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Developing Grade 3 Student Science Learning Achievement and Scientific Creativity Using the 6E Model in STEAM Education

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Abstract

The purposes of the studies were 1) to study the effects of the 6E learning model on grade 3 students' learning achievement in science with the determining criteria of 70; 2) to compare students' scientific creativity before and after implementing the 6E learning model; and 3) to evaluate grade 3 students' creative abilities after implementing the 6E learning model. The participants were 19 students in a public school in Thailand. They were selected by a purposive random sampling. The instruments were a learning management plan designed using the 6E learning model, a learning achievement test, a pre-post-test for creativity assessment, and a creative ability evaluation form. The data were analyzed using the percentage, mean score, standard deviation, median, and Wilcoxon signed-rank test (Z score). The results of the study show that the 6E learning model was effective in transferring the knowledge of science to the grade 3 students. It was also beneficial in developing participants' creative thinking and ability. The study contributes to the area of STEAM education as it provides evidence to support its effects on a younger group of learners.

Keywords: 6E learning model, STEAM education, Creativity, Science education

1. Introduction

The knowledge in science classrooms is essential for students at all levels of education. With a good knowledge of science, students can succeed in the competitive world of the 21st century. On daily basis, scientific knowledge also helps them to systematically make decisions (Schoenberger, 1998). Therefore, the concepts of sciences are included in the core curriculums of the education systems around the globe (Holbrook, 2010).

It has to be noted that students who take science classes frequently come away with the impression that scientific investigations require meticulous observation and analysis of data to test hypotheses. These processes need the development of effective thinking skills to complete (Zimmerman, 2007). In this stage, students need to be creative in applying the knowledge of science to solve problems. Teachers of sciences also have to be aware of the fact that the natural world is complicated, and the most significant and intriguing challenges in the scientific community are typically too difficult to solve directly. To develop a learner as a scientist is to constantly re-imagine these large problems, mentally breaking them down into smaller, more solvable parts (Jonassen, 2007).

In primary school education, children should devote increasing attention to science education as they grow. Science fosters learning styles such as critical thinking and problem-solving, and students would be able to apply these lifelong learning skills both inside and outside (Cobern, 2015). The scientific method is based on the process of formulating a question, developing a hypothesis, making predictions, conducting experiments, and analyzing the results of those experiments. In addition, scientists must be able to make relevant observations, record them in some form (such as a drawing, table, or graph), and apply their prior knowledge to related situations (Sumpter, 2019). This could increase students' creative learning behaviors as they are situated in a learning environment that encourages them to find new but systematic solutions to the problem. Therefore, it could be said that primary school students need creativity in science classes, and they also need science classes to be creative.

Creative thinking skills are the ability to innovate new ideas, new approaches to doing things, and new inventions that are based on originality. Creative learners have the ability to as creating new ideas, analogies, and metaphors. Andriopoulos (2000) indicated that it is difficult to define creativity since there are a lot of ambiguous components of the concept, and there is also no generally accepted definition for creativity in general. Creativity is a perplexing and complicated idea. According to Amabile (1997), creativity is defined as the production of novel and appropriate ideas in any realm of human activities such as science, arts, education, business, and even in everyday life. What should be implied from the definition is that the ideas must be new and appropriate to the opportunity or problem that is being presented. Creativity is a process that can be cultivated and improved upon. Every human possesses the capacity; hence, that potential ought to be maximized by providing people with the opportunities and chances to participate in endeavors that foster creativity (Craft, 2003).

