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Fostering Scientific Creativity in Primary Students through Outdoor STEM Education: A Case Study in Phuket Province

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Abstract. This research aimed to (1) examine Grade 4 students' scientific creative thinking skills before and after participating in outdoor STEM learning based on the context of Phuket Province, (2) develop these skills through local context-based activities, and (3) identify effective practices for organizing such learning experiences. The study involved 22 Grade 4 students from a school in Phuket during the second semester of the 2024 academic year, using a classroom action research approach with purposive sampling. Three outdoor STEM activities were implemented: eco-printing with Southern Thai plants, tie-dye using Sino-Portuguese patterns, and making "Apong" coconut milk desserts with natural dyes. A scientific creative thinking test based on Guilford's theory was used to assess four components: originality, fluency, flexibility, and elaboration. Findings revealed significant improvements in students' scientific creative thinking, particularly in fluency and elaboration. Students displayed enhanced creative behavior, confidence in presenting ideas, and the ability to solve problems using diverse, well-reasoned solutions. They creatively applied local knowledge to design unique patterns and innovate with natural color mixtures. The activities also promoted teamwork and 21st-century problem-solving skills. Post-test scores were significantly higher than pre-test scores at the 0.05 level, indicating the effectiveness of outdoor STEM learning in fostering scientific creativity through real-life context integration.

Keywords: Scientific Creative Thinking Skills, Outdoor STEM Learning, Context

INTRODUCTION

Phuket, the largest island province in southern Thailand, is internationally renowned for its tourism, natural beauty, and cultural diversity. With attractions such as Patong, Kata, and Karon beaches, along with landmarks like the Big Buddha, Mai Khao Beach, and the historic Sino-Portuguese architecture of Phuket Old Town, the province reflects a vibrant blend of Thai and Chinese cultures, especially during festivals like the Vegetarian Festival. Its economy heavily relies on tourism, and its rich cultural identity is showcased through distinctive local dishes such as *Kanom Apong* and *Oh Aew*.

Given Phuket's unique context, there is a pressing need to develop science education that reflects the province's identity and fosters students' appreciation of their local environment. Active, hands-on, and outdoor-based learning experiences are essential to connect students with real-world contexts and cultivate problem-solving skills derived from authentic experiences. This educational approach is aligned with Thailand's National Education Act B.E. 2542 (1999) and its amendments, which emphasize experiential learning, critical thinking, problem-solving, and the application of knowledge to real-life situations. Furthermore, the Revised Basic Education Core Curriculum B.E. 2560 (2017) modernizes science content to develop logical reasoning, ethical decision-making, and technological literacy, aiming to equip students with the skills necessary for navigating complex social and environmental challenges. Scientific creative thinking is a fundamental competency underpinning scientific literacy. It enables learners to discover, apply, and extend knowledge meaningfully. Thailand's second decade of educational reform (2009–2018) emphasized strategies to:

1. Improve quality and educational standards sustainably.
2. Expand equitable access to lifelong learning.
3. Promote societal participation in educational management (Patcharee Nakphong, 2019).

The Office of the National Economic and Social Development Council (2016) emphasized the urgent need to develop skills aligned with labor market demands and 21st-century competencies, particularly analytical thinking and creativity. In response, Thailand's Education 4.0 vision prioritizes cultivating learners who demonstrate independent thinking, creativity, and innovation. Supporting this direction, Supakorn Buasai (2015) cited an OECD labor market survey indicating that creativity and analytical skills are among the most highly sought-after attributes by employers. The OECD's decision to incorporate creative and critical thinking assessments into its 2021 international examinations (Isranews Agency, 2015) further underscores the global prioritization of these competencies. Despite their recognized importance, studies suggest a worrying global decline in students' creative abilities. Kim (2011) identified significant decreases in creative thinking scores, attributing this trend to rigid curricula and traditional instructional practices that suppress divergent thinking. Robinson (2011) similarly argued that education systems often prioritize conformity over creativity. In Thailand, Surachai Radakan (2012) highlighted creativity and innovation as vital for survival and competitiveness, serving as the basis for new ideas, inventions, and solutions. Mohammed and Kinyo (2020) also observed that teacher-centered instruction tends to restrict student creativity, fostering imitation rather than originality. The importance of addressing these issues is reflected in Section 24 of the National Education Act B.E. 2542 (1999), which emphasizes that educational activities should be aligned with learners' interests and aptitudes, promote experiential learning, develop independent thinking, and encourage interdisciplinary knowledge integration (Office of the National Education Commission, 1999).

In this national context, STEM education—integrating Science, Technology, Engineering, and Mathematics—has been widely promoted throughout Thailand to build essential 21st-century skills. STEM initiatives have expanded at both national and regional levels through government policies, private sector collaborations, and education reform agendas, notably under the Education 4.0 framework. In southern Thailand, most STEM efforts have been concentrated at the secondary education level, especially in science and technology-based demonstration schools and selective programs. At the primary level, STEM activities have been introduced mainly through pilot projects, teacher development initiatives, and STEM camps organized by institutions such as the Ministry of Education, SEAMEO STEM-ED Center, and local universities. These programs often focus on project-based learning, engineering design, and problem-solving processes.

However, a review of existing literature reveals that systematic research on context-based outdoor STEM education at the primary school level in southern Thailand—particularly in Phuket Province—remains very limited. Most primary-level STEM activities in Thailand have centered around general topics such as basic engineering projects (e.g., bridge construction, water filtration), environmental awareness (e.g., recycling, pollution control), simple robotics, coding, renewable energy, and basic scientific inquiry. These activities are typically conducted in classroom or laboratory settings, with relatively little integration of outdoor learning environments or local cultural and natural resources.

Uniqueness of the Current Study

This study represents the first systematic research in southern Thailand, specifically in Phuket, to integrate contextual outdoor STEM education aimed at developing scientific creative thinking skills among Grade 4 students. Unlike previous STEM initiatives that often-replicated standardized models without adaptation to local contexts, this research: Utilizes real-world, outdoor settings that reflect Phuket's ecological, cultural, and economic uniqueness. Embeds STEM learning within the local community and environment, through activities such as eco-printing with native plants, traditional Sino-Portuguese tie-dye patterns, and creating natural dyes using local foods. Focuses explicitly on enhancing scientific creative thinking, not merely on scientific knowledge acquisition or technological proficiency. This approach distinguishes the present study from earlier STEM education programs, which predominantly emphasized general content learning without deep cultural or environmental contextualization. Thus, the current research addresses a critical gap by linking scientific creativity development with local identity, place-based learning, and sustainability awareness. Given the absence of prior studies combining outdoor learning, place-based STEM activities, and scientific creative thinking development for primary students in southern Thailand, this research can be considered a pioneering effort.

