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The Use of STEM-Based Learning Activities to Promote Computational Thinking of Grade 5 Students

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Abstract

This study aimed to investigate the effects of STEM-based activities on grade 5 students' science learning achievement, computational skills, and satisfaction with the learning experience. The study involved 30 grade 5 students in the Thai context, and data were collected through a learning management plan designed using STEM-based activities, a learning achievement test, a computational thinking test, and a satisfaction questionnaire. Mean scores, standard deviation, and a paired samples t-test were used to analyze the data. The results showed that STEM-based activities had a positive impact on grade 5 students' learning achievement and computational thinking skills. Moreover, the students expressed a high level of satisfaction with the STEM-based activities, which provided an engaging and relevant learning experience. These findings contribute to the growing body of evidence supporting the effectiveness of STEM-based activities in promoting student achievement and satisfaction with the learning experience.

Keywords: STEM, computational thinking, basic programming

1. Introduction

Learning science is a complicated process that requires students to put in attempts and techniques in comprehending scientific concepts, solving problems, and applying the concept in solving real-world problems (Jessani, 2015). Therefore, one needs the development of cognitive processes as they involve mental processes such as attention, perception, memory, reasoning, and problem-solving that enable individuals to acquire, process, and retain knowledge (Chonkaew et al., 2016). Moreover, developing learners' thinking process also leads to better learning achievement in science education. Students with such skills as observing, classifying, comparing, contrasting, and analyzing tend to do well in science-related classes and complete learning achievements throughout their educational paths (Santos, 2017). Therefore, it could be claimed that teaching science is teaching students how to think.

Regarding thinking skills that could benefit science learning, computational thinking is recognized beneficial as it allows learners to develop critical thinking and problem-solving skills, and apply these skills to real-world scientific problems (Saidin et al., 2021). In brief, computational thinking can be defined as the method of approaching real-world problems using problem-solving strategies inspired by computer science (Wing, 2006, 2008, 2010). This entails decomposing complex problems into their constituent components, recognizing patterns and linkages, generating algorithms, and designing and testing solutions. In science class, Students with computational thinking can become more efficient and productive in their scientific inquiries and better equipped for professions in science and technology (Hurt et al., 2023).

However, teaching computational thinking skills can be a challenge for science teachers. First, computational thinking is complex for teachers themselves as the skill is relatively new for teachers in science education (Saidin et al., 2021). Teachers might need specific training to teach the skill with the proper use of technology, student stimulation, and curriculum integration (Angeli & Giannakos, 2020). From a student's perspective, acquiring computational thinking may also present certain obstacles. For example, students may find it difficult to comprehend and apply abstract ideas such as algorithms and data structures in the real world when computational thinking is required. In addition, students may struggle to apply computational thinking abilities to real-world settings because they lack the requisite underlying knowledge and skills. In addition, trial and error is an essential component of computational thinking; nonetheless, students may grow discouraged if they cannot find the solution to a problem instantly (Basu et al., 2016).

In the Thai context, teaching computational thinking skills to students is also a challenging process. The skill was introduced into the context in mid-2010, and the terms itself make confusion in mathematic teaching (Roungrong et al., 2018). The authors also suggested that science teachers in the Thai context lack the comprehension of the skill and perceive the skill difficult as it involves complicated terms such as algorithm, decomposition, abstraction, etc. The usage of such terms may serve to dissuade educators and lead them to perceive computational thinking skills as the sole purview of computer science instructors (Aumgri & Petsangsri, 2019). Moreover, thinking skill is a part of the problems in Thai education. In science education, Thai students have problems analyzing components of the experiment, criticizing the result of previous studies, and applying knowledge to solve problems (Chailert & Maneekosol, 2015; Ploysangwal, 2018). According to Middleton and Suwannatthachote (2021), the problem with learning and developing computational thinking skills in Thailand relies on the learning process that mainly emphasizes computer programming skills rather than problem-solving skills that involve computational thinking. This creates anxiety among students due to the complexity and difficulty of programming and prevents them from developing computational thinking.

Therefore, problems in teaching computational thinking in the Thai context need an instructional method that encourages students to develop thinking skills while applying computer science concepts in solving real-world situations. The circumstance could be appropriate to the STEM-based activities which emphasize learning via the integration of Science, Technology, Engineering, and Mathematics (STEM) subjects in teaching thinking skills. These activities can be hands-on, project-based, or experiential learning activities that help students develop a deeper understanding of computational thinking and its applications in STEM fields. Therefore, the current study applies the STEM-based activities to teach grade 5 students computational skills with the purposes of the study to 1) to study the effects of STEM-based activities on grade 5 students' science learning achievement, 2) to study the effects of STEM-based activities on grade 5 students' computational skills, and 3) to study grade 5 students' satisfaction with the STEM-based activities in learning computational skills.

