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The Use of STEAM Education Learning Package to Develop Elementary School Students' Science Process Skills and Learning Achievement of Physical Properties of Materials

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Abstract

This study aimed to: 1) assess the impact of a STEAM education learning package on grade 10 students' science process skills, 2) evaluate its effect on their learning achievement concerning the physical properties of materials, and 3) gauge the students' satisfaction with the learning package. The participants were 13 grade 10 students from a public school in Thailand, selected through convenience sampling. The study utilized a STEAM Education Learning Activity Package, a Science Process Skills Test, a Learning Achievement Test, and a Learning Satisfaction Questionnaire as instruments. Data analysis involved calculating mean scores, standard deviations, effectiveness indices (E.I, E1/E2), and normalized gains. Results demonstrated significant improvements in both science process skills and learning achievement related to the physical properties of materials. Additionally, the learning package enhanced students' satisfaction with their learning experience. These findings suggest that the STEAM education learning package could be a valuable tool for improving science education at the elementary school level.

Keywords: STEAM education, science process skills, science learning achievement

1. Introduction

In the field of scientific education, specifically at the primary level, children are exposed to a variety of ideas that gradually become more complex, starting from fundamental concepts and advancing towards more sophisticated ones. This educational methodology aims to provide a strong basis of information, which is crucial for students' capacity to comprehend and handle intricate scientific situations in the future (Alberts, 2022; Holbrook, 2010). Likewise, understanding the physical qualities of materials is crucial for young learners to connect their scientific knowledge with the concrete things and phenomena they experience in their daily lives. Acquiring an understanding of topics such as density, hardness, and conductivity, students can enhance their comprehension of the properties and actions exhibited by different materials (Burns, 2016; Wendell & Lee, 2010). Hence, it is crucial to integrate the instruction of the physical characteristics of substances into the educational program in order to augment students' comprehension.

In addition, acquiring knowledge in science necessitates essential abilities such as observation, inquiry, prediction, rudimentary experimental skills, and the ability to record and display findings (Kurniawati, 2021; Öztürk et al., 2010). These fundamental skills are essential for pupils since they establish the basis for scientific investigation and exploration. Young learners find them especially engaging because of their hands-on experiences, which enhance the tangibility and relatability of abstract concepts (Öztürk et al., 2010). Participating in activities such as experiments and observations enables students to establish a connection between their learning and the actual world, promoting a sense of curiosity and awe. Moreover, these activities frequently entail cooperative learning, wherein students collaborate, exchange ideas, and acquire knowledge from one another. The collaborative part of this not only improves their comprehension but also cultivates their abilities in communication and teamwork.

Through these experiences, students can cultivate a positive attitude toward science learning, develop critical thinking abilities, and acquire a solid understanding of scientific concepts (Gizaw & Sota, 2023). This dual focus on skill development and content knowledge helps students appreciate the relevance and excitement of science in their everyday lives.

Developing students' scientific method skills is a complex process that requires the integration of multiple components (Gizaw & Sota, 2023). These include a structured approach to teaching scientific concepts, hands-on learning materials, and a supportive environment that fosters exploration and inquiry (Ekici & Erdem, 2020; Kurniawati, 2021; Öztürk et al., 2010). Students must have opportunities to practice these skills through guided experiments, observations, and data analysis, with continuous feedback and reflection to refine their understanding. Likewise, to grasp the knowledge of physical properties of materials, students must first have a solid foundation in basic concepts such as states of matter, measurement techniques, and the relationship between materials and their uses. Understanding these foundational ideas is essential for comprehending more complex notions like density, conductivity, and hardness (Burns, 2016; Wendell & Lee, 2010). Therefore, an instructional method that effectively integrates these components of scientific methods and foundational concepts is necessary. Such an approach will not only help students learn scientific facts but also develop the skills to apply this knowledge in real-world contexts, leading to a comprehensive understanding of the physical properties of materials.