Creativity Assessment and Need for Innovation

In today's dynamic world, creativity remains a fundamental skill for student success (Beghetto & Kaufman, 2014). Nevertheless, concerns regarding the insufficient development of creativity persist across educational levels. In the context of this study, no systematic measurement of Grade 4 students' creativity skills in Phuket had been conducted before. Therefore, this research constitutes the first attempt to quantitatively and qualitatively assess creativity among this population. A preliminary assessment, based on Guilford's (1950) framework, was conducted prior to the intervention. Quantitative results showed an average creativity score of 41 out of 100, indicating moderate to low levels of creative thinking among students. Qualitative observations further revealed that while students could generate ideas, they struggled with producing original, flexible, and elaborated responses. These findings reinforce the urgent need for innovative educational approaches to foster scientific creativity through context-based outdoor STEM learning. Research supports the notion that science education should actively involve students in inquiry-based, hands-on activities that cultivate scientific process skills and promote meaningful knowledge creation. These approaches are grounded in Constructivist Learning Theory, emphasizing exploration, self-discovery, and investigation (Napaporn Piangduangjai, 2015).

Conclusion, considering the significance of creativity in 21st-century education and the distinctive cultural and environmental context of Phuket, this study aims to develop scientific creative thinking skills among Grade 4 students through outdoor, real-world STEM learning experiences. It seeks to enhance both students' creativity and scientific literacy, while providing teachers with effective strategies to innovate science instruction.

Ultimately, the development of these skills will enable students to solve real-life problems and contribute to the creation of responsible, capable citizens for the future.

Research Objectives

1. To study the scientific creative thinking skills of Grade 4 students before participating in context-based outdoor STEM learning in Phuket Province.
2. To develop scientific creative thinking skills through the implementation of outdoor STEM learning based on the local context of Phuket Province.
3. To enhance the design of outdoor STEM learning based on the context of Phuket Province in a way that promotes scientific creative thinking skills among Grade 4 students.
4. To identify best practices for organizing outdoor STEM learning activities that foster scientific creative thinking skills in Grade 4 students.

RESEARCH METHOFLOGY

Conceptual Framework

This research aims to study the effects of a learning management approach designed to develop analytical thinking and creativity among Grade 4 students. Based on a review of relevant literature and prior studies on learning management, the researcher selected the STEM education model incorporating the Engineering Design Process (Abdulyamin Hayikhader, 2017). This approach encourages students to engage in problem-solving through the integration of four disciplines: Science, Mathematics, Technology, and Engineering, to foster creative thinking (Phassorn Tidma, 2015) among upper primary students. The conceptual framework of the research is illustrated in Figure 1.

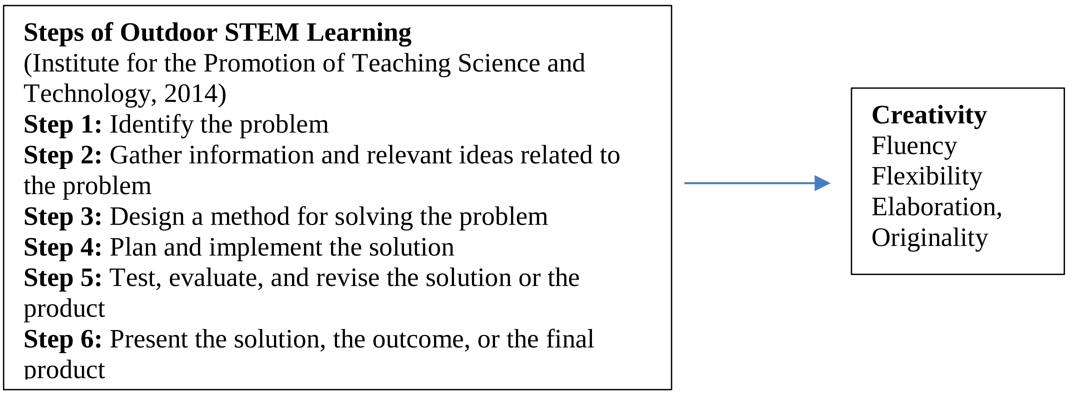

Figure 1. Research Conceptual Framework.

Research Methodology

The research design for this study is Classroom Action Research. This research adopts a pragmatic paradigm, which emphasizes knowledge and reality that help achieve life goals and improve life. It focuses on real-life experiences and best practices related to the management of learning that promotes the engineering design process. The study is mixed-methods research with an embedded design. The researcher primarily collects and analyzes quantitative data, while qualitative data collection and analysis are secondary. The results obtained are then interpreted to summarize findings related to the engineering design process through Outdoor STEM learning.

For this research, there are 5 cycles of CAR (Classroom Action Research): CAR 1: Preparation and Review of Prior Knowledge CAR 2: Learning Management Plan 1 CAR 3:

Learning Management Plan 2 CAR 4: Learning Management Plan 3 CAR 5: Reflection and Measurement of Scientific Creative Thinking Skills (Summary)

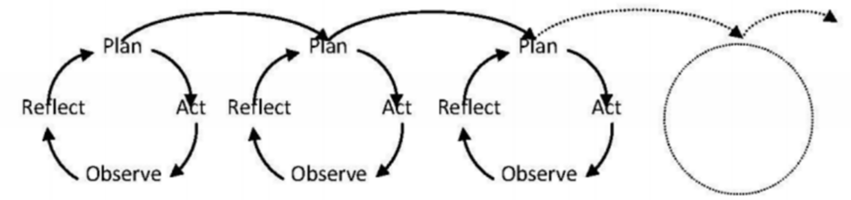

Figure 2. The Stages of Classroom Action Research (Kemmis & McTaggart, 1988)

Scope of the Research

Research Group

The research group used in this study consists of 22 students from Grade 4 at a school in Phuket, during the second semester of the 2024 academic year. The students were selected using purposive sampling, with the following criteria:

1. Students in Grade 4 who are enrolled in the science course during the second semester of the 2024 academic year.
2. Students who volunteered and were willing to participate in the research.
3. Students for whom the researcher is the instructor for the science course.

Content

In this research, outdoor STEM learning was implemented outside the classroom according to the context of Phuket. The content covered the science and technology learning area, subject code W 14101, in Chapter 1 for Grade 4 students, focusing on materials and matter, with a total teaching time of 16 hours.

Duration

In this research, outdoor STEM learning outside the classroom was implemented with Grade 4 students during the second semester of the 2024 academic year. The teaching time was 3 hours per week for 7 weeks, totaling 16 hours in-class, along with 20 hours of self-directed learning. The period of the study was from December 2024 to January 2025.

Table 1. The details of each learning plan related to activities and time.

