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Applying the 5E Model in Teaching to Enhance Students' Science Competence

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Abstract
This research aims to guide teachers in designing and conducting science lessons for junior high school students. The 5E model was revised to create a five-step teaching procedure suitable to natural science characteristics. The lesson plans contain learning activities and assessment tools to measure students' learning outcomes based on science competence criteria that students need to develop. A sample project of the Sixth Grade curriculum was planned and conducted in three classes with more than one hundred students. The qualitative (interview) and quantitative data (marks) collected after the experiments showed the interest and concentration of students in the lessons. Moreover, the data also proved the reliability and validity of assessment tools used in each 5E activity to assess students' science competence. The results indicated the effectiveness of the 5E model in helping students practice and nurture competence in teaching natural science.

Keywords: 5E model, Natural Science 6, science competence, teaching plan.

1. Introduction
Science education is one of the most important subjects that enhances students' thinking about phenomena with scientific methods (Astuti & Hayati, 2019). The 2021−2022 school year was the first time the natural science subject was taught for Grade 6 students in Vietnam, replacing three separate subjects, chemistry, physics, and biology. This integrated discipline was expected to help students to develop science competence that involves science perception, inquiry skills, and abilities to solve problems in life based on scientific knowledge (Vietnam. Ministry of Education and Training [MoET], 2018). With the new requirements, teachers needed to cover many aspects, such as lesson design and delivery, learning-environment management, level of students' engagement with meaningful content, the quality of assessments, and student data collection and analysis (Marble, 2007). Curriculum, pedagogy, and assessment are three elements that impact the quality of any teaching situation (Osborne, 2007). In particular, designing a lesson plan is one of the critical steps that impacts the subsequent activities.

Among many teaching methods, inquiry methods have been proven to effectively teach science subjects such as physics and chemistry (Hussain et al., 2011; Khan et al., 2011). These methods have been used globally since the 1960s, with positive effects on learners, such as evoking positive emotions when learners are active in the learning process, developing communication science skills, and improving problem-solving (Deters, 2005). This research study compared scientific inquiry and traditional lecture teaching methods. Hussain et al. (2011) researched the difference among three inquiry levels (guided scientific inquiry, unguided scientific inquiry, and a combination) on students' performance and proficiency in applying physics knowledge to real-life problems. The results showed that all three kinds of scientific inquiry positively impact student achievements more than the traditional physics teaching methods. Moreover, guided teaching yielded better results than unguided. Other research has also promoted guided inquiry methods (Maknun, 2020; Nivalainen et al., 2013).

Inquiry is a teaching approach through experience with activities such as asking questions, generating ideas, and observing. Teachers play a vital role in creating environments where students' ideas are always respected, tested, and improved so that they would address their intellectual concerns and approach knowledge naturally (Scardamalia, 2002). Wu and Hsieh (2006) conducted experimental research on sixth graders to determine the impact of scientific discoveries on students' discovery skills. Scientific discovery results in the cycle of inquiry, including asking questions, designing and conducting investigations, analyzing the data and drawing conclusions, creating artifacts, and sharing the findings. When participating in these discovery activities, learners have meaningful development in describing, reading data, and evaluating skills. Besides, there are many inquiry processes and models, such as TELSTAR, action research, design thinking, 5E's, and Kath Murdoch's Inquiry Approach. The 5E model is highlighted as the best method to conduct inquiry teaching in science (Duran & Duran, 2004). This model consists of five cognitive stages: engage, explore, explain, elaborate, and evaluate.

In this research, we chose the 5E model, adapted a revised model to design a sample lesson, and conducted and determined the appropriateness of this model in teaching natural science to sixth graders in Vietnam. This research aimed to answer these two research questions:

1. How is the 5E model used in teaching natural science topics to measure students' science competence?
2. What are the outcomes of students after attending one project using the 5E model?

2. Theoretical framework

2.1. The 5E model

The 5E model was created based on constructivism theory, where learners learn through experience. Compared to traditional teaching models, the 5E learning model shows advantages in developing better scientific skills for learners (Bybee et al., 2006). The 5E model consists of five stages of the teaching process (Figure 1).