Therefore, teaching science in primary school education needs to consider thinking development and scientific learning behaviors as the objective of the class along with students' learning achievement of the concepts learned in class. STEAM education was introduced to help students develop the knowledge and skills necessary to solve problems, make good use of information, and compile and assess evidence to draw a conclusion (Perignat & Katz-Buonincontro, 2019). STEAM, which stands for science, technology, engineering, art, and mathematics, is an educational approach that focuses on instilling in children a love of these subjects from a young age as they could remain with them throughout their lives (Carter et al., 2021). STEAM is developed from STEM education with the addition of Art as modeling, developing explanations, and engaging in critique and evaluation have been understated in mathematics and science education. According to the authors, the effective instruction of STEAM subjects prepares students for life whether they choose careers in the sub-areas of steam or not. Students learn how to think critically and how to solve problems which are skills that can be used throughout their lives to help them get through challenging situations.

6E model of STEAM education is an essential method that could familiarize learners with scientific methods and develop their thinking skills. Barke (2014) suggested that the 6E learning model is an adapted instruction model of 5Es inquiry-based learning (Bybee, 2009). The models are similarly developed in the constructivist model that allows students to experience concepts of science and reconsider their prior knowledge. Learners are encouraged to redefine, reorganize, elaborate, and change their initial understanding of the concepts via interactive and reflective learning activities. In the 6E learning model, a learning circle of e for "engineer" is added to let students use the concept of engineering work (*e.g.*, design, systems, modeling, human values, and resources) in their learning. The detail of each component in the 6E learning circle can be seen below.

(1) Engage

In the first stage, teachers verify the usefulness of the concepts, use handouts and other teaching aids to pique students' curiosity, interest, and engagement, and define the unit's concepts, objectives, and significance. To encourage students to believe that they, too, are capable of completing the assignment and to pique their interest, completed projects can be exemplified.

(2) Explore

The stage is meant to provide learners the opportunity to construct their comprehension of the class content. they are familiarized with the use of teaching materials and encouraged to apply the initial knowledge while also accumulating experience. Collaborative learning takes part in this section. Group work can be a discussion of how to use learning materials, idea sharing, and deepening the understanding of the concepts.

(3) Explain

Knowledge explanation and refinement are the focus of this stage. The students are allowed to reflect on what they have learned. Teachers notify of the misunderstanding of the concepts and provide feedback. In the meantime, students are guided through the discussion and clarification of concepts that they do not fully understand by using questions and answers.

(4) Engineer

The component is essential for the model as it completes the previous 5Es model in illustrating how the concept is used in real-life situations (Burke, 2014). A solution prototype is conceptualized using the knowledge learned in class. Authenticity must be prioritized in the process of raising problems for students to solve. In addition, to find a solution to the problem, students need to integrate the knowledge and skills they have acquired.

(5) Enrich

Students are given tasks that involve multiple dimensions of problems to test their ability to apply the knowledge learned in class to solve problems in more complex circumstances.

(6) Evaluate

Teachers ensure students understanding of the concept and evaluate the learning outcomes. Evaluation material is developed considering the learning outcome of the course. Teachers should employ diverse assessment tools to evaluate their students' learning needs and deficiencies.

As the 6E learning model show potential in developing learners' creativity in science, studies have been conducted with the implementation of the model in scientific classes (*e.g.*, Chung, et al., 2018; Hsiao, 2019; Lin et al., 2020; Lin & Chiang, 2019; Wu, 2019). It can be seen in the results of the study that the 6E learning model helps adult learners to gain knowledge in innovating IOT smart cane (Lin & Chiang), IOT assistant devices for the elderly (Chung, et al, 2019), and game development (Wu, 2019). Moreover, it also lets learners develop their scientific thinking in terms of technological inquiry ability (Lin et al, 2020) and computational thinking (Hsiao, 2019). However, a limited number of studies have explored the effectiveness of the model on primary school students. The current study aims to contribute to the area of STEAM education by employing the 6E learning model to develop grade 3 student creativity in science. The purposes of the studies were 1) to study the effects of the 6E learning model on grade 3 students' learning achievement in science with the determining criteria of 70, 2) to compare students' scientific creativity before and after implementing the 6E learning model, and 3) to evaluate grade 3 students' creative abilities after implementing the 6E learning model.

