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The Development of Science Learning Achievement and Analytical Thinking of Grade 7 Students Using 5E Inquiry-Based Learning Cooperated with Graphic Organizers

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Abstract

The purposes of the study were to investigate the effectiveness of the 5E inquiry-based technique integrated with graphic organizers on grade 7 students' science learning achievement and to investigate the effectiveness of the 5E inquiry-based technique integrated with graphic organizers on grade 7 students' science analytical thinking. 36 Thai 7th-graders were selected as the participants of the study using purposive random sampling. The instruments were a learning management plan designed using the 5E learning technique integrated with graphic organizers, a pre-post-test for students' learning achievement of Heat and Energy, and a pre-post-test for students' analytical thinking. The statistics used in data analysis were mean scores, standard deviation, and a paired samples t-test. The results of the

study could imply positive effects of the integration of the 5E inquiry-based technique and graphic organizers on both students' qualities.

Keywords: Science education, 5E, Graphic organizers

1. Introduction

The knowledge of science is essential for a country's development as it leads to advances in technology that are crucial for the competition in the 21st century world. This is connected to the importance of science education which plays a great role in both developing learners' skills and supporting their attitudes toward science (Holbrook, 2010). With a good command of science knowledge, students could effectively learn scientific subjects such as physics, chemistry, mathematics, etc (Anderson, 2006). Moreover, they could apply scientific methods in deciding matters in their lives (Kola, 2013). This is because science encourages learners to think of the cause and effects of things. Therefore, it is not a surprise that the knowledge of science become one of the key indicators of the quality of education management.

In learning science, learners need systematic thinking to apply the scientific methods in solving problems (Mccomas et al., 1998). In this case, they need analytical thinking ability to figure out the nature of the problems, methods that match the problems, and possible solutions to the problems. According to Perdana et al. (2019), the ability is associated with science process skills, and learners need to develop a series of mental processes to develop analytical thinking. It involves inquiry and circumstances with fewer well-defined criteria and consequences that allow students to solve problems more effectively. Robbins (2011) urges that analytical thinking is a part of the problem-solving process, which is vital for preparing children for 21st century life and work. Moreover, integrating science education with analytical thinking would improve students' learning achievements such as process skills, content knowledge, problem-solving, and learning outcomes (Santos, 2017). The ability has been considered a key outcome of science education along with other high-order thinking (*e.g.*, creative thinking, critical thinking).

Grade 7 is a crucial time in education as learners entered a high school learning environment for the first time. They need to adapt to a new learning environment where they are treated differently from a primary school level. Science learning achievement and analytical thinking are important for learners at the age of preadolescence. With decent knowledge and a positive attitude toward science learning, teenage learners would develop related skills in education that could shape their future careers (Afari, 2015). According to Harper (2018), the brain's development during adolescence is crucial for adulthood. Middle and high school students need problem-solving, analytical thinking, and other higher-order thinking abilities to apply later in life. Education administrators must guarantee that learning opportunities meet teenagers' rising cognitive capacity and provide additional resources and services to assist learning and growth.

However, both qualities are not simply developed especially in developing countries where advance in technology becomes their disadvantage. At a contextual level, Thailand has an unexpected outcome in science education in terms of both learning achievement and science

development in the country (Faikhamta et al., 2018). The recent Ordinary National Educational Test (O-Net) results show that Thai students' average science grade 12 score was 37.78 percent of the maximum score (National Institution of Education Testing Service, 2019). The average PISA 2018 science score was 82 (S.D. = 426), which is level 2 out of 6. The country rated 54th out of 78 that year (The OECD Programme for International Student Assessment, 2018). In terms of analytical thinking, Khansuk et al. (2020) suggested that Thai students lack analytical skills in processing data at a level that they could utilize in learning science. This affects their thinking processes and results in problems in science classes.

Therefore, solutions should be presented to fix problems in science education in the country. However, one must take the nature of science learning and analytical thinking development into the consideration in the process of choosing an instructional method that could most benefit their learners. Driver et al. (1996) argued for the nature of science (NOS) in science education. The authors outlined the intrinsic benefit of NOS for dealing with science-related challenges and discussions in everyday life and claimed it would help successful science learning. Schulz (2014) contends that science education should also teach knowledge, truth, and justification. Matthews (1994), indicates that the purpose of science education is not the expectation to develop prominent scientists. Instead, of communicating scientific material, we should establish scientific thinking processes in learners which should help they may understand science better. Moreover, their epistemological consciousness would be developed throughout their lifetimes. It could be concluded that teaching a scientific concept needs the teaching method that could help learners acquire the knowledge as well as develop their scientific mentality that could lead to comprehension of the scientific nature of the matters.