2. Literature Review

2.1 Nature of Primary School Students

It should be noted that primary schools are packed with students who have grown up in a completely digital environment, distinguishing them from earlier generations. Understanding the nature of their learnings would enable students to choose the most effective instructional strategy to address their difficulties. Students of this age group are renowned for their digital fluency (Seemiller & Grace, 2017). They are accustomed to incorporating technology into many facets of their lives, including education. This indicates that they are familiar with a variety of digital devices and platforms and expect technology to be integrated into their educational experiences (Seemiller & Clayton, 2019). In addition, primary school pupils are considered members of Generation Z, who are noted for their social awareness. Students are more likely to participate in learning activities that provide chances for social and civic participation (Seemiller et al., 2019). In addition, the pupils have short attention spans and like to learn in little, easily digestible portions (Giray, 2023). Kids require learning activities that captivate their interest and motivate them to learn. Consequently, educators should explore interactive and visually engaging information to deliver optimal learning experiences for their students' ages.

2.2 Computational Thinking

Computational thinking is becoming increasingly important in science education as it involves the process of using problem-solving techniques that are inspired by computer science to approach real-world problems. The term became familiar to the education area when Wing (2006) presented her paper on the subject. However, the skill is believed to have the fundamental of procedural thinking (Paper, 1996). The core idea of computational thinking is the ability to apply how computer process data as the concept of thinking. Therefore, in learning, students are expected to decompose data, put complex data into abstraction, recognize their patterns, and create algorithms.

This concept of computational thinking has been studied and defined by various scholars in the field of computer science. Shute, Sun and Asbell-Clarke (2017) describe computational thinking as the thought processes used to formulate a problem and express its solution in terms that can be applied effectively by a computer. Similarly, Wing (2014) defines it as the mental process of abstraction of problems and the creation of automatable solutions. Yadav et al. (2014) expand on the concept of computational thinking by describing it as the process of recognizing aspects of computation in the world that surrounds us and applying tools and techniques from computer science to understand and reason about natural and artificial systems and processes. Furber (2012) also emphasizes the importance of computational thinking in understanding and reasoning complex systems.

Therefore, the importance of computational thinking in understanding and reasoning complex systems cannot be overemphasized. Teaching computational thinking is not just about programming skills but about teaching individuals how to think critically and apply computation to problem-solving.

Computational thinking comprises several components, as illustrated in Figure 1. These components involve breaking down complex problems or systems into more manageable parts (decomposition), identifying patterns among and within problems (pattern recognition), focusing on relevant information while disregarding irrelevant detail (abstraction), and creating a systematic solution or a set of instructions to solve the problem (algorithms).

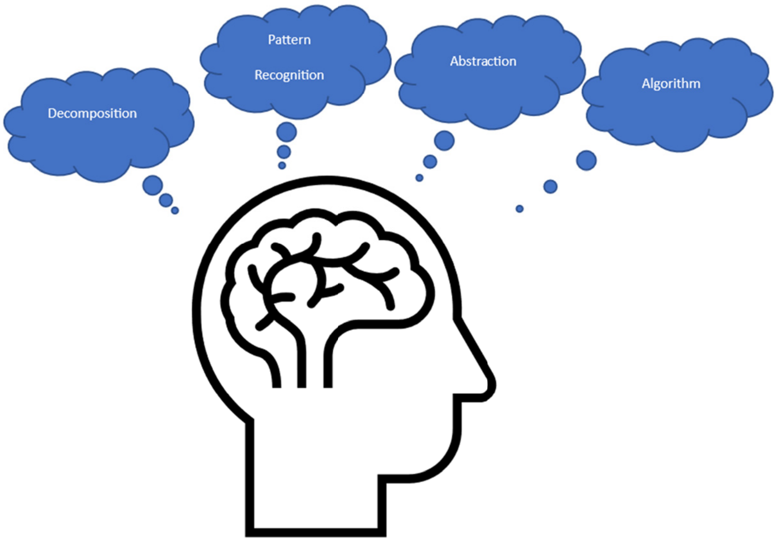

Figure 1. Components of computational thinking

In detail, students can utilize decomposition to solve complex problems by breaking them down into smaller sub-problems. For instance, when studying the human body, students can break it down into smaller sub-systems like the respiratory, circulatory, and digestive systems, which allows them to understand the overall functioning of the human body.