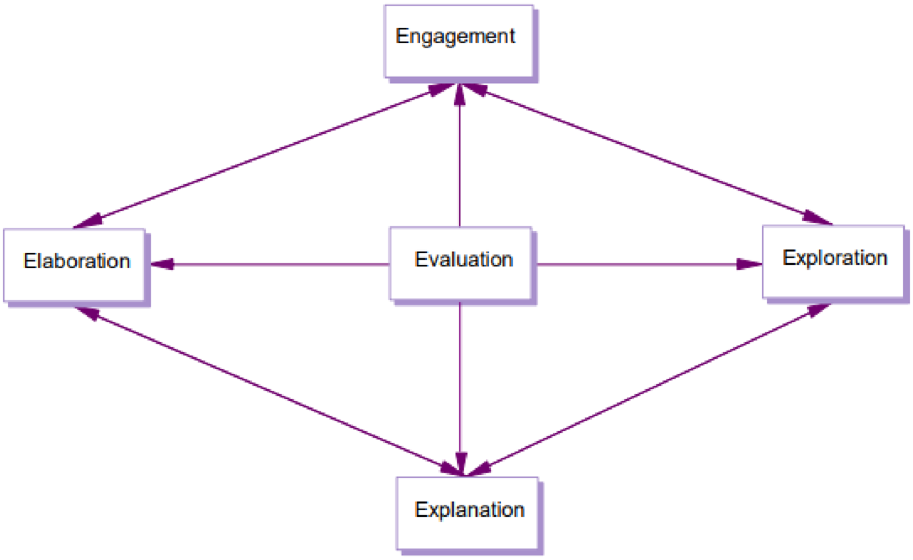


Figure 1. The 5E model (Duran & Duran, 2004)

The five steps of the 5E model are further described in Table 1 (Bybee et al., 2006).

Table 1. The 5E model (Bybee et al., 2006)

Activity	Description
E1 – Engage	Students are introduced to the new concept. Students actively connect with previous knowledge and what will be learned. Students are more proactive in predicting the results based on teachers' questions using the KWL strategy.
E2 – Explore	Teachers give students complicated tasks. Students participate in the exploring or experimenting process by observing, using scientific tools, and collecting and recording the data.
E3 – Explain	Teachers ask oriented questions. Students share their understanding in each stage of exploring and describe the observed results. Students can share in groups or with the whole class.
E4 – Elaboration	Teachers provide a chance to help students expand the knowledge learned and point to the link of knowledge related to other knowledge or problems in life.
E5 – Evaluation	Students respond or give questions to others, expressing knowledge and skills to help students or their classmates assess them.

2.2. Science competence

Science competence is one of the core goals of science subjects in the Vietnamese General Curriculum. It contains three components: science awareness, inquiry skills, and solving problems scientifically. While science awareness asks students to deeply understand the concepts and phenomena, inquiry skills allows students to research, measure, and test to find answer to their inquiry. The third component combines knowledge and scientific inquiry to solve problems in practice. Therefore, science teaching methods must also design experiments or inquiry activities to help students nurture these skills.

2.3. Adapted 5E model to apply to teaching natural science topics

Science is an experimental subject associated with everyday life. As such, these characteristics also make the differences of the 5E model in natural science that emphasize the role of experiments and problem-solving in life. From the above characteristics, the study proposes five steps of the adapted 5E model (Figure 2).

