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Development of Design Skills for Local Material Reinforced Bricks Using the STEM Education Concept through the PAR: SAPS Process of Grade 9 Students

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Abstract

This research aimed to (1) develop design skills related to local material-reinforced bricks using STEM education concepts through the PAR-SAPS process among Grade 9 (G9) students and (2) examine their satisfaction with the learning experience. The study involved 21 students from a secondary school in Surin Province. Research instruments included three STEM-integrated lesson plans, a design skills assessment (reliability = 0.86), and a satisfaction questionnaire (reliability = 0.81). Data was collected over three instructional rounds, with design skills assessed after each session and satisfaction evaluated upon completion. Descriptive statistics were used for data analysis. The results revealed significant improvement in students' design skills, with mean scores rising from 46.67 in round 1 to 60.33 in round 2 and 72.33 in round 3. Additionally, student satisfaction with the learning process was very high (mean = 4.65). These findings indicate that integrating STEM education with the PAR-SAPS model effectively enhances students' scientific process skills particularly in modeling and design while promoting meaningful, engaging learning experiences. The study highlights the model's potential for developing 21st-century competencies and its applicability in science and technology education.

Keywords: Science process skills, Formulating models, STEM education, PAR-SAPS approach

1. Introduction

Education is a crucial part of human life, leading to significant development in various fields. However, the unbounded progress in these areas may impact future living conditions. The organization for economic cooperation and development (OECD) has set a global agenda with the concept of "transforming our world" along with the sustainable development goals (SDGs) since 2015. The application of STEM education integrating science, technology, engineering, and mathematics plays a vital role in achieving these SDGs (Boon, 2019).

STEM education is a concept developed by the National Science Foundation (NSF) in the early 21st century, aimed at providing integrated learning for basic education students, fostering analytical thinking, problem-solving, creativity, and various essential traits for both current and future contexts (Sanders, 2009, 2014; Sahito and Wassan, 2024, Sarapak et al., 2025a; Sarapak et al., 2025b). In Thailand, active and integrated STEM learning has been designated as a critical component in driving strategies for producing and developing human resources, research, and innovation to enhance national competitiveness according to the national education Plan (2017-2036) (Office of the Education Council, 2017). It is also a policy focus of the Ministry of Education aimed at improving educational quality for the fiscal year 2024 (Ministry of Education, 2024). STEM-based learning has been recognized by scholars as a modern educational approach applicable to classroom settings, using diverse learning activities that lead to the development of various competencies, including 21st century skills such as academic achievement, analytical thinking, scientific process skills, problem-solving abilities, creativity, critical thinking, and scientific attitudes (Wacharaporn Ruangsit and Trikom Prommabun, 2020; Moore, Johnston, and Glancy, 2020; Yuenyong, 2019). The core principles of implementing STEM education emphasize integration, challenge, active learning, focus on essential 21st century skills, and real-life connections (Science and Technology Education Institute, 2020).

The scientific process comprises the thinking skills of scientists used for inquiry and problem-solving. Students can effectively employ scientific process skills to acquire quality knowledge. These skills include two groups: basic scientific process skills and integrated scientific process skills (Fugarasti, Ramli, and Muzzazinah, 2019; NARST, 1990). According to Fugarasti, Ramli, and Muzzazinah (2019), there are distinct names and focuses for scientific process skills, with one significant skill being model formulation. This involves creating physical or mental models of events and processes to present and explain relationships between concepts (Barman, 1992) and predict phenomena in various forms (Victoria, 2020), such as graphs, images, animations, materials, objects, and prototypes.Given the importance of integrated STEM education and the efforts to develop scientific process skills for students at all levels, the Surin Primary Educational Service Area Office 1 has promoted the active learning PAR-SAPS approach since 2022 as part of its learning activities and school supervision across the area (Surin Primary Educational Service Area Office 1, 2022). PAR stands for participatory action research, comprising P (plan), A (action and observation), and R (reflect). Meanwhile, SAPS involves four learning phases: Step 1 - start (S), which engages students with fun and challenging lessons; Step 2 - action (A), where teachers facilitate learning; Step 3 - present (P), where students present their work and teachers guide them to summarize key ideas; and Step 4 - summarize (S), which focuses on summarizing knowledge and applying it further (Surin Primary Educational Service Area Office 1, 2022).