When examining the elements that lead to good outcomes in education, it becomes apparent that conventional passive teaching methods may not yield desired results. Science education in Thailand has frequently faced criticism due to its insufficient level of active involvement. Teachers typically take on the primary responsibility in the classroom, presenting lectures while students passively listen and await instructions for textbook exercises (Faikhamta et al., 2018; Yuenyong & Narjaikaew, 2009). This technique generally offers restricted possibilities for practical experiments, classroom discussions, or applying information to real-world issues. The deficiencies of this approach are evident in the outcomes of national tests and global evaluations, such as the PISA test, where the nation's performance continues to fall short of the required benchmarks (National Institute of Educational Testing Service, 2022; OECD, 2022).

One potential approach to tackle this problem could be the implementation of STEAM education. This approach is derived from STEM education, which emphasizes the amalgamation of science (s), technology (t), engineering (e), and mathematics (m) to cultivate critical thinking and problem-solving abilities (Henriksen et al., 2019; Idin, 2018; Liao, 2019). The incorporation of the arts element in STEAM enables learners to delve into creativity and expression, hence enhancing the learning process by making it more captivating and comprehensive (Henriksen et al., 2019). By integrating artistic components, students can establish connections between scientific concepts and creative processes, so improving their comprehension and ability to remember the information (Liao, 2019).. Therefore, with this approach, students can enjoy learning science and develop both scientific method skills and a deeper understanding of the physical properties of materials, leading to improved learning outcomes and greater achievement.

As STEAM education seems to have the potential in enhancing scientific method skills and learning achievement in the physical properties of materials, the current study employs its principles to develop a comprehensive learning management plan. The outcomes of this study are expected to contribute to the field by providing evidence of the effectiveness of the STEAM approach in elementary science education.

2. Literature Review

2.1 Science Process Skills in Elementary School Level

Science process skills such as observing, questioning, formulating hypotheses, conducting experiments and investigations, collecting and measuring data, analyzing data, engaging in critical thinking and problem-solving, communicating, collaborating, considering ethical aspects, and reflecting and iterating are essential for learners to understand the functioning of scientific techniques in both educational settings and real-life situations (Kurniawati, 2021). Nevertheless, young students at the elementary school level may find some of these components very challenging. According to Öztürk et al., (2010), focusing on fundamental science process skills can better support elementary students in their scientific learning journey. These core components include observation, questioning and predicting, basic experimental skills, and data recording and presentation.

2.1.1 Observation

The ability to carefully notice and describe phenomena using the senses. This involves paying attention to details, identifying patterns, and recording observations systematically.

2.1.2 Questioning and Predicting

Formulating questions based on observations and making predictions about outcomes. This component encourages curiosity and helps guide the direction of scientific inquiry.

2.1.3 Basic Experimental Skills

Conducting simple experiments to test hypotheses. This includes designing experiments, using basic tools, and following procedures to explore scientific concepts.

2.1.4 Data Recording and Presentation

Collecting and organizing data in various formats, such as charts or tables, and presenting findings clearly. This skill involves summarizing data, identifying trends, and communicating results effectively.

2.2 Learning Achievement of Physical Properties of Materials

Learning achievement - the abilities and knowledge that learners acquire regarding a certain subject (Afari, 2015; Bolt, 2011; Phye, 2011) includes not only the comprehension of fundamental ideas but also the capacity to successfully utilize this information. Within the scope of this study, learning attainment pertaining to the physical qualities of materials encompasses comprehension of attributes such as hardness, elasticity, thermal conductivity, and electrical conductivity. These attributes are frequently encountered in the daily lives of students. Consequently, the capacity to recognize, compare, and evaluate the hardness, elasticity, thermal conductivity, and electrical conductivity of different materials in the students' surroundings could explain the term "learning achievement of physical properties of materials" in the current study. This definition emphasizes the pragmatic application of scientific ideas, therefore helping students to make links between their study and practical experience.

2.3 STEAM Education

This study uses STEAM education-a method combining science, technology, engineering, the arts, and mathematics into instruction and learning. Inspired in the ideas of encouraging critical thinking, problem-solving, and creativity by linking these fundamental disciplines in a coherent manner (Colucci-Gray, 2019; Henriksen et al., 2019; Idin, 2018; Liao, 2019), this method represents a development of STEM education. Originally created in response to the expanding need for skills in science, technology, engineering, and mathematics-fields that are ever more important in a fast-developing technological environment-STEM education was.

