Score indicator 3	Score indicator 4
		concepts.	awareness.	
STEAM Suitability	STEAM elements are not evident .	he application of STEAM and geometric concepts is still limited.	The product demonstrates the application of STEAM and geometric concepts quite clearly, though there are still minor shortcomings.	STEAM elements are clearly integrated into the product. .

Based on research findings, the implementation of STEAM-based mathematics learning—Project Based Learning (PjBL)—showed significant changes in students' critical thinking skills and engagement throughout the learning process. Students utilized recycled materials as containers to plant kale in the school environment, under teacher guidance. The series of activities included planning, container construction, planting, and reflection. These activities provided contextual experiences in food security education, particularly related to the food production process, utilization of local resources, the importance of healthy food, and environmental conservation. In the context of elementary education, planting kale is more appropriately positioned as a medium for introducing the concept of food security, rather than as a direct intervention to improve food security. Thus, the findings of this study demonstrate a contribution to contextual food security education through learning experiences that connect mathematical concepts with simple food production activities. Based on the pre-test and post-test results, An improvement was observed in the self-regulation indicator; specifically, students demonstrated a better ability to identify the problem at hand. This change was reflected in a score increase from 26.6 to 82.2—a rise of 209.0%. In the context of primary education, this concept can be realized through tangible, contextual learning activities, such as growing water spinach (*kangkung*). This activity is not intended as a direct intervention for national food security but rather serves as a learning medium to build students' understanding of fundamental food security principles, particularly regarding the dimensions of food availability and utilization. These findings align with research by Lidyasari (2023), which indicates that the Project-Based Learning (PjBL) model effectively enhances the critical thinking skills of primary school students by providing opportunities to solve real-world problems, analyze information, and generate solutions based on their inquiries. Furthermore, this model supports the development of 21st-century skills, including critical thinking, creativity, collaboration, and communication. Integrating the STEAM approach into instruction fosters a more contextual and meaningful learning experience. The application of STEAM-PjBL can stimulate critical thinking processes, as students are confronted with real-world problems requiring analysis, evaluation, and decision-making. During the planning stage, students determine the dimensions of the planting container based on previously taught material; they do not merely follow instructions but must relate the container's size to its function and the plant's needs. During the construction phase, students may encounter issues—such as a structurally unstable container or incorrect dimensions—requiring them to identify the root cause, evaluate their initial design, and determine the necessary adjustments.

Qreatif helps students understand the shapes and determine the dimensions of planting containers through design visualization prior to actual fabrication. Through these activities, students can compare various container shapes, estimate sizes, and select designs based on functionality and environmental conditions. Using Qreatif enables students to connect geometric and measurement concepts with tangible objects; this is evident when students utilize shape and size data to finalize their container designs before the construction phase. Thus, Qreatif serves as a tool to support visualization and design, while critical thinking skills are fostered through activities such as comparing, selecting, justifying choices, problem-solving, and refining designs. The STEAM approach integrates science, technology, engineering, arts, and mathematics into a single, problem-solving-oriented activity. Research by Nurmala and Rocmah (2024) indicates that implementing STEAM can stimulate students' critical thinking, as they are trained to observe phenomena, analyze information, and make independent decisions during the learning process. These findings are supported by research from Fitriana et al. (2024), which demonstrates that STEAM-based Project-Based Learning enhances critical thinking while simultaneously developing entrepreneurial and problem-solving skills through contextual project activities. The improvement in students' critical thinking aligns with research by Darmawati and Mustadi (2023), which found that instruction centered on problem-solving and active student participation significantly impacts the critical thinking abilities of elementary school students.

Learning activities requiring students to analyze, evaluate, and draw conclusions from information have been shown to enhance the quality of their thinking compared to conventional instruction. Student response surveys yielded a 73.19% approval rate—categorized as "good"—indicating that the STEAM-integrated, PjBL-based (Project-Based Learning) approach was well-received by students. Integrating technology into project-based learning offers students opportunities for more interactive and independent learning. When combined with PjBL, technology acts as a catalyst for boosting student engagement, broadening learning experiences, and fostering higher-order thinking skills. Overall, the water spinach cultivation activity served not merely as a simple agricultural task but as a context for mathematics learning, linking concepts of shape, size, measurement, capacity, and problem-solving with the introduction of food security. Improvements in critical thinking skills were evident through students' active involvement in designing, comparing, measuring, constructing, problem-solving, and presenting project outcomes. Thus, the STEAM-PjBL application provides a contextual and meaningful mathematics learning experience. The project activities presented authentic problems, while the STEAM approach enabled students to integrate various concepts to devise solutions. These findings reinforce prior research regarding the potential of STEAM-PjBL to support higher-order thinking skills. However, the interpretation of results remains limited to the context of this study and cannot be broadly generalized without a more robust research design. A limitation of the study lay in time management; the time allocated for planning, project execution, observation, and reflection was insufficient to achieve the desired depth of analysis. Effective time management is essential to ensure a comprehensive learning process and the optimal achievement of learning objectives. Despite these limitations, the study contributes significantly to improving educational quality by demonstrating an effective practice of project-based STEAM implementation.

CONCLUSION

The implementation of STEAM-PjBL instruction demonstrated an improvement in students' critical thinking skills based on data collected during the study. STEAM-PjBL can be

viewed as an approach with the potential to facilitate the development of critical thinking abilities. Following the intervention, a post-test revealed an increase in the class average score to 82.2%, with 18 students meeting the Minimum Mastery Criteria (KKM); students appeared more proficient in analyzing Higher-Order Thinking Skills (HOTS) questions and selecting appropriate problem-solving strategies, while also displaying greater confidence when presenting their answers. Student response to the instruction yielded a score of 73.19%, falling into the "good" category. Meanwhile, the quality of the project process and final products was rated highly based on assessments of student activities and the resulting outputs. Furthermore, the instruction—integrated with a project involving the creation of plant pots from recycled materials and the cultivation of edible plants—demonstrated a link to the concept of food security. Through these activities, students not only gained a contextual understanding of geometric shapes but also acquired real-world experience in simple, independent efforts to maintain local food availability. Practical implications of these results include enhanced engagement and quality in the teaching-learning process, preliminary evidence encouraging teachers to adopt or adapt the STEAM-PjBL model for mathematics instruction, and a basis for curriculum developers to incorporate project-based activities that stimulate higher-order thinking skills. However, the study has limitations—such as a small sample size and a restricted classroom context that limit the generalizability of findings to a broader population, as well as the use of a one-shot case study design without a control group. Given these limitations, recommendations for future research include employing a quasi-experimental or mixed-methods design—utilizing validated critical thinking instruments, a comparison group, and a larger sample—to more robustly test the effectiveness of STEAM-PjBL.

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