Previous studies have highlighted the importance of integrating STEM education to promote interdisciplinary learning, especially when connected to real-life contexts and using locally available materials (Arslan & Genç, 2024; Nugraha et al., 2024). Learning activities that incorporate the engineering design process—a crucial element of STEM education—have been shown to improve students' problem-solving abilities and design-thinking skills (Ting, 2016). Furthermore, utilizing local materials in educational projects, such as reinforced bricks or programmable materials, has been recognized for raising students' awareness of sustainability, resource efficiency, and the relevance of knowledge to their local environment (Sipitakiat & Blikstein, 2010; Tyas et al., 2023). Additionally, the PAR: SAPS process, a participatory action research framework, has been adopted to encourage creative and collaborative learning by integrating disciplines such as science, art, philosophy, and social studies. This approach aims to enhance students' capacity for material design and knowledge construction in authentic contexts (Alpian, 2023; Tyas et al., 2023). Collectively, these studies support learner-centered instructional models that bridge theory and practice, aligning with the goals of 21st century education.

This research, grounded in the principles of STEM education—which integrates science, technology, engineering, and mathematics was collaboratively conducted by vocational and mathematics teachers at the lower secondary level, in partnership with faculty members from the Faculty of Education at Surindra Rajabhat University (SRRU). The specific objectives of the research were (i) to develop the design skills of G9 students in constructing bricks reinforced with local materials using STEM education concepts integrated with the PAR-SAPS process; and (ii) to assess the satisfaction of students participating in this learning experience. These objectives address both cognitive and affective dimensions of learning, underscoring the value of hands-on, interdisciplinary, and student-centered educational practices. It also plays a crucial role in applying abstract concepts to practical situations. Consequently, this research contributes to the advancement of educational practices that foster the development of 21st century competencies and provides a model for effective, locally relevant, and sustainable science and technology education.

2. Methodology

2.1 Target group

The target group for this study consisted of 21 Grade 9 students enrolled at Ban Janrom School, located in the Mueang Surin District of Surin Province. The school falls under the jurisdiction of the Surin Primary Educational Service Area Office 1. The research was conducted during the first semester of the 2024 academic year. Participants were selected through purposive sampling, which was based on factors such as their accessibility, relevance to the research context, and the school's readiness to implement an integrated STEM learning model. This specific group was deemed appropriate for examining the effectiveness of instructional interventions using the PAR-SAPS process, as it facilitated close observation, in-depth engagement, and iterative implementation of learning activities that aligned with the study's objectives and scope.

2.2 Content

The instructional content used in this study was drawn from the vocational education curriculum for G9 students, focusing specifically on the topic of "mixing and molding cement using pre-made mMolds." This topic was chosen because of its practical relevance to local community construction practices and its potential for interdisciplinary integration across STEM fields. The learning unit was designed to encompass a total of 12 instructional hours, which were systematically divided into three lessons that aligned with the PAR-SAPS instructional model. The selected content not only supports the development of essential technical skills such as understanding material properties, measurement, and structural design but also provides a real-world context for developing scientific process skills, particularly model formulation. This topic allowed students to participate in hands-on activities that link vocational knowledge with broader scientific and mathematical concepts, making it well-suited for STEM-based instruction. Additionally, the content's local relevance and real-world applicability contributed to enhancing student motivation and contextual understanding, both of which are crucial for fostering meaningful and sustainable learning outcomes.

2.3 Tools

1) Lesson Plans: The development of lesson plans follows these guidelines:

(1) Draft lesson plans consisting of three PAR-SAPS lesson plans, integrated with STEM education concepts. Each plan comprises 3 hours of instruction.