Originally, STEM education became well-known in the late 20th and early 21st centuries when teachers and legislators realized they had to equip pupils for professions in these disciplines. Concerns about national competitiveness in the global economy, especially in fields like technology and engineering where innovation is essential, motivated the effort. Emphasizing hands-on, experiential learning, supports inquiry-based techniques, and encourages the application of knowledge in real-world settings, STEM education has the ability to increase learners' scientific skills according to Henriksen et al., (2019). Through interdisciplinary learning, STEM education not only deepens students' knowledge of scientific ideas but also provides the tools they need to creatively and successfully solve challenging challenges.

STEAM education-which includes the arts into the conventional STEM framework-helps to strengthen this basis even more by including design thinking and creativity into technical and scientific education, this inclusion extends the field of learning (Liao, 2019). STEAM education helps students learn science by mixing analytical and creative processes, therefore enabling more thorough and varied exploration of scientific ideas.

2.3.1 Science

In STEAM education, the learning process revolves mostly around science. Students are taught to see the natural world by study, experimentation, and observation. Combining science with other fields helps students to better grasp scientific ideas and grow in capacity to apply them in different situations. Encouragement of research and experimentation helps students to develop critical thinking, ask questions, and investigate answers to practical concerns.

2.3.2 Technology

STEAM education's technology gives pupils the means to investigate and creatively apply mathematical and scientific ideas. By means of digital tools, software, and other technology resources, students can replicate experiments, model intricate systems, and participate in projects needing the use of both technical and artistic abilities. Technology also clarifies for students the useful consequences of science and engineering in the contemporary society.

2.3.3 Engineer

STEAM education's engineering stresses the design, construction, and testing process for problem solutions.

Students gain knowledge of using mathematical and scientific ideas to produce creative and useful goods or systems. STEAM education's engineering projects foster teamwork, critical thinking, and the iterative design improvement process as well as the by helping students to grasp the link between theory and practice, this practical approach promotes a greater respect of the way things actually work.

2.3.4 Arts

Including the arts into STEAM courses gives the educational process a creative element. The arts inspire students to approach problems from many angles, think creatively, and communicate their ideas in original and inventive ways-that is, beyond the box. STEAM education improves students' capacity to express difficult ideas, think creatively, and link scientific principles with human experience and culture by including artistic components including design, visual arts, and performance.

2.3.5 Mathematics

The language connecting all the STEAM areas is mathematics. It offers the fundamental abilities required for data analysis, problem-solving, pattern and relationship understanding. Mathematics is taught in STEAM education not in a vacuum but rather in concert with science, technology, engineering, and the arts to demonstrate its relevance in practical contexts. This method inspires children to approach mathematics with confidence and inquiry and helps them to recognize its significance in daily life.

Along with developing students' knowledge and skills in science, STEAM education provides a comprehensive approach to learning that promotes creativity, critical thinking, and problem-solving ability. This combined approach equip students with the tools they need to create, cooperate, and flourish in a fast changing environment, therefore preparing them for the demands of the future.

2.4 Previous Studies

Scholars (e.g., Arpaci et al., 2023; Colucci-Gray, 2019; Eroğlu & Bektaş, 2022; Erol et al., 2023; Jongluecha & Worapun, 2022; Ozkan & Umdu Topsakal, 2021; Ültay et al., 2020) have highlighted the benefits of STEAM education as an effective approach for teaching science concepts and related skills. Specifically, Jongluecha and Worapun (2022) and Ozkan and Umdu Topsakal (2021) demonstrate that STEAM education can enhance learning achievements in general science and in understanding concepts like force and energy. Additionally, the approach has been shown to develop essential supportive skills such as creative thinking (Eroğlu & Bektaş, 2022) and problem-solving (Erol et al., 2023). Moreover, the approach also helps science courses in different learning environments (Arpaci et al., 2023; Colucci-Gray, 2019). Combining science, technology, engineering, arts, and mathematics into a coherent learning experience, therefore promotes a more complete knowledge of scientific ideas, creative thinking, and improved problem-solving skills. Students are ready to use their knowledge in several useful situations.