Learning Standards	Indicators	Learning Plan	Time (hours)
W 2.1 Understand the properties of matter, the components of matter, the relationship between the properties of matter and the structure and forces between particles, the principles and nature of the change of state of matter, the formation of solutions, and the occurrence of chemical reactions.	**P.2/1** Compare the water absorption properties of materials using empirical evidence and identify the application of the water absorption properties of materials in creating objects for daily life.	1.Eco-print with Southern Botany - 6 hours	6
		2. Tie-dye fabrics with Sino-Portuguese design - 6 hours	6
		3. Apoong coconut milk from natural dyes - 4 hours	4

In each lesson plan, such as Lesson Plan 1: "Eco-Print with Southern Botany," the teacher initiates the session by establishing a relaxed and supportive atmosphere, creating a positive learning environment. Learning beyond the classroom setting offers an invaluable opportunity to nurture students' creativity and enhance their connection to the surrounding natural world. As part of Step 1: Identifying the Problem, students are introduced to a real-world issue scenario relevant to their local context to spark inquiry and investigation.

For Lesson Plan 1, students are presented with the issue:

"How can we creatively utilize the natural plant diversity of our local environment to design eco-friendly products that reflect the unique identity of southern Thailand?"

This problem scenario integrates indicators from all four STEM subjects:

Science: Understanding plant properties, pigments, and ecosystems.
Technology: Exploring eco-printing techniques and materials.
Engineering/Occupational: Designing and optimizing the eco-print process (e.g., how to apply pressure, moisture, and heat effectively).
Mathematics: Measuring leaf sizes, calculating fabric dimensions, and timing the steaming/dyeing process.

The "Walking Map" activity is employed to allow students to explore and survey natural resources in the community, collecting data on local flora that could be used in the eco-printing process.

Similarly, in Lesson Plan 2: "Tie-Dye Fabrics with Sino-Portuguese Design" (6 hours), students are tasked with the scenario:

"How can we preserve and modernize traditional Sino-Portuguese designs through innovative fabric dyeing techniques using local knowledge and resources?"

STEM integration in this lesson includes:

Science: Investigating chemical reactions between natural dyes and fabrics.
Technology: Applying techniques for dye fixing and colorfastness.
Engineering/Occupational: Designing patterns and engineering a dyeing process that achieves aesthetic and durable results.
Mathematics: Creating geometric designs, calculating proportions of dye mixtures, and measuring symmetry in patterns.

In Lesson Plan 3: "Apoong Coconut Milk from Natural Dyes" (4 hours), students explore the issue:

"*How can we innovate traditional Apoong desserts by using natural dyes to create visually appealing and environmentally friendly food products?"*

This integrates:

Science: Understanding chemical properties of natural colorants and their interaction with food ingredients.
Technology: Applying techniques for safe and effective food coloring.
Engineering/Occupational: Modifying recipes and cooking methods to maintain color stability and texture.
Mathematics: Measuring ingredient quantities accurately and adjusting proportions based on experimental outcomes.

Research Data Collection Instruments include:

1. Creativity Skills in Science Assessment - Topic: Materials and Matter (Pre- and Post-Learning). The total teaching time is 16 hours, covering situations or scenarios occurring within the context of Phuket, combined with open-ended questions.

2. STEM Activity Sheets - These focus on creativity skills in science as part of the learning plans for students during the learning activities. They include questions aligned with the creativity skills in science, used to collect research data during the learning process by categorizing answers according to specified criteria.

Development and Evaluation of the Quality of Research Instruments

1. Steps in Creating the STEM Learning Plan Outside the Classroom Based on the Context of Phuket, Topic: Materials and Matter

1.1 Review relevant documents and research related to the development of creativity skills in science by using an integrated learning model that combines scientific knowledge, technology, engineering design processes, and mathematics (STEM Education). This will serve as a guideline for structuring the content and activities appropriately.

1.2 Study the content details used in this research from the 4th-grade science textbook, part of the science learning area, according to the Basic Education Core Curriculum B.E. 2551 (Revised in 2017).

1.3 Study the principles, concepts, and theories related to the integration of scientific knowledge, technology, engineering design processes, and mathematics (STEM Education) to apply these principles in creating the STEM learning plan related to the context of Phuket, on the topic of materials and matter. This includes 3 learning plans, totaling 16 hours of science learning, based on the Basic Education Core Curriculum B.E. 2551 (Revised in 2017).

1.4 Present the learning plans created by the researcher to 3 experts for evaluation of the alignment between the learning plans and the learning objectives. The evaluation is done using the following scale: +1 indicates certainty that the learning plan aligns with the learning objectives, 0 indicates uncertainty about alignment, and -1 indicates certainty that the learning plan does not align with the learning objectives.

1.5 The researcher revises and adjusts the learning plans according to the feedback from the experts.

1.6 Implement the revised and appropriately adjusted learning plans with a target group like the research group.

2. Steps in Developing Scientific Creativity Skills

2.1 Study documents, academic articles, collect data, and analyze research studies related to creativity skills.

2.2 Create a conceptual framework to measure scientific creativity skills.

2.3 Develop a tool to measure scientific creativity skills, which involves answering questions based on given situations, and establish criteria for evaluating scientific creativity skills.

2.4 Present the developed tool for measuring scientific creativity skills and the evaluation criteria to experts for validation.

2.5 The researcher revises and adjusts the tool for measuring scientific creativity skills and the evaluation criteria based on the experts' recommendations.

2.6 Implement the revised tool for measuring scientific creativity skills with the target group.

DATA COLLECTION PROCESS

1. Select 4th-grade students, chosen through purposive sampling, from one classroom with a total of 22 students.
2. Conduct a pre-test with the research group using the researcher-developed scientific creativity skills measurement tool to categorize the responses and present the data.

3. Clarify the learning process and introduce the learning plan using the STEM (Science, Technology, Engineering, and Mathematics) integrated approach to ensure students understand and can participate in the learning process and achieve the learning objectives.
4. The researcher conducts the learning process with the study group, taking the role of instructor and using the STEM learning plan on the topic of materials and matter. This follows the 4 stages of classroom action research: planning, acting, observing, and reflecting. This process is carried out in 3 action cycles with 4th-grade students at a school in Phuket, during the second semester of the 2024-2025 academic year. A total of 22 students from one class were selected using purposive sampling. The total teaching time is 16 hours.

DATA ANALYSIS

This research is a Classroom Action Research, involving both qualitative data and quantitative data. Therefore, content analysis and statistical analysis methods were used. The researcher analyzed the data obtained from various tools as follows:

The scientific creativity skills measurement tool consists of open-ended questions based on the content of the lessons, divided into two sets (pre-test and post-test), covering all four indicators: 1) Originality, 2) Flexibility, 3) Fluency, 4) Elaboration.