Lesson Plan 1: Introduction to cement and worm bricks

Lesson Plan 2: Local material reinforced bricks
Lesson Plan 3: Local material reinforced bricks

(2) The appropriateness of the lesson plans was assessed by three experts with knowledge and expertise in STEM education, assessment and evaluation, and curriculum and instruction. The average rating for the plans' suitability was 80.4.

2) Design Skills Assessment: The development of the design skills assessment follows these guidelines:

The design skills assessment was adapted from the Science and Technology Education Institute (2018) for evaluating activities related to battery charging with clean energy. It includes six components: the application of scientific principles, mathematics, technology, and engineering design processes; project success; use of local materials; planning and collaboration; creativity; and analytical thinking, with a total score of **100** points.

A design skills assessment was created, including scoring criteria for each component and each level.

The assessment was tested by having five G9 students collaboratively create local Material-Reinforced worm bricks in two rounds. The assessment was applied during the second round, where two teachers from the testing and evaluation field scored the students based on the developed assessment.

The scores from both teachers were correlated, resulting in a correlation coefficient of 0.86, indicating a high level of reliability.

3) Satisfaction Questionnaire for the Learning Process on Local Material-Reinforced Bricks Using STEM Education Concepts through the PAR-SAPS Process: The satisfaction questionnaire for the learning process regarding local material-reinforced bricks, using STEM education concepts through the PAR-SAPS process, was a **-5**point Likert scale assessment with the following steps:

(1) Study concepts related to assessing satisfaction with the learning process and define specific terms.
(2) Draft a satisfaction assessment questionnaire regarding local material-reinforced bricks using PAR-SAPS concepts, comprising **8** items.
(3) Submit the created satisfaction assessment questionnaire to three experts for evaluation of the alignment between the questions and the defined terms.
(4) Calculate the index of consistency (IOC) between the questions and the defined terms using the formula by Rovinelli and Hambleton (1977)cited in Phisit Tanthawanich and Phana Jindasri,(2018) finding an IOC value of **1.00** for all items.
(5) Administer the satisfaction questionnaire to G9 students at Ban Janrom School after conducting the learning activities on local Material-Reinforced bricks using STEM education concepts through the PAR-SAPS process, resulting in a reliability value of 0.81.

4) These evaluation forms—the Learning Management Plan Evaluation Form, the Design Skills Evaluation Form, and the Satisfaction Evaluation Form—are tools used to collect opinions and suggestions from experts regarding the synthesized model. The operational steps are as follows: Operational Steps

(1) Study the process of creating evaluation forms and define questions that cover all desired evaluation aspects to draft a preliminary version of the model's suitability assessment. This involves using data from expert interviews to construct a 5-point Likert scale questionnaire.

(2) Submit the questionnaire to the advisor for content validity review of the questions, ensuring they cover all research issues and checking the accuracy and appropriateness of the language and wording used in the questionnaire.

(3) Administer the questionnaire to five experts to assess the content validity of each question.

(4) Revise and correct any deficiencies in the questionnaire based on expert suggestions. Print the final version of the questionnaire for actual data collection.

2.4 Data Collection and Analysis

The data collection and analysis procedures in this study were systematically conducted to evaluate the effectiveness of STEM-based instructional activities integrated with the PAR-SAPS process, focusing on the topic "Local Material-Reinforced Bricks." The study targeted Grade 9 students and was carried out over nearly one month, from September 5 to September 30, 2024. The collected data aimed to assess both the behavioral development of students in terms of design skills and their affective responses to the instructional approach.

1) Collection of Design Skill Data. The assessment of students' design skills was conducted through structured classroom observations by instructors during each learning session. The instrument used was a performance-based rubric developed in accordance with STEM education principles, which included six core components: application of scientific knowledge, project success, utilization of local materials, collaborative planning, creativity, and analytical thinking. Students worked in groups throughout three instructional rounds, and their performance was observed and rated in each session. The rubric allowed for a holistic assessment of the students' real-time application of interdisciplinary knowledge and skills in the context of hands-on project development. This method of authentic assessment was employed to ensure that the evaluation reflected the students' actual design capabilities within a collaborative and contextualized learning environment.