The pattern recognition skill involves identifying similarities and patterns within and among problems. This component involves recognizing commonalities between different problems or different instances of the same problem and using this knowledge to develop effective solutions. For example, when traveling to a new place, learners start noticing patterns and similarities in situations or systems, which can guide them in making effective decisions or solutions.

Students can also use abstraction which is a way of simplifying a problem or solution by removing extraneous information and focusing only on what is essential to understanding or solving the problem. In physics, for example, students can simplify a complex physical system by focusing only on the most essential details, like ignoring air resistance when studying projectile motion.

Lastly, developing algorithms involves creating a systematic set of instructions or a step-by-step solution to solve a problem. For instance, students studying viruses may use algorithms to model the virus's spread in a population and analyze different scenarios under varying conditions.

The four components of computational thinking—decomposition, pattern recognition, abstraction, and algorithms—can benefit student learning in science by providing a structured and systematic approach to problem-solving. By breaking down complex problems into smaller sub-problems, identifying patterns, simplifying the problem through abstraction, and creating a systematic solution through algorithms, students can approach scientific problems with a deeper understanding and a more effective strategy. Overall, the use of computational thinking in science classrooms can promote critical thinking, creativity, and problem-solving skills, which are valuable for success in scientific careers and beyond.

2.3 STEM-Based Activities

STEM education has become increasingly popular in recent years, with a focus on integrating Science, Technology, Engineering, and Mathematics into education. STEM education aims to develop an in-depth understanding related to STEM areas and achieve development towards technology (White, 2014). The four disciplines can be taught independently or integrated, and it is not always necessary to involve all four disciplines at the same time. According to the National Science Foundation (2020) the goal of STEM education is to equip individuals with the skills needed to meet the workforce needs of the 21st century. Aguilera et al. (2021) presented a theoretical framework for STEM education that identified three levels of integration: multidisciplinary, interdisciplinary, and transdisciplinary. In all three levels, STEM disciplines are incorporated into the same activity, but the learning goals and level of integration vary. In multidisciplinary integration, each discipline has its own learning goals, and all STEM disciplines are equally relevant. In interdisciplinary integration, the learning goals are merged within a specific concept, while in transdisciplinary integration, learning goals focus on real-world problems and their social implications. Likewise, Vasquez et al. (2013) also discussed different levels of integration, describing a continuum of increasing levels of integration, namely multidisciplinary, interdisciplinary, and transdisciplinary. They noted that flexibility for educators exists within this continuum, with teachers needing to adapt the content to students' age and cognitive development. For example, primary school teachers may play a more relevant role in adapting content to students, while secondary and higher education teachers may provide more interdisciplinary or transdisciplinary integration with the teacher in a secondary role.

Therefore, learning activities designed based on STEM education have the potential to provide students with a comprehensive learning experience. These activities aim to promote critical thinking, problem-solving, and inquiry-based learning, with a focus on real-world problems and their solutions (English, 2016). STEM-based activities can be designed to be hands-on, inquiry-based, or project-based, providing students with the opportunity to explore STEM concepts and develop the skills needed to succeed in the 21st-century workforce (Idin, 2018). Examples of STEM-based activities include building and testing a bridge, designing and coding a mobile app, conducting experiments to investigate a scientific phenomenon, and using data to solve a real-world problem. The goal of STEM-based activities is to prepare students for success in STEM fields and equip them with the skills needed for success in the 21st century.

STEM-based activities can benefit the teaching of computational skills by providing a comprehensive learning experience that integrates different disciplines, such as Science, Technology, Engineering, and Mathematics. These activities are often hands-on and involve problem-solving and collaboration, which are key aspects of computational thinking. Students are given opportunities to apply theoretical knowledge in practical settings, which helps them develop their computational skills (Sengupta et al., 2018)). STEM-based activities are designed to tackle real-world problems, which require students to think critically and develop systematic approaches to problem-solving (Sen et al., 2018). Through collaborative problem-solving, students can develop communication and teamwork skills that are important for success in computational fields. From this perspective, students can develop the skills of decomposition, pattern recognition, abstraction, and algorithm by participating in STEM-based activities.