Each set of the scientific creativity skills measurement tool contains questions that assess the indicators related to the topic of materials and matter to measure the abilities before and after the learning process. The tool was validated for content validity by 3 experts and was pilot tested (try out) with 10 students like the target group to establish scoring criteria for evaluating responses that demonstrate scientific creativity skills.

RESEARCH FINDING

1. The development of scientific creativity skills of Grade 4 students before participating in the STEM-based outdoor learning program in the context of Phuket

The study on the development of scientific creativity skills related to the topic "Materials and Matter" of Grade 4 students, before applying the STEM-based outdoor learning approach in the context of Phuket, which included six steps: 1) Identifying the problem, 2) Collecting data and ideas related to the problem, 3) Designing a solution, 4) Planning and implementing the solution, 5) Testing and evaluating, 6) Presenting the results. The findings on the development of scientific creativity skills in the topic "Materials and Matter" included 8 open-ended questions, covering the content of the "Materials and Matter" learning unit. The test was a subjective type, with a full score of 20 points. The results of the scientific creativity skills assessment (including originality, flexibility, fluency, and elaboration) showed that the percentage of students' scores before the learning process was as follows: Students with scores below 5 points: 0.00% Students with scores between 5-9 points: 54.55% Students with scores between 10-14 points: 45.45% Students with scores between 15-20 points: 9.10% As shown in Table 2. A score below 5 points (0-4 points) means that the students have very low or almost no display of creative scientific thinking skills in the topic of materials and matter. A score of 5-9 points means that students have low creative scientific thinking skills and can express some ideas, but they are not comprehensive or diverse. This score range has the highest percentage (54.55%), indicating that most students still require further development in creativity.

Table 2. Percentage distribution of scores for the development of scientific creativity skills in "Materials and Matter".

Score Range	**Number of Students (People)**	**Percentage**
Below 5 points	0	0.00
5-9	12	54.55
10-14	8	36.36
15-20	2	9.10

Figure 3 shows the percentage of scores for the development of creative scientific thinking skills in the topic of materials and matter for Grade 4 students before using outdoor STEM learning activities in the context of Phuket.

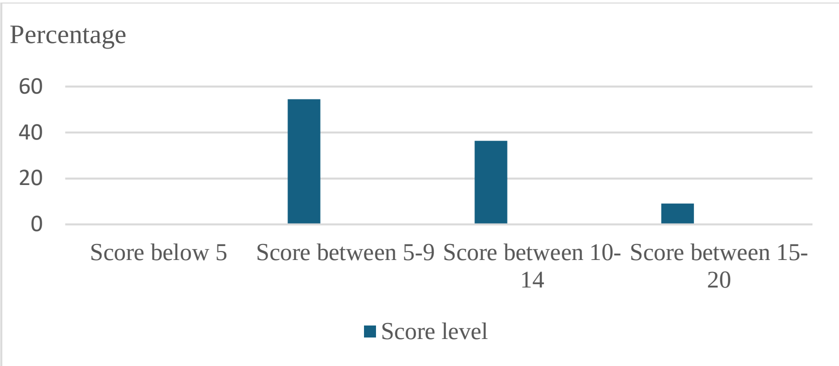

Figure 3. The percentage of scores for the development of creative scientific thinking skills in the topic of materials and matter.

A score of 10-14 points means that students have moderate creative thinking skills and can demonstrate creativity in some respects, such as problem-solving, design, or applying knowledge to new situations.

A score of 15-20 points means that students have high creative thinking skills and can express themselves clearly, covering multiple dimensions such as initiative, flexibility in problem-solving, and creating useful work.

2. The development of scientific creative thinking skills of Grade 4 students during their participation in the STEM-based outdoor learning program in the context of Phuket province. The details of the score levels for measuring creativity in each aspect were assessed through the STEM outdoor learning program in the context of Phuket province, both before and after the learning process. The researcher compared the scores as shown in Tables 3 to 6.

Aspect of Fluency in Thinking

The comparison of creativity skill levels in the aspect of fluency in thinking (Table 3) shows that (before learning), the highest number of students, 11 students (50.00%), answered at level 2. Five students (22.72%) answered at level 1, four students (18.18%) answered at level 3, and two students (9.09%) answered at level 4. No students answered at levels 0 or 5. In the creativity skill level assessment (after learning), the highest number of students, 15 students (68.18%), answered at level 4, and 7 students (31.81%) answered at level 5. No students answered at levels 0, 1, 2, or 3.

Table 3. The comparison of creativity skill levels in the aspect of fluency in thinking before and after participating in the STEM-based outdoor learning program.

Score level	N	Before learning		After learning	
		Number of students	Percentage	Number of students	Percentage
5	22	0	0.00	7	31.81
4	22	2	9.09	15	68.18
3	22	4	18.18	0	0.00
2	22	11	50.00	0	0.00
1	22	5	22.72	0	0.00
0	22	0	0.00	0	0.00

Figure 4 shows the results of the development of scientific creative thinking skills in the aspect of fluency in thinking of Grade 4 students during the STEM-based outdoor learning program in the context of Phuket province.

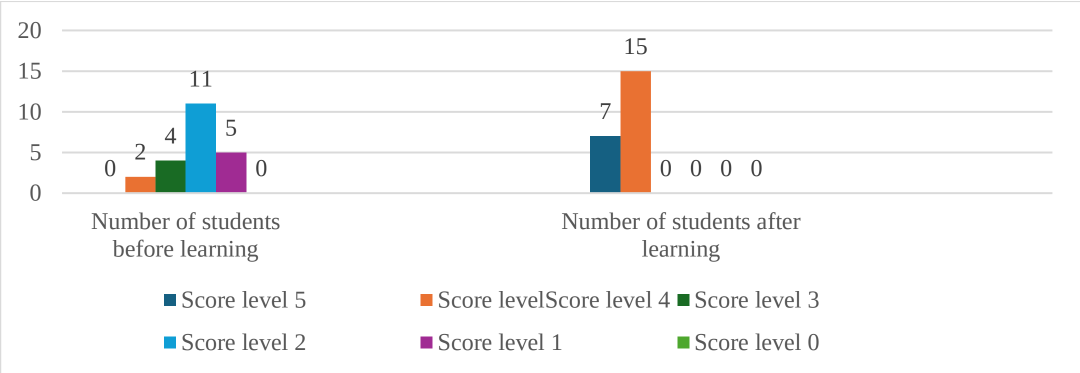

Figure 4. The results of the development of scientific creative thinking skills in the aspect of fluency in thinking during the STEM-based outdoor learning program.