2) Collection of Satisfaction Data. To assess students' affective responses, a satisfaction questionnaire was administered after the completion of the third and final session. The questionnaire consisted of eight items rated on a 5-point Likert scale, focusing on various aspects of the learning experience. These included the quality of instructional planning, effectiveness and diversity of learning materials, appropriateness of time allocation, promotion of self-directed learning, opportunities for group collaboration, relevance to daily life, problem-solving skills, and interdisciplinary integration. This instrument was designed to gather students' perceptions of how well the learning process supported their engagement, interest, and the applicability of the knowledge gained. Collecting this data post-instruction provided comprehensive feedback on the instructional model and its alignment with student needs and expectations.

3) Data Analysis. All data collected from the design skill assessments and satisfaction questionnaires were analyzed using descriptive statistical methods, specifically mean and standard deviation. This analysis provided insight into the progression of students' design abilities over the course of the study and the overall level of satisfaction with the instructional process. The results were then interpreted to determine the effectiveness of the STEM-integrated PAR-SAPS learning model and to inform potential improvements for future instructional planning

3.Results and Discussions

3.1 Design Skills

The assessment of design skills in this study was conducted through group activities that involved the practical creation of locally made material-reinforced bricks. This assessment took place over three consecutive instructional sessions, each representing a complete cycle of learning through the PAR-SAPS process. Students were divided into three working groups: Group 1 (G1), Group 2 (G2), and Group 3 (G3). Their performance was evaluated using a rubric that addressed six key domains central to STEM-based project work: (1) application of STEM principles, (2) project success, (3) use of local materials, (4) collaborative work planning, (5) creativity, and (6) analytical thinking and criticism. Each component was assigned a score weight, with a maximum possible score of 100 points for each session per group.

The data summarized in Table 1 and Figure 1-3 show a clear and consistent improvement in students' design skills across the three sessions. The mean total scores increased from 46.77 in Session 1 to 60.33 in Session 2, and ultimately to 72.33 in Session 3. This positive progression strongly indicates that repeated, structured exposure to the design tasks guided by STEM concepts and the participatory, reflective nature of the PAR-SAPS model significantly enhanced students' problem-solving, planning, and execution abilities. In Session 1, although students demonstrated initial engagement with the task, their performance was relatively modest. Group 1 scored the highest in project success (15/20), while all groups scored zero in the use of local materials, reflecting a lack of awareness or practical integration of community resources at the beginning of the learning process. Creativity scores were also low (5/15 across all groups), suggesting limited innovation and originality in their initial designs.

Table 1. Score-table design skills from group activities on local material reinforced bricks.

Content	Full Score	Score								
		Session 1			Session 2			Session 3		
		G1	G2	G3	G1	G2	G3	G1	G2	G3
The application of STEM principles	20	8	10	10	9	10	10	10	14	12
Project success	20	15	13	12	15	13	12	18	15	15
The use of local materials	15	0	0	0	8	8	8	11	12	11
Collaborative work planning	15	8	10	9	10	12	10	10	14	11
Creativity	15	5	5	5	8	8	10	10	11	13
Analytical thinking and criticism	15	10	10	10	10	10	10	10	10	10
Total	100	46	48	46	60	61	60	69	76	72
Mean		46.77			60.33			72.33		

By Session 2, noticeable improvements were observed in almost all domains. All groups began to integrate local materials into their projects, each receiving 8/15 for that component, reflecting both effective teacher guidance and students' growing understanding of the importance of contextual materials. Group 1 again led in project success and demonstrated stronger planning and collaboration. Creativity scores also increased, particularly for Group 3, which achieved 10/15—evidence of enhanced design confidence and experimentation. In Session 3, the students reached their highest level of performance. Group 2 emerged as the top-performing group with a total score of 76, followed by Group 3 with 72 and Group 1 with 69. This session reflected the culmination of previous learning cycles, as students demonstrated clear competence in multiple areas, particularly in creativity (up to 13/15 for G3), use of local materials (up to 12/15 for G2), and collaborative work (up to 14/15 for G2). Notably, all groups consistently achieved full or near-full scores in analytical thinking across all three sessions, indicating strong skills in critical evaluation, reasoning, and refinement of their design choices.