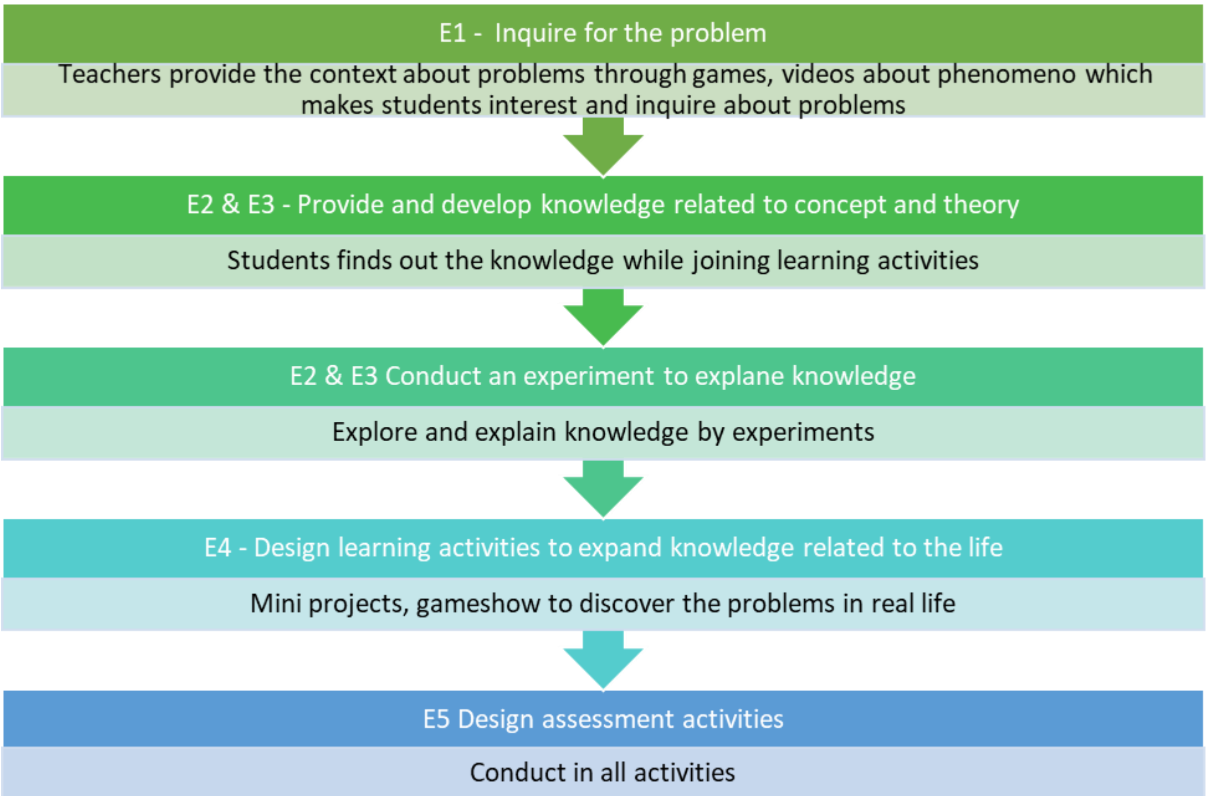


Figure 2. The 5E model for the science lesson (Author proposed)

To effectively apply the 5E model in teaching science at junior high school, teachers need to take note of the following. First, these activities need to cover the six levels of Bloom's Taxonomy. Bloom's Taxonomy is a widely used scale used to measure learners' levels of awareness. Phases of the model should be deployed so that the prior activities provide knowledge to conduct higher level missions. Table 2 offers an example of the appropriate level of awareness for the model phases.

Table 2. The appropriate level of awareness for the model phases

	Remembering	**Understanding**	**Applying**	**Analyzing**	**Evaluating**	**Creating**
Basic						
Activity 1 E1						
Activity 2 E2 & E3						
Activity 3 E2 & E3						
Advanced						
Activity 4 E4						
E5 – Evaluation						

Second, teachers should note that although they come in at the end of the process, the assessment activities should be carried out in all the teaching activities to stick to the objectives and evaluation criteria.

Third, based on the conditions, teachers can use virtual experiments instead, especially in Covid-19 times. With the support of technology, teachers should use various and effective educational websites to simulate and design virtual experiments and natural phenomena.

Using this model, the paper proposes a lesson plan used to teach a mixture of topics in the Sixth Grade science curriculum.

2.4. Designing lesson plans for the project: "How to classify mixtures and separate the mixture"

Main topic

Mixture; method of separation of substances: extraction, filtration, distillation.

General objectives

After studying the lessons, learners can distinguish two types of mixture: homogeneous mixture and heterogeneous mixture. Based on the physical properties of substances and the characteristics of the mixture, learners can effectively use tools and methods to separate the substance from the mixture in practical situations.
Objectives: Science competence – criteria built based on research about science competence (Le et al., 2020).

Science awareness

TC 1.1. Present the basic scientific knowledge: mixtures, homogeneous mixtures, heterogeneous mixtures, and separation method of substances.
TC 1.2. Explain the connection between the physical properties of some common substances and the method of separating them from the mixture. Make diagrams of how these methods are performed.

TC 1.3. Apply knowledge of separation methods to analyze and handle some familiar situations.
TC 1.4. Analyze and synthesize the knowledge of separation methods in all contexts.

Inquiry skills
TC 2.1. Ask questions, plan the selection of methods and tools for separating substances, and design appropriate implementation plans (converting saltwater into freshwater, cleaning the oil-contaminated water and dirt).
TC 2.2. Implement the proposed plans to use learned substance separation methods effectively.
TC 2.3. Present and analyze the results of implementation: water quality after treatment.
TC 2.4. Discuss scientific results and make conclusions on principles, methods, and appropriate ways of implementation in each case.

Solving the problems scientifically
TC 3.1. Select the suitable tools and methods of substance separation between the physical properties of substances and the purpose of use in practice.
TC 3.2. Propose some new methods to separate the mixture.
TC 3.3. Make use of the waste after the separation process, draw a diagram of reuse substance treatment of the waste from separation.