Moreover, it should be noted that analytical thinking is a complicated process and instructors need to consider elements to establish it in their class. Sternberg (2006) suggested 4 processes including taking apart an issue and understanding its elements, explaining how a system works: why something happens, or problem-solving steps, comparing two or more elements, and criticizing features of the matter. Likewise, the ability assists learners to scrutinize and detangle facts and concepts through strengths and weaknesses (Chonkaew et al., 2016). Moreover, Art-in (2017) utilized Bloom's taxonomy of learning and presented 3 types of analytical thinking including analysis of elements, analysis of relationships, and analysis of organizational principles.

The author further explains that the analysis of elements refers to the ability to discern reasons, differentiate between individual and collective behavior mechanisms, and separate a conclusion from supporting information. Meanwhile, analysis of relationships refers to the ability to recognize, identify, and differentiate the relationship between the elements such as facts and assumptions, cause-and-effect of other sequential relationships, statements, the relevance of statements, logical fallacies, and causal relations, and the details from the historical account. Lastly, analysis of organizational principles involves the ability to analyze the relation of the materials that contribute to the elements and organization of an artwork, recognize the meaning that form and pattern in literacy or artistic works represent, and make a connection between examples and the concept of science, philosophy, history, and identify the persuasive techniques used in advertising, propaganda, and detect speakers' bias point of

view on historical events.

It could be seen that both science learning achievement and analytical thinking need an instructional method that encourages learners to construct the knowledge of science concepts and develop the process of thinking. The 5E inquiring technique was introduced to be a solution in science-related subjects. It allows learners to use their background knowledge of the concept in learning collaboratively and automatedly. Bybee (2009) claimed that the technique lets students build their knowledge of class concepts from what they've learned or experienced. Teachers facilitate the learning circle and evaluate students' development. 5Es in the technique refers to the learning circle of engaging, exploring, explaining, elaborating, and evaluating. The conceptual framework of the teaching model can be seen below.

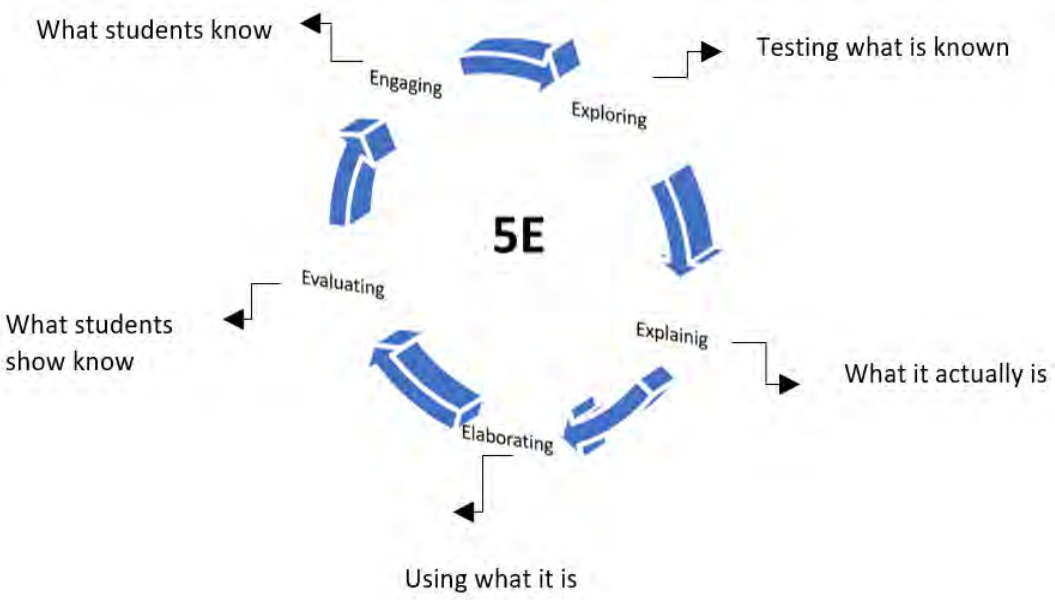

Figure 1. 5E inquiring approach learning circle

In the engaging stage, teachers apply techniques to draw students' attention to the concept being taught in the class. Questions can be asked to assess students' background knowledge of the concept. This is to let the students construct the knowledge from what they know.

In the exploring stage, students are encouraged to test what they know about the concept. They might be asked to watch the examples or do experiments related to the class concept. In this process, students are expected to make a connection between their prior knowledge and the results of the empirical evidence related to the concept.

In the explanation stage, teachers could give a lecture to explain the principle of the science concepts. This involves the explanation for the phenomena happening in the experiments, comparison between the experiment results and class prior knowledge, exemplification of related scientific phenomena, etc.

In the elaborating stage, learners are assigned to use what is learned in real practice. A project or presentation should be assigned to let students ensure the process of learning. This would encourage collaboration among class members.

In the last learning circle of evaluation, students' knowledge, skill, and ability are assessed.

