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Development of Science Learning Achievement and Problem-Solving Thinking by STEM Education Management with Engineering Design Process for Grade Six Students

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Abstract: This research aimed to compare the science learning achievement of students before and after learning through STEM education management with Engineering is Elementary, in order to compare the problem-solving and thinking ability of students before and after learning through STEM education management with Engineering is Elementary, and studying the satisfaction of the students with STEM education management with Engineering is Elementary. The research sample consisted of 29 Grade Six students studying in the first semester of the 2022 academic year, obtained by cluster sampling. The research instruments were lesson plans, achievement tests, problem-solving thinking tests, and a satisfaction questionnaire. The statistics used in data analysis included mean, standard deviation, and a dependent t-test. The results showed that the science learning achievement and problem-solving and thinking abilities of the students after learning through STEM education management with Engineering is Elementary are higher than that of before learning with the statistical significance at a level of .05. Overall, the students were satisfied with the STEM education management with Engineering is Elementary at a high level.

Keywords: Science learning achievement, Problem-solving thinking, STEM education, Engineering is Elementary

Introduction

The 21st century is an era of creating and developing learners to be thinkers. The development of learners to use technology to solve problems creatively is both vital and necessary for the present and the future (Wijarn Panit, 2012: 16). With the recognition of the importance of science learning management in the 21st century with the utmost aim of the achievement of learners at the Institute for the Promotion of Teaching Science and Technology (IPST) developed the indicators and core learning of science subjects (Ministry of Education, 2017:13-105). Design and technology have been defined as the essence of learning. The focus of the technology of learning management is on living in a rapidly changing society. Additionally, the application of knowledge and skills in the sciences, mathematics, and other subjects to solve problems or develop work creatively according to the engineering design process and the selection of appropriate technology by taking into account the impact of technology exploitation on life, society and environment were emphasized (Ministry of Education, 2017: 4). Similarly, the 20-year National Strategy (2018-2037) mentioned that educational management should be organized with the integration of science, mathematics, engineering, technology, etc. in order to develop an integrated learning system focused on learning by doing and building learners to be able to supervise their learning skills and creativity (Government Gazette, Vol. 135, No. 82 Kor, dated October 31, 2018: 36-37). Notification of National Strategy, 2018: 36-37. This mentioned learning management is in line with STEM education, which integrates four sciences: S (science), T (technology), E (engineering), and M (mathematics). STEM education management is different from traditional learning management by transforming rote learning into learning through experimentation with an emphasis on creativity and problem-solving (Wasini Israsena Na Ayutthaya, 2016: 2).

Ban Sa Nam Som School has encountered problems with the quality of learners, especially in terms of problem-solving and resulting in lower learning achievement than the set value of 70% (Ban Sa Nam Som School Annual Report, 2020: 5). This is one of the learning problems and obstacles of students. Regarding the teachers at Ban Sa Nam Som School, classical teaching could not solve the ongoing problem because of its focus on recitation, which caused less successful educational management. Therefore, the concept of STEM education management was studied. Consequently, the engineering design process was found to be an alternative way of learning (Ministry of Education, 2017: 7). It was found that the engineering design process is a scientific method that engineers use to create work (Marut Patphol, 2016: 1). The engineering design process is one of the teaching processes commonly used in schools in Texas and Massachusetts in the USA. This teaching method enhanced student thinking skills, i.e., problem-solving and creativity (Wasini Israsena Na Ayutthaya, 2016: 55). Engineering is Elementary (EiE) was developed by the Museum of Science, in Boston in the USA. EiE comprises a series of five steps (Schachter, 2012: 42-45; Wasini Israsena Na Ayutthaya, 2016: 97-142). (1) *Ask* refers to asking questions about the learning topic; (2) *Imagine* refers to encouraging students to think and imagine; (3) *Plan* refers to students planning a solution; (4) *Create* refers to the students creating the work; and (5) *Improve* refers to students developing and improving work performance. EiE is popular in the United States and other countries due to its flexibility of implementation and ease for elementary school students. Moreover, the teaching processes directly support the creativity of students: *imagine* and *create* steps. However, the IPST has never mentioned this step (Wasini Israsena Na Ayutthaya, 2016: 2). There is no research report on the implementation of the EiE learning process in Thai elementary schools, thus the researcher was interested in developing science learning achievement and problem-solving thinking through STEM education management with EiE for Grade Six students as a guide for the further development of science learning management. This research aimed to compare the science learning achievement of students before and after learning through STEM education management with Engineering is Elementary, to compare the problem-solving thinking and ability of students before and after learning through STEM education management with Engineering is Elementary, and study the satisfaction of students with STEM education management with Engineering is Elementary.

Research Methodology

Research Population and Sample

The research population in this study was 320 Grade Six students. They were from 15 medium-sized schools in Kamphaeng Saen District, Nakhon Pathom Province. The sample in this study were 29 Grade Six students who studied at Ban Sa Nam Som School in Kamphaeng Saen District, Nakhon Pathom Province, studying in the first semester of the 2022 academic year. They were obtained by cluster sampling.