2. Methodology

2.1 Research Design

A quasi-experimental is employed in the research design. One group of participants was assigned. Participants' learning achievements were assessed at the end of the process compared to the determining criteria of 70. Their creativity before and after the treatment was compared, and their creative ability was evaluated during the creation session of the learning management.

2.2 Participants

The participants were 19 students in a public school in Thailand. They were selected by a purposive random sampling. The participants were in grade 3 when the data collection took place. They were treated with respect for ethics, and their information was kept secret.

2.3 Instruments

The instruments were a learning management plan designed using the 6E learning model, a learning achievement test, a pre-post-test for creativity assessment, and a creative ability evaluation form. In detail, the learning management plan consisted of 4 lesson plans including creating new material using a mixture of the same material, creating new material using a mixture of the different materials, changes in the material in heat, and changes in the material in cold. The process took 12 class hours. The plan was evaluated by 5 experts and experienced teachers and found appropriate ($\bar{x}$ = 4.61-4.73). The learning management plan was tested in a preliminary study and revised before being employed in the data collection. The learning achievement test consists of 20 multiple choice question items. The test development indicates an appropriate level of validity (IOC = 0.6-1.0), difficulty (p = 0.54-0.77), and discrimination (r = 0.24-0.88) of the question items. The test reliability was 0.74. The pre-post-test was designed in a subjective design. It consists of 2 writing tests which account for 20 points. Students' scores were evaluated considering originality, flexibility, and fluency of thinking. The creative ability evaluation form was designed in a 4-scale rating assessment. The aspects of evaluation include planning, plan execution, presentation, evaluation and reflection, and improvement.

2.5 Data Analysis

The data were analyzed using the percentage, mean score, standard deviation, median, and Wilcoxon signed-rank test (z score).

3. Results

Table 1. Students' learning achievement as a result of the 6E learning model

Student	Learning achievement score	Percentage	Interpretation
1	14	70.00	Pass
2	16	80.00	Pass
3	15	75.00	Pass
4	15	75.00	Pass
5	14	70.00	Pass
6	18	90.00	Pass
7	16	80.00	Pass
8	12	60.00	Under criteria
9	12	60.00	Under criteria
10	16	80.00	Pass
11	14	70.00	Pass
12	15	80.00	Pass
13	18	90.00	Pass
14	14	70.00	Pass
15	18	90.00	Pass
16	12	60.00	Under criteria
$\bar{x}$	14.88	74.38	Pass

The results of the study show that students overall learning achievement passed the determining criteria of 70 ($\bar{x}$ = 14.88). In detail, 13 out of 16 participants (81.25%) pass the criteria while only 3 (18.75%) participants failed to reach the determining criteria. It could be interpreted that the learning management was effective in developing students' learning management in science as the class showed improvement in science knowledge after using the 6E learning model at a certain level of expectation.

Table 2. The comparison between pre-test and post-test of students' creativity

Test	N	Med	Wilcoxon Signed-Ranks Test (z)	Sig.
Pre-test	16	6.00	-3.53	.00
Post-test	16	13.00		

The results of the study also suggest the improvement of students' creativity after using the 6E learning model. A Wilcoxon Signed-Ranks test indicates that the median post rank of the participants (*Med* = 13.00) was significantly higher than their median pre rank (*Med* = 6.00), $Z = -3.53$, $p = 0.00$. It could be interpreted that the 6E learning model was effective in developing students' creativity in learning science.