Design activities
Table 3. Lesson plan

	General process	Self-assessment/ observation form	Student task form	Presentation/ group review
Lesson 1	Act. 1. Introduction to mixtures and types of mixtures (E1)	TC 1.1, TC 1.2	TC 1.1	
	Act. 2. Practice making hand sanitizer (E2, E3)	TC 2.1, TC 2.2, TC 2.3		TC 2.4
	Act. 3. Experiment to discover two kinds of mixtures (E3, E4)	TC 2.3, TC 2.4, TC 1.3, TC 1.4	TC 1.2	
	Act. 4 and 5. Find the mixture around us (E4)	TC 3.1		
Lesson 2	Act. 1. Introduction of some basic substance separation methods and practical application (E1)	TC 1.3, TC 1.4	TC 1.3, TC 1.4	
	Act. 2 and 3. Watch experiment videos	TC 2.1, TC 2.2 TC 2.3, TC 2.4	TC 2.1, TC 2.2	TC 2.4

	General process	Self-assessment/ observation form	Student task form	Presentation/ group review
	dealing with a number of situations in practice related to the separation of substances (E2, E3)		TC 2.3, TC 2.4	
	Act. 4 and 5. Diagramming of the processing process and the results after the separation of substances (E3, E4)	TC 3.1, TC 3.3	TC 3.1, TC 3.3	

Lesson 1

Act. 1. Engage (E1)

The students become acquainted with the mixture before the experiment. The teacher asks them to observe three cups respectively containing water, sand, and sugar on the table. They have to predict what would happen after pouring water into the three cups.

Act. 2. The students have to conduct activities to study the characteristics of homogeneous and heterogeneous mixtures (E2).

Methods: experiments

The teacher asks the students to carefully observe the cups containing the three mixtures and to answer the following question: Fill out the suitable answer in the blank spaces to describe the characteristics of the mixtures.

	Water + sand mixture	**Water + salt mixture**	**Water + oil mixture**	**Water + wine mixture**
Initial substance state	Liquid + solid	Liquid + solid	Liquid + liquid	Liquid
Post-mixing state	Liquid	Liquid + solid	Layered liquid	Liquid + solid
The original substance can be observed (Yes/No)	Yes	No	Yes	No
Homogeneous or heterogeneous mixture	Heterogeneous	Homogeneous	Heterogeneous	Homogeneous

Act. 3. Practice creating a homogeneous and heterogeneous solution (E3).
Methods: experiments, work in four groups. Mission: prepare hand sanitizer in a heterogeneous and homogeneous solution.

1. The teacher divides the class into four groups and conducts experiments to prepare hand sanitizer in a heterogeneous and homogeneous solution from the given ingredients: alcohol, carbomer, antiseptic seeds, and glycerin. Groups 1 and 2 make a homogeneous mixed hand sanitizer; groups 3 and 4 make a heterogeneous mixture.
2. The groups choose their materials and test the raw materials to meet the requirements.
3. Representatives of each group introduce the products and present how to choose and implement it.

Act. 4. Determine the properties of substances present in practical phenomena (E4 & E5).
Methods: experience, problem-solving

1. Ask students to imagine being in the family kitchen and make a list of homogeneous and heterogeneous mixtures created from ingredients in the kitchen. (Teachers can provide slides of basic materials.)
2. Students work in a group to discuss their work.
3. Ask the presenters of each group to present the results and talk to their classmates.

Homework: Testing classroom predictions by mixing at home under parental supervision. Some guidelines are provided, such as making the sauces and lemonade.

Lesson 2
Act. 1. (E1) Ask students to watch a video about separating sand and water. The teacher raises the problem of how to separate two liquids.

Act. 2. (E2) Determine three separation methods.

Methods: experiments
Students perform in groups; students watch videos about the process of implementing four basic separation methods, and fill out the following table:

	Filtering sand from water	**Heating water for deposition, filtering residue**	**Fuel and water extraction**	**Oxygen-producing segment distillation of oxygen**
Substances to be separated	Sand + water	Dirt + water	Gasoline + water	Oxygen + impurities
State of two substances to be separated	Solid + liquid	Solid + liquid	Liquid + liquid	Gas + gas

Prefilter mixture (Homogeneity /non-uniformity)	Heterogeneous	Homogeneous	Heterogeneous	Homogeneous
Tools needed	Filter paper	Kettle, alcohol lamp	Pot (funnel) extract	Distiller
Implementat-ion process				
Product	Clean water and sand	Clean water and dirt	Gasoline and water separately	Oxygen and other gases

Act. 3. Practice selecting the tools and methods for separating substances (E3).

Methods and forms of teaching: experience, group

1. The students divide the class into three groups – ask them to work in groups – plan, conduct experiments with available tools, and present the results.