Aspect of Flexibility in Thinking

The comparison of creativity skill levels in the aspect of flexibility in thinking before and after participating in the STEM-based learning program on the topic of materials and matter, as presented in Table 4. The comparison of creativity skill levels in the aspect of flexibility in thinking shows that (before learning), the highest number of students, 15 students (68.18%), answered at level 2. Five students (22.27%) answered at level 3, and two students (9.09%) answered at level 4. No students answered at levels 0, 1, or 5. In the creativity skill level assessment (after learning), the highest number of students, 16 students (72.72%), answered at level 4, and 6 students (27.27%) answered at level 5. No students answered at levels 0, 1, 2, or 3.

Table 4. The comparison of creativity skill levels in the aspect of flexibility in thinking before and after participating in the STEM-based learning program.

Score level	N	Before learning		After learning	
		Number of students	Percentage	Number of students	Percentage
5	22	0	0.00	6	27.27
4	22	2	9.09	16	72.72
3	22	5	22.27	0	0.00
2	22	15	68.18	0	0.00
1	22	0	0.00	0	0.00
0	22	0	0.00	0	0.00

Figure 5 shows the results of the development of scientific creative thinking skills in the aspect of flexibility in thinking of Grade 4 students during the STEM-based outdoor learning program in the context of Phuket province.

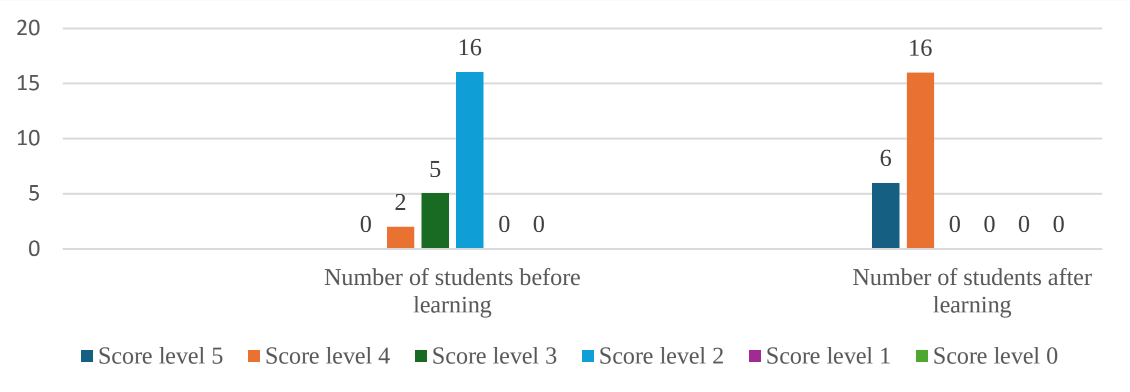

Figure 5. The results of the development of scientific creative thinking skills in the aspect of flexibility in thinking during the STEM-based outdoor learning program.

Aspect of Elaborate Thinking

The comparison of creativity skill levels in the aspect of elaborate thinking before and after participating in the STEM-based outdoor learning program on the topic of materials and matter, as presented in Table 5.

Table 5. The comparison of creativity skill levels in the aspect of elaborate thinking before and after participating in the STEM-based outdoor learning program.

Score level	N	Before learning		After learning	
		Number of students	Percentage	Number of students	Percentage
5	22	0	0.00	4	18.18
4	22	2	9.09	14	63.64
3	22	3	13.64	4	18.18
2	22	14	63.63	0	0.00
1	22	3	13.64	0	0.00
0	22	0	0.00	0	0.00

The comparison of creativity skill levels in the aspect of elaborate thinking from Situation 1 shows that (before learning), the highest number of students, 14 students (63.63%), answered at level 2. Three students (13.64%) answered at level 1, three students (13.64%) answered at level 3, and two students (9.09%) answered at level 4. No students answered at levels 0 or 5. In the creativity skill level assessment (after learning), the highest number of students, 14 students (63.64%), answered at level 4. Four students (18.18%) answered at levels 5 and 3, respectively. No students answered at levels 0, 1, 2, or 3.

Figure 6 shows the results of the development of scientific creative thinking skills in the aspect of elaborate thinking of Grade 4 students during the STEM-based outdoor learning program in the context of Phuket province.

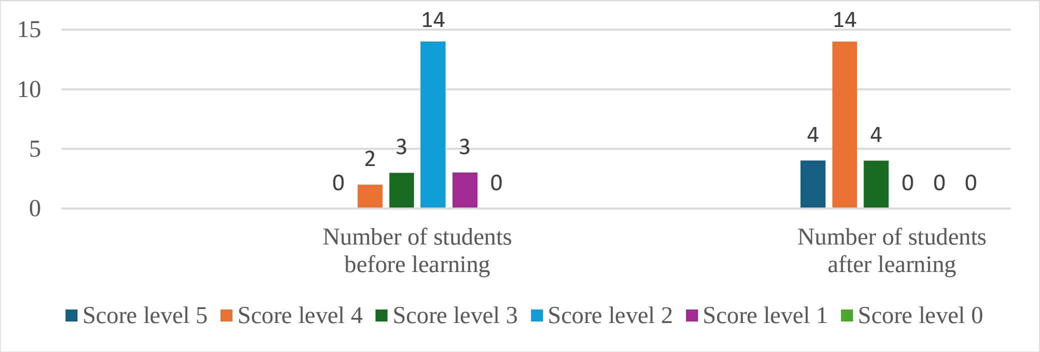

Figure 6. The results of the development of scientific creative thinking skills in the aspect of elaborate thinking during the STEM-based outdoor learning program.

Aspect of Initiative in Thinking

The comparison of creativity skill levels in the aspect of initiative in thinking before and after participating in the STEM-based learning program on the topic of materials and matter, as presented in Table 6.

Table 6. The comparison of creativity skill levels in the aspect of initiative in thinking before and after participating in the STEM-based learning program.

Score level	N	Before learning		After learning	
		Number of students	Percentage	Number of students	Percentage
5	22	1	4.54	4	18.18
4	22	3	13.63	18	81.81
3	22	6	27.27	0	0.00
2	22	8	36.36	0	0.00
1	22	4	18.18	0	0.00
0	22	0	0.00	0	0.00

Table 6, the comparison of creativity skill levels in the aspect of initiative in thinking from Situation 1 shows that (before learning), the highest number of students, 8 students (36.36%), answered at level 2. Six students (27.27%) answered at level 3, four students (18.18%) answered at level 1, and one student (4.54%) answered at level 5. In the creativity skill level assessment (after learning), the highest number of students, 18 students (81.81%), answered at level 4, and 4 students (18.18%) answered at level 5. No students answered at levels 0, 1, 2, or 3.