It could be noted that previous studies have highlighted the need for further research into the application of STEAM education across a broader range of scientific concepts and supportive skills in science education. Scholars have called for additional exploration to better understand how STEAM can be utilized to enhance various aspects of science learning. The current study aims to address this gap by employing STEAM education to develop both science process skills and the understanding of physical properties of materials. This research seeks to contribute to the field by investigating how STEAM can effectively enhance students' grasp of fundamental scientific concepts and skills. The purposes of the study were 1) to examine the effects of STEAM education learning package on grade 10 students’ science process skills, 2) to examine the effects of STEAM education learning package on grade 10 students’ learning achievement of physical properties of materials, and 3) to investigate grade 10 students’ satisfaction with STEAM education learning package.

3. Methodology

3.1 Research Design

The study utilized a one-group experimental design. The principles of STEAM education were applied to develop a comprehensive learning activity package, which included key components such as principles, objectives, learning activities, and evaluation methods. This package was implemented in a 4th-grade science classroom within the Thai educational context. The primary objectives were to enhance students' science process skills, improve their learning achievement related to the physical properties of materials, and assess their learning satisfaction.

3.2 Participants

The participants were 13 grade 4 students in a public school in Thailand. They were selected by a convenient sampling. The participants were treated anonymously. The ethical issues in human research were strictly considered during the data collection.

3.3 Instruments

3.3.1 STEAM Education Learning Activity Package

The learning activity package was developed based on the principles of STEAM education, with the goal of enhancing participants' science process skills and learning achievement related to the physical properties of materials. This package integrates the concepts of science, technology, engineering, art, and mathematics to create a hands-on, authentic, and collaborative learning environment. Through this approach, students not only grasp the concept of physical properties but also simultaneously develop essential science process skills. The package includes four main learning activities: understanding the physical properties of materials, using leftover materials to create toys, applying the knowledge of elasticity to design a toy car, utilizing thermal conductivity to design a house for a penguin, and designing a light pole using knowledge of electrical conductivity. An example of how STEAM education was applied is detailed in Table 1.

The package was refined through a series of tryouts: an initial one-on-one trial with 3 students, a small group trial with 10 students, and a field trial with 30 students who had similar characteristics to the target sample. The results from these tryouts confirmed the appropriateness and quality of the learning activity package before its implementation with the participants.

Table 1. Example of STEAM Education activities

Science	Students learn about the physical properties of materials, such as hardness and elasticity, by touching and stretching different objects (like rubber bands, clay, or plastic). They discuss how these materials could be used to make parts of a toy car, focusing on how elastic materials can make the car move.
Technology	Students use simple technology, like watching a short video or using a basic tablet app, to see how toy cars are made and how different materials work together. This helps them get ideas for their own designs.
Engineering	In this step, students build their toy cars using leftover materials, such as cardboard, rubber bands, and bottle caps. They focus on making sure their cars can roll and move, using elastic bands to power the movement.
Arts	Students get creative by decorating their toy cars with drawings, stickers, or paint. They can think about how to make their cars look fun and interesting while still being able to move.
Mathematics	Students measure the length of the rubber bands and the distance their toy cars travel. They might count how many times the wheels turn or compare the speed of different cars. This helps them see how numbers and measurements are important in making things work.

3.3.2 Science Process Skill Test

The test consisted of 30 multiple-choice questions, with 4 options for each question. The content focused on assessing skills in observation, formulating questions and predictions, basic experimental techniques, and data collection and presentation. The test was validated, with an Index of Item-Objective Congruence (IOC) ranging from 0.5 to 1.0, and demonstrated high reliability with a KR-20 value of 0.87. Additionally, the test items were found to have appropriate levels of difficulty (p=0.2-0.77) and discrimination (b=0.2-0.5).