The findings from the design skills assessment confirm the effectiveness of the PAR-SAPS-integrated STEM instructional approach. Through repeated and reflective cycles of planning, action, presentation, and summarization, students not only improved their technical design capabilities but also deepened their understanding of the interdisciplinary nature of STEM learning. The process helped them transfer abstract concepts into concrete applications, enhancing their creativity, teamwork, and resource utilization. These outcomes align well with the goals of 21st-century education, emphasizing student agency, innovation, and contextual problem-solving.

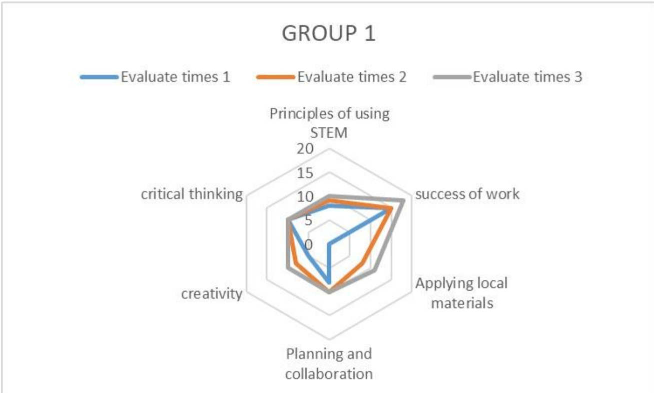

Figure 1. Design skills of Group 1from three assessments.

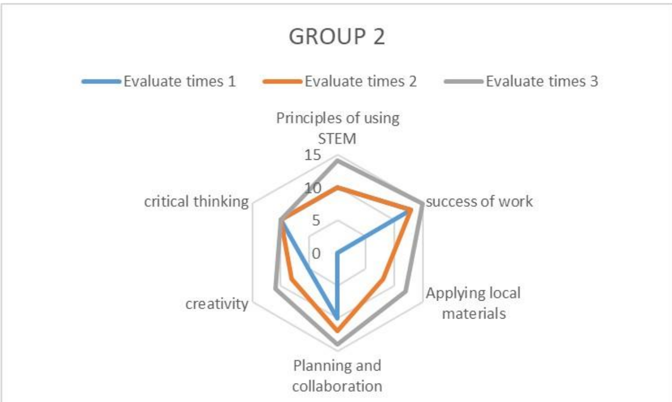

Figure 2. Design skills of Group 2from three assessments.

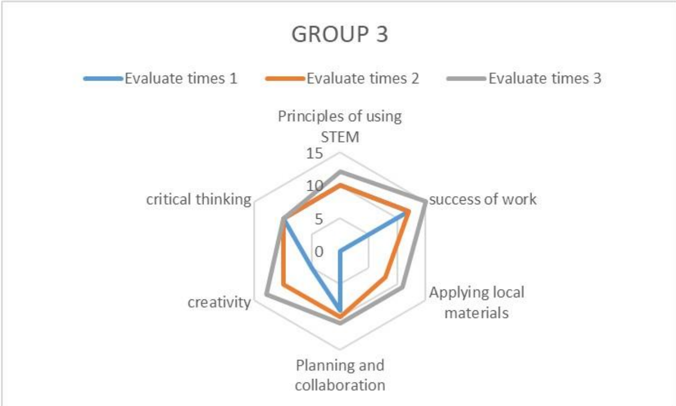

Figure **3.** Design skills of Group **3** from three assessments.