Figure 7 shows the results of the development of scientific creative thinking skills in the aspect of initiative in thinking of Grade 4 students during the STEM-based outdoor learning program in the context of Phuket province, which enhanced the scientific creative thinking skills of Grade 4 students in all 4 aspects (initiative in thinking, flexibility in thinking, fluency in thinking, and elaborate thinking) before and after participating in the STEM-based learning program.

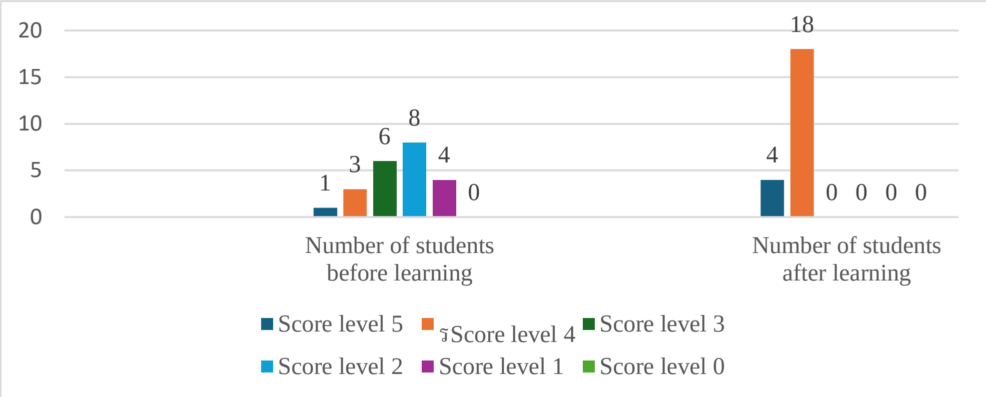

Figure 7. shows the results of the development of scientific creative thinking skills in the aspect of initiative in thinking during the STEM-based outdoor learning program

Figure 8 shows the results of the development of the STEM-based outdoor learning activities in the context of Phuket province, which enhanced the scientific creative thinking skills of Grade 4 students in all 4 aspects (initiative in thinking, flexibility in thinking, fluency in thinking, and elaborate thinking) before and after participating in the STEM-based learning program.

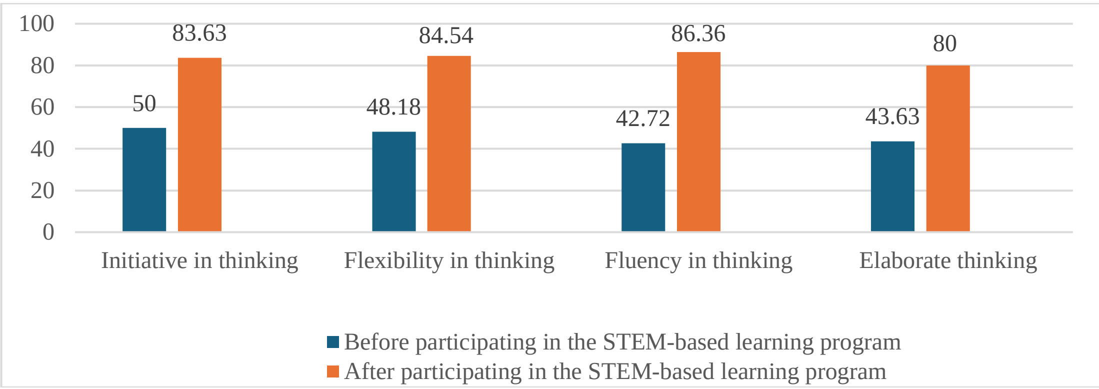

Figure 8. The results of the development of the STEM-based outdoor learning activities in all 4 aspects (initiative in thinking, flexibility in thinking, fluency in thinking, and elaborate thinking) before and after participating in the STEM-based learning program.

Figure 8, it shows the percentage of students according to the indicative behaviors with scientific creative thinking skills based on the scientific creative thinking skill assessment. Examples of student work that demonstrate behaviors aligned with the development of scientific creative thinking skills in all 6 aspects before and after participating in the STEM-based outdoor learning program in the context of Phuket province are as follows:

It presents examples of student responses with indicators of scientific creative thinking skills, specifically initiative in thinking, in Figure 9.

Ask students to observe the characteristics of monocot and dicot plant leaves and compare them to something in daily life. **Initiative in thinking.** *A monocot leaf is like a road, while a dicot leaf is like a city.*

Figure 9. The responses of students demonstrating the initiative in thinking indicator of scientific creative thinking skills.

Figure 9, the comparison of plant leaf characteristics (monocot and dicot) with something encountered in daily life, such as linking them to "roads" and "city maps," is a creative way of drawing on knowledge from experience. This demonstrates an understanding of the content and the ability to apply knowledge in different contexts.

It presents examples of student responses with the flexibility in thinking indicator of scientific creative thinking skills in Figure 10.

If students had to explain the difference between monocot and dicot leaves to their friends, what aspects would they choose to compare? For example, the use in daily life, growth, or plant structure, and provide examples. **Flexibility in thinking.** *Growth: Monocot plants are characterized by having a fibrous root system, such as tamarind.*

Figure 10. The responses of students demonstrating the flexibility in thinking indicator of scientific creative thinking skills.

Figure 10, students were able to apply their knowledge of monocot and dicot leaves in a different perspective. Not only they described the basic characteristics of the plants, but they also linked it to real-life examples (mango tree) and expanded on the root system. This demonstrates that students did not limit their thinking to just the information they learned but were able to adapt and explain it systematically, allowing them to communicate the differences between the two types of plants more clearly. It presents examples of student responses with the fluency in thinking indicator of scientific creative thinking skills in Figure 11.

What are the characteristics of monocot and dicot leaves? **Fluent thinking**

Dicot plants	***Monocot plants***
Veins are branched	*One cotyledon*
Taproot	*Fibrous roots*
No distinct nodes	*Clear nodes*
Two cotyledons	*Parallel-veined leaves*

Figure 11. The responses of students demonstrating the fluency in thinking indicator of scientific creative thinking skills.

Figure 11, students were able to organize and present information about the differences between monocot and dicot plants in an orderly, easy-to-understand, and concise manner. They responded quickly using clear and systematic language. Additionally, students were able to correctly link key characteristics of both types of plants, such as leaf veins, root systems, and the number of cotyledons, without confusion. This demonstrates their understanding of the content and their ability to arrange information effectively. It presents examples of student responses with the elaborate thinking indicator of scientific creative thinking skills in Figure 12. Students drew diagrams of monocot and dicot leaves, paying close attention to the details of the leaf structure. They not only depicted the shape of the leaves but also clearly labeled various components such as leaf veins, cross-section of the leaf, back of the leaf, and petiole.