Assessing the Quality of Research Instrument

The research instruments were validated by three experts as follows:

1. There were three lesson plans based on STEM with EiE for 15 teaching hours, which were validated for content validity and reliability with an index of item objective congruence between 0.67-1.00.

2. The science learning achievement test was a four-choice test with the index of item objective congruence of 1.00, a difficulty value of 0.30-0.79, the power of discrimination (r) of 0.35-0.71, and a reliability of 0.88.

3. The problem-solving thinking ability test consisted of four situational questions with an index of item objective congruence of 1.00 and reliability values of 0.83, 0.85, 0.81, and 0.78, respectively.

4. The satisfaction questionnaire of learning through STEM education management with EiE had a five-level scale questionnaire and an index of item objective congruence between 0.67-1.00 and a reliability of 0.91.

Data Collection

The data were collected using the following steps:

1. The researcher clarified the research approach to the sample students, as well as explaining the role of the students and the researchers in this study.

2. The researcher carried out a pre-test of learning-based STEM education management with EiE.

3. The researcher conducted learning based on STEM education management with EiE with Grade Six students from Ban Sa Nam Som School. The three lesson plans, created by the researcher, were a five-week experiment for three hours a week.

4. The post-test was carried out with the sample. The pre-test was the same as the post-test, but the question items were switched in order.

5. The satisfaction of the students with learning through STEM education management with EiE was surveyed and the results were further analyzed.

Data Analysis

The data were analyzed in the following manner:

1. The science learning achievement and the problem-solving thinking ability of the students before and after learning through STEM education management with EiE were analyzed. The statistics used were mean $(\overline{X})$, standard deviation (SD), and a dependent t-test.

2. The satisfaction with learning based on STEM education management with EiE was analyzed. The statistics used were mean $(\overline{X})$ and standard deviation (SD).

Research Results

The research results are presented in the following tables and divided into three parts.

Part 1: An analysis of the science learning achievement of students before and after learning through STEM education management with EiE.

Part 2: An analysis of the problem-solving thinking ability of students before and after learning through STEM education management with EiE.

Part 3: The analysis of student satisfaction with STEM education management with EiE.

Table 1 The analysis of the science learning achievement of students before and after learning through STEM education management with EiE is presented in Table 1. (Full score equal to 25 points).

(n=29)

Testing	M	SD	$\overline{d}$	$S.D_{\overline{d}}$	t
Pre-test	10.21	3.16	5.83	0.59	9.82*
Post-test	16.03	3.04			

* Statistical significance at .05 level

From Table 1, the science learning achievement of the students after learning through STEM education management with EiE (M= 16.03, S.D. = 3.04) was higher before (M= 10.21, S.D. = 3.16) with a statistical significance level of .05.

Table 2 The analysis of the problem-solving thinking ability of students before and after learning through STEM education management with EiE is presented in Table 2. (Full score equal to 16 points).

(n=29)

Testing	M	SD	$\overline{d}$	$S.D_{\overline{d}}$	t
Pre-test	10.68	1.97	2.68	0.25	10.59*
Post-test	13.37	1.96			

* Statistical significance of .05

From Table 2, the problem-solving thinking of the students after learning through STEM education management with EiE (M= 13.37, S.D. = 1.96) is higher than before learning (M= 10.68, S.D. = 1.97) with a statistical significance of .05.

Table 3 An analysis of student satisfaction with STEM education management with EiE is presented in Table 3.

Aspect	M	S.D.	Level	Order
Learning content	4.23	0.37	High	3
Learning activities	4.35	0.35	High	2
Measurement and evaluation	4.36	0.58	High	1
Total	4.32	0.35	High	

* Statistical significance of .05

From Table 3, the satisfaction of the students with STEM education management with EiE was at a high level (M = 4.32, SD = 0.35). Specifically, the aspects in descending order were measurement and evaluation (M = 4.36, SD = 0.58), learning activities (M = 4.35, SD = 0.35), and learning content (M = 4.23, SD = 0.37).