Table 3. Students' creative ability throughout the process of learning management

Lesson plans	Planing		Plan execution		Presentation		Evaluation and reflection		Improvement		$\bar{x}$	S.D.
	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.		
1	2.00	0	2.00	0	1.75	0.5	1.25	0.50	1.25	0.5	1.65	0.30
2	2.25	0.5	2.25	0.5	2.00	0	2.00	0	1.5	0.58	2.00	0.32
3	3.00	0	2.75	0.5	3.00	0	2.50	0.58	2.00	0	2.65	0.22
4	3.00	0	3.00	0	3.00	0	2.50	0.58	2.50	0.58	2.80	0.23

It could be seen in table 3 that the participants continuously developed their creative ability from lesson plans 1 to 4. Out of the maximum point of 4, students' average score on creative ability was 1.65 (S.D. = 0.30) at the beginning of the learning management plan. The score improved to 2.00 (S.D. = 0.32) in the second lesson plan, 2.65 (S.D. = 0.22) in the third lesson plan, and 2.80 (S.D. = 0.23) in the fourth lesson plan respectively. Consequently, it could be interpreted that the use of the 6E learning model positively affected the development of students' creative ability.

4. Discussion

What could be prioritized as the key issue in the discussion of the results of the study is the benefits of the 6E learning model on grade 3 students' learning achievement, creativity, and creative ability. The results of the study join the previous studies (*e.g.*, Chung et al., 2018; Hsiao, 2019; Lin et al., 2020; Lin & Chiang, 2019; Wu, 2019) who also found the usefulness of the instructional method in scientific and technology classes. Moreover, apart from technological inquiry ability (Lin et al., 2020). and computational thinking (Hsiao, 2019), creativity in learning science is also found to be the thinking process that is positively affected by the 6E learning model. According to Bybee (2009), the inquiry-based instructional method focusses on the principles of the constructivist teaching model that allows students to experience scientific concepts and reevaluate their prior knowledge. Through interactive and reflective learning activities, students are encouraged to redefine, reorganize, elucidate, and alter their initial conceptual understanding. In the 6E learning model (Burke, 2014) students are also exposed to the learning circle of "engineer" which is added to encourage students to apply the concept of engineering work to their learning. Therefore, implementing the 6E learning model in the current study results in both students' knowledge (learning achievement) and thinking process (creativity).

Moreover, it could also be noted that the 6E learning model was effective in developing creative ability in terms of planning, plan execution, presentation, evaluation and reflection, and improvement. In this case, Burke (2014) urged that adding the component of "engineer" into the learning circle would educate learners to understand the processes of work. Therefore, it accounted for the continued development of students' abilities in project work from the start to the end of the learning management.

The results of the study could also indicate that implementing an instructional method designed in STEAM education is beneficial for developing learners in the early stage of education as in the junior primary school of grade 3 in the current study. The result of the study supports Duban et al. (2018) who also found the benefits of the approach in elementary school education in Turkey. According to the authors, the integration of science, technology, engineering, art, and mathematics effectively supports the subjects of science, mathematics in daily life, basic engineering knowledge, etc. The authors also implied that the addition of art contributed to an enjoyable learning atmosphere which is crucial for teaching young learners.

5. Conclusion

The study was conducted with the idea to reveal how the 6E learning model, an instructional method in STEAM education, affects grade 3 students' learning achievement, creativity in science, and creative ability. The research purposes were fulfilled by a quasi-experimental design of data collection. The results of the study show that the 6E learning model was effective in transferring the knowledge of science to the grade 3 students. It was also beneficial in developing participants' creative thinking and ability. The contribution of the current study to the research area is how it proves the benefits of STEAM education in a class with students of early age.

The results of the study could be implicated in an educational setting as stakeholders such as instructors, administrators, and policymakers could use the 6E learning model and other instructional methods in STEAM education in young learners' science skills development. It should be marked that both behavior and ability learning outcomes could be expected.

Further studies should be conducted to test the effectiveness of the 6E learning model in various concepts of sciences. It should be noted that the design of learning management using the model should focus on both integrating subjects in the STEAM education and the learning circle in the 6E learning model. Therefore, scholars should make sure that these components are supported. In addition, employing qualitative data collection could provide a broader picture of the mode effects.