Consequently, the model is dependent on the logical reasoning and critical thinking of the students. The 5E model is a template for pedagogical activities that are designed to increase student participation. A constructivist method is used in the model design. This approach is used to examine students' abilities and knowledge, as well as to raise students' concerns and assist them to develop lesson-related potential.

In addition, the use of graphic organizers should also help students to analyze scientific concepts more systematically. A graphic organizer helps students organize and interpret new information. Cognitive instructional advance organizers increase learning and retention. To explain, linking old knowledge to new one is crucial. The technique helps students) realize the content they're learning is not completely new and provide concept-based teaching explanations. Graphic organizers are different from a simple summary, review of the previous lesson, description of the current topic, and lesson objectives that emphasize essential themes. It shows the concept of organization and relationships visually. Graphic organizers can be utilized in every lesson process with diverse purposes, while advance organizers are used at the beginning. They can be utilized during a lesson or subsequently for review. Graphic organizers assist students to organize their information and encourage active participation in discussions. Therefore, visual organizers can help students understand complex expository texts (Gil-Garcia & Joaquin, 2003).

In addition, studies have been conducted to show the association between the use of the 5E teaching model and the improvement of science learning achievement (Choowong & Worapun, 2021; Sen & Oskay, 2017; Thangjai & Worapun, 2022) and analytical thinking (*e.g.*, Miarti et al., 2021; Ramadani et al., 2021; Suckoo & Ishizaka, 2021). In contrast, the use of graphic organizers in science education research is limited. Ayverdi et al. (2014) suggested that graphic organizer techniques such as semantic future analysis, pyramid, flow diagram, comparison contrast matrix, spider web, mind map, etc. can be applied in science and technology classes. However, considering its benefits in helping learners make a connection between prior and constructed knowledge, the graphic organizer technique could be integrated into the 5E teaching model. Therefore, the integration of the methods could be an alternative solution for science education in Thailand. The current study employed the 5E inquiry-based technique integrated with graphic organizers to develop science learning achievement and analytical thinking of grade 7 students. The purposes of the study were to investigate the effectiveness of the 5E inquiry-based technique integrated with graphic organizers on grade 7 students' science learning achievement and to investigate the effectiveness of the 5E inquiry-based technique integrated with graphic organizers on grade 7 students' science analytical thinking.

2. Methodology

2.1 Research Design

The study was conducted in a quasi-experimental design. Therefore, only one group participated. The participants' learning achievement and analytical thinking were evaluated using the comparison of their pre and post-test scores. Independent variable: the learning management plan designed using 5E learning integrated with the graphic organizer. As the integration of the two methods is rarely evidenced, a null hypothesis was selected to investigate the results of the study.

2.2 Participants

36 Thai 7th-graders were selected as the participants of the study using purposive random sampling was used. The criteria were data gathering convenience, student scientific performance, and science education experience. A Thai public school hosted the participants. They took 12 scientific classes as required by the core curriculum (Ministry of Education, 2008) before the time of data collection. Participants learned from one of the writers. Human subjects were treated ethically.

2.3 Research Instruments

2.3.1 Learning Management Plan

The plan was designed using the 5E learning technique integrated with the graphic organizer. The class concept was Heat and Energy. The learning management plan consisted of 8 lesson plans and required 12 class hours to complete. The learning processes in each lesson plan were managed along with the 5 learning circles of the 5E inquiring-based technique with the integration of the graphic organizer. 5 experts of 3 scholars and 2 professional teachers were assigned to evaluate the learning management plan. The evaluation indicates a very high level of appropriateness of the plan ($\bar{x} = 4.53$).

The detail of each circle is presented below.

Table 1. Learning process in the learning management plan

Learning circle	Learning activities—Topic: Heat and Energy
Engagement	- Teachers used the leading questions on the concepts of Heat and Energy. - Students were separated into groups.
Exploration	- Teachers gave a lecture and used learning material. - Students were assigned to do an experiment related to Heat and Energy. - Students observed the experiment and made a report.
Explanation	- Students create a graphic organizer to summarize what they learn and present to the class. - Teachers gave feedback and asked questions to ensure learners' learning.
Elaboration	- Teachers asked more questions related to the experiment to encourage further discussion.
Evaluation	- Students did class exercises.

2.3.2 Learning Achievement Test

A pre-post-test for students' learning achievement of Heat and Energy was designed in a four-multiple choice. 20 items accounted for 20 maximum points for both pre and post-tests. The 5 experts were also assigned to evaluate the test and the index of item objective congruence (IOC) was 0.6-1.0.

2.3.3 Analytical Thinking Test

The test was a pre-post-test. It consisted of 15 four-multiple choice question items. The maximum point was 15 for both pre and post-tests. The 5 experts were also assigned to evaluate the test and the index of item objective congruence (IOC) was 0.6-1.0.