Discussion

The research results showed that the science learning achievement of the students after learning through STEM education management with EiE was higher than before with a statistical significance of .05. In particular, the students learned through the engineering design process which integrated knowledge with learning by doing in problem-solving scenarios. Real action was one of the teaching models of engineering design projects for providing the students with a variety of learning styles. (Mangold & Robinson, 2013: 23). The EiE design process consists of 5 steps: *Ask*—study the problematic situation, *Imagine*—brainstorm problem solutions, *Plan*—plan work operations using flow charts, *Create*—perform work according to the designed plan, and *Improve*—improve and present work performance (Wasini Israsena Na Ayutthaya, 2016: 65). The students used various technologies to search for and to collect data, and the retrieved information was organized systematically. With this method, learning does not place importance on recitation on the hands-on experiences of students. Consequently, students learned by themselves directly with the problem-solving process. In terms of learning management, students are encouraged to experiment and solve problems. The lesson content is learned from practice, experimentation, and observation, which makes students more understanding and less boring. In this research, the teacher acted as an instructor who guided and advised on the topic of the Earth and its Changes, and the Consequences of the Greenhouse Effect. The engineering design process representing the application of scientific, mathematical, and technological concepts under rules and constraints to improve human life (Cunningham, Mott and Hunt, 2018:53-60). Students understood the lesson content through a variety of learning materials. For example, in the lesson plan on reducing the use of household chemicals, students solved the problem of chemical use from their everyday situations and created work that could reduce the use of chemicals in their homes. They searched for chemicals in their daily lives, as well as the effects of household chemicals. They found that the more household chemicals are used, the more chemicals are produced. Industrial facilities released toxins into the air, causing global warming accordingly. Students then used skills and knowledge with agility and expertise to create workpieces to use at home according to the set plan. Afterward, they checked, improved, and tested the efficiency of their work to get the best product. Consequently, after finishing the lesson, students are enthusiastic about seeking knowledge to solve problems and exchanging information among friends in their group. Students learned from their experiences by doing instead of listening to lectures. As a result, students improved their academic achievement. The results of this research are consistent with the findings of Kamolchart Klomim (2019: 2) in that the engineering design process is an acting process for developing various skills and knowledge to solve problems in daily life, and ensuring better learning achievement among students. Accordingly, Pholsak Saengpromsri (2015: 411) claimed that STEM education management resulted in higher attitudes and achievements in science skills than traditional learning.

The results showed that problem-solving thinking ability after learning through STEM education management with EiE was higher than before and with a statistical significance of .05. This was because learning through STEM education management with EiE and helping to efficiently develop problem-solving thinking skills. Students can express their understanding of problems and their problem-solving ability by brainstorming ideas based on the imagination of goal achievement (Ministry of Education, 2017: 3). From the flexible steps of EiE, students can review the process and solve problems logically based on the information obtained. They can innovatively create flowcharts of operation according to

the set plan. The STEM education management with EiE consisted of five steps. In Step 1, study the problem, problem situations are set to stimulate problem-solving thinking ability, starting from identifying problems through various media. In Step 2, imagining and brainstorming ideas, teachers consider what students need to study and determine learning resources to facilitate learning. Students are encouraged to apply theories to solve problems in daily life with the use of scientific reasoning skills by gathering information and planning solutions. Subsequently, students performed activities so that they can design work and create a unique product. In Step 3, planning the operation using mind maps, each group discussed the problem and defined engineering thinking information according to thinking principles. The best and most concise working conditions and questions under the restrictions of design and creation are defined technologies were devised by engineers Jocz and Lachapelle (2012: 3) In Step 4, building and implementing, according to the designed plan, the teacher observed student performance and advised students, as well as encouraging students to work safely. Students check their performance and discuss engineering design. Consequently, they had problem-solving thinking ability by using scientific knowledge to invent a product based on scientific principles. Finally, in Step 5, they improved and discussed the design work, each group presented a product, evaluated the design work, and improved their work according to scientific problem-solving principle. This is in line with the research of Marisa Homduang, Somsiri Singlop and Chade Sirisawat (2021: 72), that after learning through STEM education management, students had higher problem-solving thinking and learning achievement. Students were imaginative and took the initiative to solve problems. In real life, work comes from doing it yourself and applying scientific knowledge to design and create inventions to achieve desired goals.

Overall, the results showed that the students were satisfied with STEM education management at a high level. When considering each aspect, student satisfaction was at a high level in all aspects: measurement and evaluation, learning activities, and learning content, respectively. Students had the opportunity to assess themselves and their peers. They checked and improved their work regularly. As a result, students are motivated to learn science through learning by doing, Lachapelle et al (2011: 4). Due to the content being difficult to understand, once students have searched for knowledge by themselves, they can choose to learn through media that fit their needs and easy to learn. Group activities are conducted to promote problem-solving thinking. From the activities, students enjoy learning and like to exchange ideas with each other. Students are enthusiastic because they want to apply what they learn in their daily lives. They commit to work and have good morale. The engineering design process is a simple, easy-to-understand procedure and can be an operational guide for students, from easy to difficult levels. With positive feelings, they help each other work happily. The product is efficient since students have invented it with pride. This is in line with Nasrin Boussa (2015: 4), who mentioned that students are highly satisfied with STEM education. It is because science subjects are normally characterized as recitation. With learning by doing, students have a positive attitude because they can come back to check, correct, and improve their work.

Conclusion

The science learning achievement and problem-solving thinking ability of students who have learned through STEM education management with EiE after learning are higher than that of before learning with a statistical significance of .05. Overall, the students were satisfied with the STEM education management with EiE at a high level. The use of STEM

education management with EiE in a teaching process allows students to have higher problem-solving ability. Therefore, teachers should focus on the step of imagining and brainstorming problem-solving thinking by constantly asking students questions to provide them with effective information, and stimulating their attention to express opinions to solve problems.

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