Draw the shape of dicot and monocot plants and indicate the positions.
Meticulous thinking

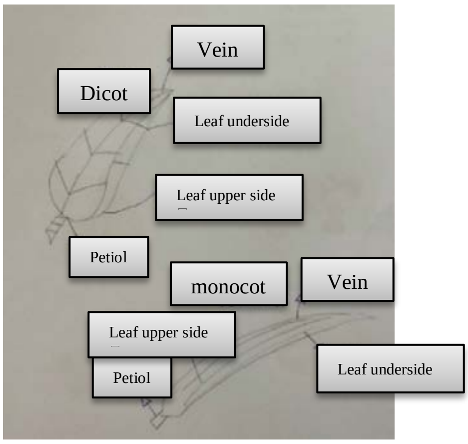

Figure 12. The responses of students demonstrating the elaborate thinking indicator of scientific creative thinking skills.

Results of the Development of Scientific Creative Thinking Skills of Grade 4 Students Who Participated in STEM Outdoor Learning in the Context of Phuket Province

The results of the development of scientific creative thinking skills of grade 4 students before and after participating in STEM outdoor learning in the context of Phuket province are as follows: The study found that the students' scientific creative thinking skills improved after participating in the activity, with higher scores than before the activity. The learning process was structured in 6 steps: 1) identifying the problem, 2) gathering data and ideas related to the problem, 3) designing a solution, 4) planning and executing the solution, 5) testing and evaluating the results, and 6) presenting the findings.

The researcher used a scientific creative thinking skills assessment tool to score and analyze the results of the students' scientific creative thinking achievement before and after participating in the STEM outdoor learning activity in the context of Phuket province. The results of the analysis are shown in Table 8.

Table 8. Results of the analysis of achievement in the development of scientific creative thinking skills of grade 4 students who participated in STEM outdoor learning.

Score	Full Score	$\bar{x}$	S.D.	t	Sig.
Before learning	20	8.14	2.46	21.77*	0.00
After learning	20	16.23	1.11		

*Statistically significant at the .01 level

Table 8, the results of the development of scientific creative thinking skills of Grade 4 students before receiving STEM-based out-of-classroom learning according to the Phuket context showed an average score of 8.14 with a standard deviation of 2.46. After receiving STEM-based out-of-classroom learning according to the Phuket context, the average score increased to 16.23 with a standard deviation of 1.11. The difference was tested using a t-test, and it was found that the average score after learning was significantly higher than before learning at the statistical level of 0.00 (t = 21.77, sig = 0.00).

Best Practices in Outdoor STEM Learning

STEM-based out-of-classroom learning according to the Phuket context is a teaching method that encourages students to independently explore knowledge while the teacher acts as a facilitator and provides guidance. This method promotes students' development of scientific creative thinking skills. Based on the post-lesson analysis of the topic "Materials and Matter," the following best practices should be applied for outdoor STEM classroom learning that fosters the development of scientific creative thinking skills.

Creating a Learning Environment that Supports Learning: The teacher should create a welcoming and interactive classroom atmosphere and encourage students to share their ideas, leading to discussions and conclusions based on data.

Teaching Practice

In each lesson plan, such as Lesson Plan 1 on **"Eco-Print and Southern Botany,"** the teacher begins by establishing a relaxed and supportive classroom atmosphere. Learning experiences outside the classroom offer valuable opportunities to foster students' creativity and deepen their understanding of the natural environment. As part of this approach, the **"Walking Map"** activity was designed for students to explore and study the local community, with a focus on surveying the abundance and diversity of natural resources in the area. To assess students' responses effectively, teachers developed a scoring rubric specifically designed to evaluate scientific creativity skills. This criterion is structured to be clear, measurable, and grounded in research, aligning with established creativity assessment frameworks such as those proposed by **Guilford** and **Torrance**, while focusing on scientific applications. The rubric is presented in Table 9.

Table 9. A scoring rubric designed specifically for evaluating answers that demonstrate scientific creativity skills.

Criteria	Level 4 (Excellent)	Level 3 (Good)	Level 2 (Fair)	Level 1 (Needs Improvement)
Originality (Uniqueness of the idea)	Provides highly original ideas or solutions that are rare, imaginative, and demonstrate novel scientific thinking.	Provides somewhat original ideas that show creative scientific thinking, though partially predictable.	Provides common or familiar ideas with little uniqueness; demonstrates limited scientific novelty.	Repeats conventional ideas without any originality; minimal scientific creativity shown.
Fluency (Number of ideas generated)	Generates a wide range (5 or more) of scientifically plausible ideas or solutions.	Generates several (3–4) scientifically plausible ideas or solutions.	Generates a few (1–2) ideas with some scientific relevance.	Struggles to generate ideas; provides only 0–1 idea with limited scientific relevance.

Criteria	Level 4 (Excellent)	Level 3 (Good)	Level 2 (Fair)	Level 1 (Needs Improvement)
Flexibility (Variety of categories or approaches)	Demonstrates high flexibility by shifting between different scientific perspectives or approaches effectively.	Demonstrates some flexibility by considering alternative scientific approaches or explanations.	Demonstrates limited flexibility; mainly sticks to a single perspective.	Shows rigid thinking with no alternative approaches considered.
Elaboration (Level of detail and development)	Ideas are thoroughly developed with rich scientific details, explanations, and connections.	Ideas are explained with adequate scientific detail but could be more thoroughly developed.	Ideas are simple, with minimal scientific detail or explanation.	Ideas are vague, undeveloped, and lack scientific support.
Scientific Feasibility (Scientific plausibility and logic)	Ideas are highly feasible, scientifically sound, and demonstrate logical cause-and-effect relationships.	Ideas are generally feasible and scientifically appropriate, with minor gaps in logic.	Ideas show some misunderstanding of scientific principles or weak logic.	Ideas are scientifically incorrect or illogical with major misconceptions.

Classroom Practice

Students gained confidence in sharing their thoughts and were more enthusiastic in the classroom. They became eager to answer questions asked by the teacher, especially in Cycle 2, where students could discuss, express their opinions, and conclude about making eco-print-related products.