2.4 Data Analysis

The study was conducted with a quantitative approach. The results of the study rely on the comparison between pre and post-test scores. The statistics used in data analysis were mean scores, standard deviation, and a paired samples t-test.

3. Results

Table 2. The comparison between students' learning achievements before and after the learning management

N		Pre-test	Post-test	t	p
36	$\bar{x}$	10.15	11.92	-2.552	0.015*
36	S.D.	3.13	2.99		

Note. * p > .05.

The results of the study indicate the potential of the learning management plan in the participants' learning achievement of the heat and energy concept. The results rejected a null hypothesis as a paired-samples t-test indicate a significant difference between participants' average scores on the pre-test ($\bar{x}$ = 10.15, S.D. = 3.13) and post-test ($\bar{x}$ = 11.92, S.D. = 2.99), t = -2.552, p = 0.015. Since the score post-test was higher than the pre-test, it could be interpreted that the 5E learning inquiring-based technique with the integration of graphic organizers positively affected participants' performance in learning the concept of Heat and Energy.

Table 3. The Comparison between students' analytical thinking before and after the learning management

N		Pre-test	Post-test	t	p
36	$\bar{x}$	7.77	9.05	-2.485	0.018*
36	S.D.	2.40	2.59		

Note. * p > .05.

The results of the study also indicate the capability to develop participants' analytical thinking of the learning management plan. The results rejected a null hypothesis as a paired-samples t-test indicate a significant difference between participants' average scores on the pre-test ($\bar{x}$ = 7.77, S.D. = 2.40) and post-test ($\bar{x}$ = 9.05, S.D. = 2.52), t = -2.485, p = 0.018. Since the score post-test was higher than the pre-test, it could be interpreted that the 5E learning inquiring-based technique with the integration of graphic organizers positively affected the development of participants' analytical thinking. The results of the study are discussed further.

4. Discussions

The results show that the participant statistically improve both learning achievement and analytical thinking after learning in a course instructed with the integration of the 5E learning inquiring-based technique and graphic organizers. The results of the study add more empirical evidence to support the previous investigation on the effectiveness of the method on science education (*e.g.*, Choowong & Worapun, 2021; Sen & Oskay, 2017; Thangjai & Worapun, 2022). This could imply the benefits of the 5E learning inquiring-based technique as a constructivist teaching method that could encourage learners to use prior knowledge or life experience to learn science concepts (Bybee, 2009). Moreover, the graphic organizers help them practice connecting the elements of science to learn the concept of Heat and Energy. Further studies are encouraged to use the integration of the teaching method in teaching other concepts of science.

Moreover, the results of the study also provide empirical evidence to support the previous investigation on the effects of the 5E learning inquiring-based technique and graphic organizers on analytical thinking development (*e.g.*, Miarti et al., 2021; Ramadani et al., 2021; Suckoo & Ishizaka, 2021). According to Bybee (2009), the 5E teaching technique is also beneficial in developing learners' thinking processes. Passing through the learning circle of engaging, exploring, explaining, elaborating, and evaluating, students are exposed to the science concept with the demand to differentiate input, connect elements, and summarize the ideas. This is related to the concept of analytical thinking described in Art-in (2017) as analysis of elements, analysis of relationships, and analysis of organizational principles. Moreover, the participants need to practice using their analytical thinking skills to draw a graphic organizer. Therefore, they could develop their abilities as shown in the results of the study. The direction for further investigation is to study the effects of the methods on each element of analytical thinking.

However, it has to be accepted that learning management was only statistically effective in developing both qualities of participants' performance. However, the average score of the participants on learning achievement and analytical thinking cover only 59.60 % for the former and 60.33 % for the latter of the maximum points. This number is not desirable for teaching in practice. This could be explained in both teaching and learning aspects. In terms of teaching, the process of the 5E learning inquiring-based technique relies on the process of the explanation stage. Teachers might need to improve their instructional techniques to make learners understand the content. Students need prior knowledge to learn effectively in the methods. Limited knowledge of science and world experience might obstruct the process of the 5E technique.

5. Conclusion

The study was conducted to integrate the teaching technique of 5E inquiry-based teaching and graphic organizers to design a learning management plan and implement it to develop 7-graders' science learning achievement and analytical thinking ability. It could be claimed that the learning management statistically improved both qualities of the investigation. The results of the study could be implicated in pedagogical settings as teachers could integrate the

two techniques and use them to teach content and develop students' thinking processes. However, teachers should be aware of learners' background knowledge and their techniques in giving lectures. Otherwise, the learning outcomes might not be as expected. For academic implications, the 5E inquiry-based teaching and graphic organizers could be used in an investigation regarding other science concepts and high-order thinking such as analytical thinking, critical thinking, and creative thinking. Further studies are encouraged to look closer into the elements of analytical thinking.

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