Previous studies

Several studies found the benefit of STEM-based activities in science education (e.g., Eroğlu & Bektaş, 2022; Jongluecha & Worapun, 2022; Sahin, Ayar, & Adiguzel, 2014; Sarican & Akgunduz, 2018; Ültay et al., 2020; Yuliati, Parno, Yogismawati, & Nisa, 2018). It was found that using STEM-based activities can lead to desirable outcomes in science education in terms of scientific literacy, 21st-century skills, and science learning achievement. Moreover, previous studies also suggested the benefits of STEM-based activities on the instruction of computational thinking skills. For example, Yang et al. (2021) implemented a STEM + computational thinking curriculum, guided by project-based learning, in after-school programs, and found positive reactions from teachers and students. Colclasure et al. (2022) evaluated a PD program for STEM teachers, focused on science and engineering practices, showing limited prior use of SEPs in teaching and significant improvement in confidence and interest to incorporate SEPs after attending the program. Sengupta et al. (2018) argue for a paradigmatic shift in viewing coding and computational thinking as a complex form of experience, with implications for teaching and learning STEM in K-12 classrooms.

The previous studies discussed in the literature review emphasize the importance of integrating computational thinking into STEM education. While most studies on STEM education in science classrooms focus on secondary school students, who are better equipped to create STEM projects, developing thinking skills is fundamental for future STEM success. To explore the new area, this study utilized STEM-based activities in a science class for 5th-grade students. The study aims to improve science learning achievement, develop computational thinking skills, and enhance satisfaction with the learning experiences. The expected outcomes of this study are significant, as they can inform the development of effective strategies for integrating computational thinking in STEM education for younger students.

3. Methodology

3.1 Samples

The study consisted of 30 grade 5 students in primary school in Thailand. The average age of the participants was 11. These participants were chosen using a cluster random sampling method, which involved dividing the population of 120 students into smaller groups (or clusters), and then selecting a random sample of students from each cluster. This method was chosen to ensure that the sample was representative of the larger population, and to minimize the risk of sampling bias. It is important to note that the researchers took caution with ethical issues in human research, which suggests that they followed appropriate ethical guidelines and procedures to protect the rights and welfare of their study participants. This may have included obtaining informed consent from the students and their parents or guardians, ensuring confidentiality and anonymity of the data collected, and taking steps to minimize any potential harm or discomfort that the students may have experienced as a result of their participation in the project.

3.2 Instruments

3.2.1 A STEM-Based Learning Management Plan

The main instrument used in the study was a learning management plan designed to teach a general science class and develop computational skills for grade 5 students. The plan was specifically designed using STEM-based activities, with a focus on logical reasoning and problem-solving, logical programming, information, and safe internet use. The plan was designed to be completed in 12 class hours, with each sub-lesson plan containing a series of STEM-based activities that were aimed at enhancing the student’s understanding of the class content and their computational thinking skills. The STEM-based activities included a range of different approaches, such as hands-on experiments, group projects, and online research assignments. For example, one activity might involve students working together to design and build a simple robot using basic programming concepts, while another activity might involve researching different online resources to learn more about safe internet use and cyber security. The learning management plan was evaluated by five experts who were scholars in education and professional teachers. The evaluation demonstrated a high level of plan quality, indicating that the plan was well-designed and effective in achieving its intended goals.

3.2.2 Learning Achievement Test

The learning achievement test used in this study was designed to measure students’ knowledge and understanding of programming concepts related to message programming, mapping programming, conditional programming, program evaluation, and the use of Scratch. The test consisted of 30 items, each with four multiple-choice options. To ensure the content validity of the test items, a team of five experts was selected to perform an Inter-Observer Consistency (IOC) test, which involved rating each item according to its relevance and appropriateness for measuring the intended construct. The IOC test was conducted to determine the level of agreement among the experts and to identify any items that required further revision or refinement. Based on the IOC test results, the content validity of each test item was found to be between 0.6–1.0, indicating a high level of agreement among the expert raters. This suggests that the test items were appropriate for measuring the intended construct and that the test as a whole was a valid measure of students’ learning achievement in the areas of programming covered in the study.

3.2.3 Computational Thinking Test

The computational thinking test used in this study consisted of eight items and was designed to assess students’ skills in decomposition, pattern recognition, abstraction, and algorithm design. The test required students to provide written answers demonstrating their ability to apply these skills to problem-solving tasks. The content validity of each test item was assessed using an Inter-Observer Consistency (IOC) test involving a panel of five experts, with a high level of agreement observed (0.6–1.0). Overall, the test was a valid and reliable measure of students’ computational thinking skills in the areas covered by the test.