Evidence

- Post-lesson records/observations of student behavior showing their thinking and participation in class discussions.
- Activity logs submitted by students showing their understanding and ability to apply scientific creative thinking skills.
- Photos of activities related to STEM-based out-of-classroom learning according to the Phuket context, such as "Eco Print and Southern Botany."
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Figure 14. Organizing Classroom Activities

RESEARCH RESULT AND DISCUSSION

The development of scientific creative thinking skills among Grade 4 students was assessed following the implementation of outdoor STEM learning activities contextualized to Phuket. The findings revealed a marked improvement in students' scientific creative thinking skills compared to their performance prior to the intervention. This improvement can be attributed to the learning opportunities provided by the outdoor STEM activities, which enabled students to explore real-world issues derived from their everyday experiences in Phuket. Through these experiences, students engaged in analyzing problems, conducting independent inquiry, collecting relevant data, generating ideas, designing solutions, planning investigations, and verifying results on their own (Ünal Çoban, 2013 and Mohammed & Kinyo, 2020). Furthermore, they effectively presented their findings and communicated their ideas, indicating both cognitive engagement and creative output. The research also showed a significant positive impact on teacher candidates' perceptions of the development of students' scientific creativity. This aligns with the findings of Kocabas (1993), Ongowo and Indoshi (2013), and Zhang et al. (2012), who argue that scientific creativity encompasses more than the mere organization of observable information. When science is taught through inquiry-based and problem-solving processes, students not only develop essential scientific process skills but also cultivate more positive attitudes toward science, thereby enhancing their creativity. Scientific process skills—such as observation, classification, measurement, inference, and communication—are transferable across science disciplines and are fundamental to inquiry-based STEM learning. Outdoor STEM activities allow students to apply these skills in authentic contexts, bridging academic knowledge with real-life applications. When students engage in the engineering design process, their creative thinking is further stimulated as they iterate, prototype, and test ideas. This is supported by research from Rawan Thilanant (2015), who found that Grade 12 students participating in STEM project-based learning demonstrated significantly higher creative thinking skills post-intervention. Similarly, Suchanart Suwanphiboon (2016) reported that Grade 7 students engaged in an integrated STEM unit on "Eco-Friendly Homes" showed statistically significant gains in creativity. To effectively foster such skills, teacher education programs must prepare pre-service teachers with both theoretical understanding and practical experience in the engineering design process. Studies by Liang (2002), Meador (2003), and Wyke (2013) emphasize that well-qualified science teachers who are proficient in engineering design are better equipped to nurture their students' creativity and design competencies. When teachers pose thought-provoking questions, act as facilitators, and grant students' autonomy, they create a learning environment that supports innovation and exploration (Leung, 2023).

In this context, creativity plays a critical role in complementing scientific thinking, particularly in science and technology-oriented learning (Villalba, 2008). Scientific creativity—defined as the application of creative thinking within scientific domains—has become a central aim of modern science curricula. Achieving this objective requires deliberate integration of content, pedagogy, and learner-centered strategies. As creativity becomes increasingly vital in a rapidly evolving, globalized world, educational institutions must take an active role in cultivating students' creative capacities. Among all disciplines, science education stands out as a key driver of high-level creative thinking (Miles, 2008; Park, 2011 and Torkos, 2021), making the role of science teachers indispensable in this developmental journey.

Characteristics of STEM-Based Out-of-Classroom Learning Activities that Develop Scientific Creative Thinking Skills

The Outdoor STEM learning activities according to the Phuket context, which developed the scientific competencies of Grade 4 students, consisted of one unit on learning about "Materials and Matter" through three lesson plans:

1. Lesson Plan 1: "Eco Print and Southern Botany"
2. Lesson Plan 2: "Tie-Dye and Sino-Portuguese Architecture"
3. Lesson Plan 3: "Natural Dyes from Coconut Milk"

These activities helped to develop scientific creative thinking skills because the learning process involved six steps:

1. Problem identification
2. Collecting information and ideas related to the problem
3. Designing solutions
4. Planning and implementing problem-solving actions
5. Testing and evaluation
6. Presentation

These steps can be observed as follows:

Step 1: Problem Identification

Before participating in STEM-based out-of-classroom learning, students were unable to clearly identify the problem according to the conditions of the activity, making it difficult for them to decide on the next steps. This reflected an underdevelopment of creative thinking skills, especially in initiative. After engaging in the learning activities, students were able to identify problems more clearly and demonstrated improved initiative. They were able to come up with creative ideas to solve problems and present new concepts, which shows significant development in their skills because of the learning process.

Step 2: Gathering Information and Ideas Related to the Problem

Before implementing STEM-based out-of-classroom learning according to the Phuket context, students were unable to gather information and understand scientific concepts. They lacked the skills to analyze data, connect knowledge, and explain ideas systematically. After participating in the learning activities, students were able to present more detailed ideas. For example, they could explain concepts in more detail, present relevant information, and better connect prior knowledge to new situations.

Step 3: Designing Solutions

Before the STEM-based out-of-classroom learning, students lacked the ability to design effective solutions. They were unable to apply knowledge creatively to systematically devise solutions. After engaging in the learning activities, students could design solutions using relevant scientific principles and technologies. For instance, they could choose appropriate natural materials for dyeing using the Eco-printing method. Additionally, students could present creative solutions, such as designing fabric patterns using natural dyes to represent the local culture of Phuket, demonstrating the development of both applied creativity and effective problem-solving skills.

Suggestions Based on the Research

Suggestions for Utilizing Research Findings

1. Since the research findings show that STEM-based learning can enhance students' creative thinking skills, learning activities should be implemented in teaching to effectively develop students' learning outcomes.
2. Developing students' creative thinking skills requires time. Therefore, educators must organize learning activities that continuously promote and support student development.
3. It is essential to allow sufficient time for research and problem-solving. Educators need to understand the nature of each student and group, as the problems each group

investigates and solves will differ, leading to different approaches to finding solutions.

4. Educators must instill the importance of the working process in students. The outcome may not be the final measure of success, but the process of obtaining the results and knowledge is more important. The focus of STEM-based learning lies in understanding problems and finding reasonable solutions.

Suggestions for Future Research

1. Future studies should explore the development of STEM-based learning across different subjects and learning areas to examine the effects on students.
2. Future studies should explore learning strategies that connect with local wisdom, such as using local materials and incorporating traditional handicraft techniques into STEM projects.

ETHICAL CONSIDERATIONS

The ethical approach to this research, particularly in relation to concealed research data, was carefully managed to comply with academic and legal ethical standards. The research methodology adhered to the following ethical principles:

1. Informed Consent: The researcher ensured that appropriate consent forms were obtained from parents and guardians of the research participants, and approval was secured from the school where the research took place. Upon completion of the research, participants were informed about the use of concealed data and given the option to withdraw their data.
2. Privacy Protection: The researcher used anonymization or data encryption methods and restricted access to data to authorized personnel only.
3. Minimizing Ethical Harm: In collaboration with the supervising teacher and academic advisors, the ethical risks and potential impacts on participants were carefully assessed. If any issues regarding concealed data that might have negative effects were identified, the researcher ensured a transparent research approach.
4. Debriefing: After the research was completed, participants were informed about the true nature of the study, and they were provided with the opportunity to ask questions or share feedback about the research process.
5. Reporting Research Results: The researcher ensured that the results of the study were shared transparently, with clear explanations of methods used, reasons for data concealment, and efforts to avoid distortion of data or misleading the public.

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