3.3.3 Learning Achievement Test

The test consisted of 30 multiple-choice questions, each with 4 answer options. The content focused on understanding material properties such as hardness, elasticity, thermal conductivity, and electrical conductivity, as well as data collection and presentation. The test was validated with an Index of Item-Objective Congruence (IOC) ranging from 0.5 to 1.0 and demonstrated high reliability with a KR-20 value of 0.95. The items also exhibited appropriate levels of difficulty (0.20-0.73) and discrimination (0.20-0.5).

3.3.4 Learning Satisfaction Questionnaire

The questionnaire was designed to assess students' learning satisfaction with the activity package. It included 25 items, covering 5 aspects: content, learning management methods, learning materials, usefulness of learning, and evaluation and assessment, with 5 items for each aspect. The questionnaire items were validated, with an Index of Item-Objective Congruence (IOC) ranging from 0.5 to 1.0.

3.4 Data Analysis

The effectiveness of the learning activity package was analyzed using the Effectiveness Index (E.I) and the ratio $E1/E2$. The E.I was calculated by subtracting the pre-test scores from the post-test scores, then dividing by the product of the number of students and the maximum score, minus the pre-test scores. E1 was determined by the percentage of students' average scores relative to the maximum score in the learning activities, while E2 was calculated by the percentage of students' average scores relative to the maximum score in the post-test. The ratio $E1/E2$E1/E2 was compared to a predetermined criterion of 80/80. The development of participants' science process skills and learning achievement was assessed by calculating the Normalized Gain from the pre-test and post-test scores. Questionnaire results were analyzed using mean scores and standard deviations, with the following criteria: 0-1.5 (very low), 1.51-2.50 (low), 2.51-3.50 (average), 3.51-4.50 (high), and 4.51-5.00 (very high).

4. Results

4.1 Effectiveness of the Learning Activity Package

Table 2. Effectiveness index (E.I) of the learning activity package

n	Sum		Effectiveness index (E.I.)
	Pre-test	Post-test	
13	143	319	0.71

The findings indicate that the participants' initial assessment scores totaled 214, which increased to 363 in the follow-up evaluation. With a maximum possible score of 390, the calculated Effectiveness Index (E.I.) for the STEAM education learning activity package is 0.71. This reflects a substantial improvement, showing that students' science process skills increased by 71%.

Table 3. Effectiveness (E1/E2) of the learning activity package

Effectiveness	Maximum point	Sum	$\bar{x}$	%
The Effectiveness of the process (E_1)	440	5033	387.15	87.99
The effectiveness of the product (E_2)	390	319	24.54	81.79

The effectiveness of the learning activity package **(E_1/E_2)** = 87.99/81.79

The findings showed that students achieved an average score of 387.15 out of 440 during the learning activities, reflecting 87.99% proficiency. On the posttest, they scored an average of 24.54, or 81.79% of the maximum 30 points. The effectiveness of the learning activity package in enhancing participants' science process skills was calculated as 87.99/81.79 (E1/E2), exceeding the predetermined criterion of 80/80. These results suggest that the STEAM-based learning activity package significantly enhances participants' science process skills, both throughout the learning process and upon its completion.

Table 4. Normalized gain of participants' learning achievement

n	Pretest ($\bar{x}$, %)	Posttest ($\bar{x}$, %)	<g>	Interpretation
13	11.00 (36.67%)	24.54 (81.79)	0.71	High

Table 4 presents the normalized gain of participants' learning achievement, comparing pretest and posttest scores. For the group of 13 participants, the average pretest score was 11.00, which corresponds to 36.67% of the total possible score. After participating in the learning activities, the average posttest score increased to 24.54, or 81.79% of the total score. The normalized gain (<g>) was calculated as 0.71, which is interpreted as a high level of improvement in learning achievement.