3.2.4 Satisfaction Questionnaire

To assess students’ satisfaction with the learning experience gained through the learning management plan, a questionnaire was designed with 20 items using a five-point Likert scale. There are 5 aspects of satisfaction assessment including content, learning management, learning material, evaluation and assessment, and application in real-world situations. The questionnaire was subjected to an Inter-Observer Consistency (IOC) test using a panel of experts, which revealed a high level of agreement (0.6–1.0) regarding the content validity of each item. The questionnaire was designed to measure students' subjective experiences and opinions regarding the learning management plan and can be a valuable tool for educators and researchers interested in understanding the effectiveness of different teaching approaches and methods.

3.2.5 Data Collection and Data Analysis

The study was designed in a one group experimental design. Therefore, students took a pre-test to assess their learning achievement and computational thinking skills before engaging with the learning management plan. After completing the learning management plan, students took a post-test to measure their learning achievement and computational thinking skills again. Additionally, students completed a questionnaire to assess their satisfaction with the learning experience.

To analyze the data, descriptive statistics such as percentage, mean score, and standard deviation were calculated for the learning achievement test, computational thinking test, and questionnaire responses. Furthermore, a paired samples t-test was used to compare the pre-and post-test scores for learning achievement and computational thinking skills and to evaluate the effectiveness of the learning management plan.

4. Results

The results of the study were as follows.

Table 1. The effects of STEM-based activities on students' learning achievement

Learning achievement	N	Fullmark	$\bar{x}$	S.D.	% of Mean	t	Sig
Pre-test	30	30	11.87	1.52	39.56	17.55*	.000
Post-test	30	30	21.77	2.35	72.56		

The results of the study indicate that there is a significant difference between the pre-test and post-test scores of students' learning achievement related to programming concepts. Specifically, the mean score on the pre-test was 11.87 (SD = 1.52), while the mean score on the post-test was 21.77 (SD = 2.35), t = 17.55, $p < 0.001$. This finding suggests that the STEM-based activities, which aimed to improve students' understanding of programming concepts related to message programming, mapping programming, conditional programming, program evaluation, and the use of Scratch, were successful in achieving their intended outcomes. The significant increase in post-test scores compared to pre-test scores indicates that the STEM-based activities had a positive impact on students' learning achievement related to programming concepts.

Table 2. The effects of STEM-based activities on Students' computational thinking

Computational thinking	N	Fullmark	$\bar{x}$	S.D.	% of Mean	t	Sig
Pre-test	30	24	8.23	2.63	34.31	18.89*	.000
Post-tes	30	24	18.10	1.37	75.42		

Moreover, the study's results demonstrate a significant contrast between students' computational thinking skills before and after taking the pre-test and post-test. The pre-test had a mean score of 8.23 (SD = 2.63), while the post-test had a mean score of 18.10 (SD = 1.37), with a t-value of 18.89 and a p-value of less than 0.001. These outcomes indicate that the STEM-based activities implemented in the study to enhance students' computational thinking skills were successful in achieving their intended goals. The significant increase in post-test scores compared to pre-test scores implies that these STEM-based activities had a beneficial effect on students' computational thinking skills.

Table 3. Students' satisfaction with the STEM-based activities

Aspects	x̄	**S.D.**	**Degree of Satisfaction**
Content	**4.23**	**0.67**	High
Learning activitiy management	4.22	0.68	High
Learning material	4.21	0.69	High
Evaluation and assessment	4.18	0.68	High
Application in real-world situations	4.11	0.70	High
Average	**4.19**	**0.68**	High

The results of the study indicate that the incorporation of STEM-based activities in teaching programming concepts and computational thinking skills yielded high levels of satisfaction among the participating students. The overall mean score for satisfaction was 4.19 with a standard deviation of 0.68. Furthermore, the students expressed high levels of contentment with various aspects of the class, including the content of the learning management plan (x̄ = 4.23, SD = 0.67), learning activity management (x̄ = 4.22, SD = 0.68), learning material (x̄ = 4.21, SD = 0.69), evaluation and assessment (x̄ = 4.18, SD = 0.68), and application in real-world situations (x̄ = 4.11, SD = 0.70). The students' positive evaluation of the STEM-based activities is further exemplified in their feedback, where they described the content of the learning management plan as easy to comprehend, the activities as enjoyable and informative, the learning material as interesting and informative, the evaluation and assessment as fair and easily verifiable, and the application in real-world situations as realistic. The findings of this study suggest that the STEM-based activities implemented were effective in promoting the acquisition of programming concepts and computational thinking skills. The high levels of satisfaction expressed by the students indicate that the STEM-based activities were engaging, informative, and relevant to their learning needs, which supports the notion that the use of STEM-based activities can improve students' learning outcomes.