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References

Amabile, T. M. (1997). Motivating creativity in organization: On doing what you love and loving what you do. *California Management Review, 40*(1), 39-58. https://doi.org/10.2307/41165921

Andriopoulos, C. A. (2000). *Mind stretching: A grounded theory for enhancing organizational creativity* (Unpublished PhD thesis, University of Strathclyde).

Burke, B., N. (2014). The ITEEA 6E learning byDeSIGN™ Model. *Technology and Engineering Teacher, 73*, 14-19.

Bybee, R. W. (2009). *The BSCS 5E instructional model and 21st-century skills.* Colorado Springs, CO: BSCS.

Carter, C. E., Barnett, H., Burns, K., Cohen, N., Durall, E., Lordick, D., … Ussher, S. (2021). Defining STEAM approaches for higher education. *European Journal of STEM Education, 6*(1), 13. https://doi.org/10.20897/ejsteme/11354

Chung, C.-C., Lin, C.-L., & Lou, S.-J. (2018). Analysis of the learning effectiveness of the steam-6E special course—A case study about the creative design of IOT assistant devices for the elderly. *Sustainability, 10*(9), 1-16. https://doi.org/10.3390/su10093040

Cobern, W. W. (2015). The lifelong learning of science. *International Journal on Lifelong Education and Leadership, 1*(1), 1-10. https://doi.org/10.25233/ijlel/2015-v1i1p1

Craft, A. (2003). Creative Thinking in the early years of education. *Early Years, 23*(2), 143-154. https://doi.org/10.1080/09575140303105

Duban, N., Aydoğdu, B., & Kolsuz, S. (2018). STEAM implementations for elementary school students in Turkey. *Journal of STEM Arts, Craft, and Constructions, 3*(2), 41-58.

Holbrook, J. (2010). Education through science as motivational innovation for science education for all. *Science Education International, 21*(2), 80-91.

Hsiao, H. S., Chen, J. C., Lin, Y. W., & Tsai, H. W. (2019). *Using a 6E model approach to improve students learning motivation and performance about computational thinking* (pp. 122-127). Proceedings of International Conference on Computational Thinking Education, CTE 2019, The Education University of Hong Kong. Retrieved from https://scholar.lib.ntnu.edu.tw/en/publications/using-a-6e-model-approach-to-improve-students-learning-motivation-2

Jonassen, D. H. (2007). *Learning to solve complex scientific problems*. Routledge.

Lin, C., & Chiang, J. K. (2019). Using 6E model in steam teaching activities to improve university students' learning satisfaction: A case of development seniors IOT smart cane creative design. *Journal of Internet Technology, 20*(7), 2109-2116.

Lin, K.-Y., Hsiao, H.-S., Williams, P. J., & Chen, Y.-H. (2020). Effects of 6E-oriented STEM practical activities in cultivating middle school students' attitudes toward technology and technological inquiry ability. *Research in Science & Technological Education, 38*(1), 1-18. https://doi.org/10.1080/02635143.2018.1561432

Perignat, E., & Katz-Buonincontro, J. (2019). STEAM in practice and research: An integrative literature review. *Thinking Skills and Creativity, 31*, 31-43. https://doi.org/ 10.1016/j.tsc.2018.10.002

Schoenberger, E. (1998). Science and everyday life. *Environment and Planning A: Economy and Space, 30*(4), 575-576. https://doi.org/10.1068/a300571b

Sumpter, J. P. (2019). What makes a good scientist? Karl Fent as an example. *Journal of Hazardous Materials, 376*, 233-238. https://doi.org/10.1016/j.jhazmat.2019.05.016

Wu, C. (2019). The design of 6E model for STEAM game development. *International Journal of e-Education, e-Business, e-Management and e-Learning, 9*(3), 212-219. https://doi.org/ 10.17706/ijeeee.2019.9.3.212-219

Zimmerman, C. (2007). The development of scientific thinking skills in elementary and middle school. *Developmental Review, 27*(2), 172-223. https://doi.org/10.1016/j.dr.2006. 12.001