3.2 Satisfaction with the learning process on local material-Reinforced bricks using the STEM education concepts through the PAR-SAPS process.

To evaluate the affective domain of student learning experiences, a satisfaction survey was conducted among Grade 9 students following the completion of STEM-integrated learning activities based on the PAR-SAPS instructional model. The purpose of this survey was to gather student perceptions across various aspects of the instructional experience, including planning, instructional materials, content relevance, self-directed learning, collaboration, real-life application, problem-solving, and interdisciplinary integration. The results, including mean scores and standard deviations for each item, are summarized in Table 2.

Overall, student satisfaction was very high, with a mean score of 4.65 out of 5.00 and a standard deviation of 0.35. This indicates a strong positive response to the instructional approach, suggesting that the learning design effectively met students' expectations regarding content quality, engagement, and applicability. Among the individual items, the highest-rated statement was: **"**Students can apply skills in creating and designing projects in their daily lives**"** **(**Mean = 4.86, S.D. = 0.36**)**. This reflects students' perceptions of the relevance and practicality of the learning activities, affirming that the PAR-SAPS process successfully helped them connect classroom knowledge to real-world contexts. The next highest scores were observed in items related to the diversity and contextual alignment of the teaching materials **(**Mean = 4.81**)** and the promotion of collaborative group processes **(**Mean = 4.71**)**. These results underscore the importance of varied and locally relevant learning resources in fostering student engagement. Conversely, the lowest average score was reported for the item: **"**The content is appropriate for the duration of the learning process**"** **(**Mean = 4.38, S.D. = 0.59**)**. While this score still falls within the **"**good**"** range, it suggests that students felt the allocated time was insufficient to fully explore the material or complete their projects to their desired extent. This observation highlights the need to reconsider time allocation in future implementations to allow for deeper exploration and reflection.

The satisfaction results strongly support the effectiveness of the PAR-SAPS model in delivering a meaningful, engaging, and contextually relevant learning experience. The high levels of student approval across most dimensions demonstrate the model's capability to integrate STEM principles in a way that resonates with learners. Moreover, the findings emphasize the value of incorporating local materials and real-world challenges into classroom learning to foster motivation, skill development, and long-term retention.

Table 2: Mean and standard deviation of satisfaction with the learning process on local material-reinforced bricks using the STEM education concepts through the PAR-SAPS process.

	Content	Mean	S.D.	Meaning
1	The teacher plans and prepares the learning process.	4.71	0.46	Excellent
2	The teaching materials are diverse, interesting, and can incorporate local materials for effective learning.	4.81	0.40	Excellent
3	The content is appropriate for the duration of the learning process.	4.38	0.59	Good
4	It promotes self-directed learning.	4.62	0.59	Excellent
5	It fosters group processes, allowing students to listen to others' opinions and express their own views.	4.71	0.64	Excellent
6	Students can apply skills in creating and designing projects in their daily lives.	4.86	0.36	Excellent
7	They are able to plan their work and solve various problems.	4.52	0.60	Excellent
8	They can integrate knowledge from science, technology, engineering, and mathematics into practical applications.	4.57	0.51	Excellent
	Total	4.65	0.35	Excellent

As discussion above, the study on research that develops scientific process skills, it was found that there are skills at two levels: Basic science process skills and integrated science process skills. Scholars studying this topic recognize the importance of scientific process skills for practical applications and as a foundation for learning. However, the selection of scientific skills for study varies, with some skills being less examined than others; for example, the skill of Formulating Models may appear in some texts and not in others (Fugarasti, Ramli, and Muzzazinah, 2019).