5. Discussion

5.1 Positive Effects of STEM-Based Activities on Students' Learning Achievement

The results of this study suggest that incorporating STEM-based activities into grade 5 science classes can enhance students' knowledge and learning outcomes. These findings align with the results of previous studies that have also demonstrated the benefits of STEM education on science education (Eroğlu & Bektaş, 2022; Jongluecha & Worapun, 2022; Sahin, Ayar, & Adiguzel, 2014; Sarican & Akgunduz, 2018; Ültay et al., 2020; Yuliati, Parno, Yogismawati, & Nisa, 2018). The effectiveness of STEM-based activities in promoting science education can be attributed to several factors. For instance, STEM education provides a practical and hands-on approach to learning that encourages students to apply scientific concepts in real-world scenarios. Additionally, STEM-based activities incorporate various disciplines such as science, technology, engineering, and mathematics, which provide students with a comprehensive understanding of how different fields intersect and influence one another. Furthermore, STEM education fosters critical thinking and problem-solving skills, which are essential for success in science-related fields.

5.2 Positive Effects of STEM-Based Activities on Students' Computational Thinking

The results of this study also indicate that incorporating STEM-based activities into grade 5 education can lead to improved computational thinking skills among students. These findings are consistent with previous studies that have demonstrated the positive impact of STEM education on computational thinking skills (Colclasure et al., 2022; Sengupta et al., 2018; Yang et al., 2021). STEM-based activities can provide students with opportunities to engage in computational thinking skills, such as the ability to decompose data, recognize patterns, prioritize components, and develop a systematic plan for solving problems. This is important because computational thinking skills are critical for success in today's digital world, where technologies such as artificial intelligence, big data, and the internet of things are becoming increasingly prevalent. The integration of STEM-based activities in grade 5 education has the potential to not only improve computational thinking skills but also prepare students for future success in STEM-related fields. By equipping students with these valuable skills, educators can help them to become more innovative, analytical, and critical thinkers.

5.3 The Satisfying Learning Environment Provided by STEM-Based Activities

The results of this study indicate that grade 5 students expressed a high level of satisfaction with STEM-based activities. STEM-based activities provided students with opportunities for active learning, technology-based learning, and connection with real-world problems. These findings align with the nature of Generation Z learning presented by previous literature (Giray, 2023; Seemiller & Clayton, 2019; Seemiller & Grace, 2017; Seemiller et al., 2019). The integration of STEM-based activities in education provides students with opportunities to engage in active learning by participating in hands-on activities and solving real-world problems. Technology-based learning, which is a core component of STEM education, offers students the opportunity to engage with technology and digital tools to enhance their learning experiences. This type of learning is particularly relevant for Generation Z learners who have grown up with technology as a ubiquitous part of their daily lives. Moreover, the connection between STEM-based activities and real-world problems creates a sense of relevance and purpose for students. This approach to learning is highly valued by Generation Z learners, as it allows them to see the practical applications of the concepts they are learning.

6. Conclusion

In conclusion, in this study, we investigated the effects of STEM-based activities on grade 5 students' science learning achievement, computational skills, and satisfaction with the learning experience. 30 grade 5 students in the Thai context were involved in the study. The results of the study relied on the effectiveness of a learning management plan designed using STEM-based activities with a learning achievement test, a computational thinking test, and a satisfaction questionnaire as assessment tools. The results of the study showed that STEM-based activities had a significant effect on grade 5 students' learning achievement and computational thinking skills. Furthermore, the students expressed a high level of satisfaction with the STEM-based activities, which provided an engaging and relevant learning experience.

The implications of this study are important for educators and curriculum developers who seek to improve the quality of science education and promote the development of computational thinking skills. By incorporating STEM-based activities into the curriculum, educators can create a dynamic and engaging learning environment that aligns with the needs and preferences of students. Furthermore, the results of this study highlight the importance of considering student satisfaction with the learning experience as an essential component of effective STEM education.

Future studies could investigate the long-term effects of STEM education on student outcomes, such as academic achievement and career success. Additionally, studies could explore the impact of different types of STEM-based activities on student learning outcomes and satisfaction with the learning experience. Moreover, studies could investigate the impact of cultural context on the effectiveness of STEM education. For example, studies could explore how the implementation of STEM-based activities varies across different cultural contexts and how cultural factors may influence student engagement and motivation.

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