Table 5. Participants' learning satisfaction with the STEAM Education

Aspects	$\bar{x}$	**S.D**	**Degree of satisfaction**
Content	4.51	0.55	Very high
Learning management methods	4.65	0.49	Very high
Learning materials	4.38	0.71	High
Usefulness of the learning activity package	4.52	0.54	Very high
Evaluation and assessment	4.66	0.61	Very high
Average	4.50	0.58	High

Table 5 summarizes participants' learning satisfaction with the STEAM Education approach across various aspects. The content aspect received an average score of 4.51 (S.D = 0.55), categorized as "very high" satisfaction. Learning management methods scored an average of 4.65 (S.D = 0.49), also rated as "very high." Learning materials received a slightly lower score of 4.38 (S.D = 0.71), categorized as "high" satisfaction. The usefulness of the learning activity package was rated at 4.52 on average (S.D = 0.54), again falling under "very high" satisfaction. Evaluation and assessment were the highest-rated aspect, with an average score of 4.66 (S.D = 0.61), also rated as "very high." Overall, the average satisfaction score across all aspects was 4.50 (S.D = 0.58), indicating a "high" degree of satisfaction with the STEAM Education learning package.

5. Discussion

The results of the study lead to the following issues of discussion.

5.1 The Effectiveness of STEAM Education on Science Process Skills

The results demonstrate that the implementation of the learning activity package effectively enhanced the participants' science process skills. This improvement is evident both in the comparison of pre- and post-test scores, as indicated by the Effectiveness Index (E.I.), and in the participants' performance during and after the learning activities (E1/E2). The significant increase in these scores suggests that the STEAM education-based learning package contributed positively to the development of the students' skills. This improvement can be attributed to the hands-on, interdisciplinary nature of the STEAM approach, which actively engages students in the learning process, fostering critical thinking, creativity, and problem-solving skills. These findings align with the work of several scholars (e.g., Arpaci et al., 2023; Colucci-Gray, 2019; Eroğlu & Bektaş, 2022; Erol et al., 2023; Jongluecha & Worapun, 2022; Ozkan & Umdu Topsakal, 2021; Ültay et al., 2020), who have also identified STEAM education as a highly effective method in promoting science education.

5.2 The Effectiveness of STEAM Education on Students' Learning Achievement

After interacting with the STEAM education learning program, the results also show that the participants effectively understood the idea of the physical features of materials. The STEAM education model, which combines science, technology, engineering, art, and mathematics to offer a complete learning experience that supports conceptual knowledge, can help to explain this development. Through practical, project-based activities, students explored and applied the ideas of hardness, elasticity, thermal conductivity, and electrical conductivity in real-world settings, therefore strengthening their knowledge. This approach not only facilitated the learning of scientific concepts but also helped students to connect theory with practice, enhancing retention and understanding. These findings are consistent with the studies of Jongluecha and Worapun (2022) and Ozkan and Umdu Topsakal (2021), who also identified significant benefits of STEAM education in improving students' achievement in science concept learning.

5.3 Learning Satisfaction with STEAM Education

The results also indicate high levels of participant satisfaction with the learning activity package. Through the STEAM education activities, students actively engaged in the learning process and took ownership of their learning. This approach not only allowed them to develop science process skills but also enhanced their understanding of the physical properties of materials. According to Thiessen & Cook-Sather (2007), factors such as class participation, hands-on activities, and collaborative learning contribute to a satisfying learning experience, particularly among young learners. These findings align with those of Jongluecha and Worapun (2022), who also observed that STEAM education fosters greater learning satisfaction in science education.

6. Conclusion

The study aims to investigate the effectiveness of STEAM education as a foundational principle for a learning activity package designed to develop Grade 4 students' science process skills and learning achievement. The results of this one-group experimental design study, conducted within the context of Thai science education, indicate significant improvements in students' skills, learning achievement, and satisfaction with the method. These findings have important implications for pedagogical practices, suggesting that integrating STEAM education can enhance science education at the elementary level. Additionally, the study provides a basis for future research to explore similar approaches in different educational contexts or with larger sample sizes.

However, the study does have limitations. One significant limitation is the lack of a qualitative component, which could have provided deeper insights into the students' learning experiences and perceptions. Another limitation is the small sample size, which may affect the generalizability of the findings. Future studies should consider incorporating qualitative methods to enrich the data and expanding the sample size to ensure more robust and widely applicable results.

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Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Informed consent

Obtained.

Ethics approval

The Publication Ethics Committee of the Canadian Center of Science and Education.

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Provenance and peer review

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Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.

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