Additionally, a review of relevant literature on teaching and learning reveals that while some skills are frequently mentioned, others are completely absent. For instance, the study of scientific process skills in the primary school textbooks of Greece by Sidri and Skoumios (2021) found that the most prevalent skill was observation, accounting for 74%, while the skill of designing models was found in only 11%. A study on scientific process skills from practical biology exams in secondary education from 2002 to 2012 by Ongowo and Indoshi (2013) found no mention of design skills. In contrast, a study by Kanitha Kamprad, Janthima Satsamon, and Wanpen Kamthep (2022) examined the types of scientific process skills in the revised 2017. Basic Science curriculum textbooks for lower secondary education in Thailand and found that basic scientific process skills were more prevalent than integrated scientific process skills, with data interpretation skills being the most common at 51.30%, while design skills were not included in the study. The aforementioned points reflect that all scientific process skills are essential for learning and their application in instructional management. If scholars focus their research on a limited number of skills, it may lead to a lack of effective examples or practical guidelines for those skills.

The design skills of the targeted student group showed an overall significant improvement in design skills, with scores increasing from 46.77 in the first round to 66.33 in the second round, and 72.33 in the third round. This indicates a positive development in design skills, which resulted from hands-on practice and learning from the operational environment (Fugarasti, Ramli, and Muzzazinah, 2019). Additionally, the use of STEM education processes in engineering design served as a foundation for developing design skills, allowing students to choose materials based on their prior knowledge and utilize trial-and-error methods to refine their projects until they met the specified criteria (Park, Park, & Bates, 2018). This aligns with the notion that learning based on concrete materials tends to facilitate easier knowledge transfer. When students have access to a diverse and sufficient range of materials to aid in their thinking, challenging concepts can become more tangible. This enables students to construct knowledge independently. When students have the opportunity to create this knowledge themselves, they gain a deeper understanding and enhance their learning capabilities (Papert, 1993).

Satisfaction with Learning Management on Local Material Reinforced Bricks Using STEM Concepts through the "PAR-SAPS" Process. The overall satisfaction level is very high ($\bar{x}$ = 4.65). This may be due to the researcher's use of STEM education concepts, which involve integrating various learning resources and allowing students to engage more with topics of personal interest. This is consistent with the evaluation results, where the question "The teaching materials are diverse, interesting, and applicable to local materials for learning management" received the second highest average score. Moreover, the learning management on local material-enhanced bricks has significantly increased students' interest, as it relates closely to their real-life experiences. This aligns with Jarunpong Cholsinthun (2018), who stated that the scenarios used in teaching should correspond to students' real lives and promote collaborative analysis for solving problems together.

4. Conclusions

This research emphasizes the importance of integrating STEM education with the PAR-SAPS process to enhance creative design skills among Grade 9 students in a local context. The study had two main objectives (i) to develop students' design skills in creating bricks reinforced with local materials using a STEM education approach through the PAR-SAPS process, and (ii) to assess their satisfaction with this learning experience. The research involved 21 G9 students and utilized three STEM-integrated lesson plans centered around the topic of reinforced bricks made from local materials. Learning activities were structured around the PAR-SAPS cycle, which includes the phases: start, action, present, and summarize. Students engaged in three rounds of group-based project-based learning, with their design skills assessed at each stage. A satisfaction questionnaire was administered at the end of the sessions. Findings revealed a significant improvement in students' design skills across the three learning sessions, with mean scores rising from 46.77 in the first round to 60.33 in the second, and to 72.33 in the third. This increase highlights the effectiveness of hands-on, STEM-based learning in enhancing students' abilities to apply scientific concepts, collaborate in planning, think analytically, and creatively solve problems using local materials. Regarding student satisfaction, the overall mean score was very high (4.65 out of 5.00), with the highest rating given to the statement: "Students can apply the skills to design and create projects in their daily lives" (4.86). The lowest-rated item related to time allocation, indicating that students wished for more time to develop their projects in depth (4.38). In conclusion, the integration of STEM education with the PAR-SAPS model has proven effective in developing essential scientific process skills, particularly in modeling and design, while also fostering high levels of engagement and meaningful learning experiences. This approach supports the development of 21st-century competencies and demonstrates strong potential for wider application in science and technology education.

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