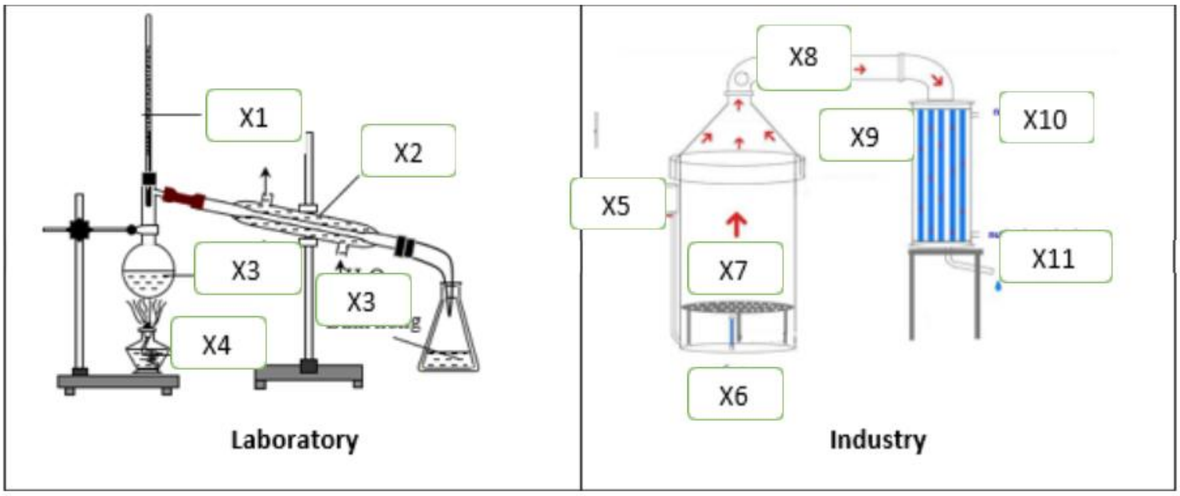
Group 1: The eastern sea is experiencing a shipwreck accident waiting for oil. The consequences are that life in the ocean is harmed. Suggest an oil treatment for the spilled seawater to save marine life in the laboratory and practice.

Group 2: People on the island in the middle of the sea often spend time and money transporting freshwater from the mainland. Do experiments and propose methods to remove salt from seawater so islanders can save money.

Group 3: Due to negligence in the repair process, a large amount of sand and gravel fell into the water tank of Minh's family. Do experiments and propose treatments so that you can purify the water and do research to present an effective water filtration system that removes many impurities.

2. Groups perform tasks.
3. Groups send representatives to introduce products and present how to choose and implement it.

Act. 4. Observe the wine distillation diagram and fill in the names of the processes that take place (E4 + E5).



Act. 5. Select an effective separation method towards sustainable development (E5).
Teaching methods: experience, problem-solving
Request students to redraw the diagram of the process of separating substances from preparation to finish; note that the waste solution must promote sustainable development.

3. Methods
The experiment method was applied to measure students' achievement and enjoyment when doing a lesson created based on the 5E model. The data collected from grading students and interviews were analyzed to address the research purposes. The participants were 107 students from 3 classes in 1 junior high school. One of the three classes followed the Cambridge program in which students study a particular science curriculum. The lesson was conducted based on the lesson plan above. The lesson plan was sent to three teachers with clear explanations and guidelines. The relevant student documents (textbook and worksheet) were sent to the participants over two weeks. The teacher asked them to read the text carefully before teaching. The assessment activities were performed during the class to collect data about participants' achievements.

4. Results
The data were gathered using three tools to assess the level of goal achievement of the participants.

- Tool reliability
Eleven objectives were divided into three groups: (1) science awareness, (2) inquiry skills, and (3) solving the problems scientifically. The reliability results are presented in Table 4.

Table 4. Reliability Results

	Number of items	Cronbach's alpha
Science awareness	4	.830
Inquiry skills	4	.935
Solving the problems scientifically	3	.736

The Cronbach alpha values confirmed the reliability of the tools used when teaching science following the 5E model. The results also showed that the 5E model can cover all the objective aspects of scientific competence, aligning with Vietnam's current competence development orientation.

- Level of excitement of participants with activities

Using observation and interview methods, we noted the focus and excitement of participants in the 5E lessons, especially with the E2 and E3 phases. In quick interviews with six participants in three classes, all participants expressed their interest in participating in the learning experience activities. They commented that "*[l]essons pass faster*"; that they "*carried out experiments to help us understand the lesson better*"; and that "*[t]he tasks in this class require us to think, explore, cooperate, which make us so inspired.*"

- Level of the participants' goal achievement

The chart below describes the level of achievement of participants' learning goals (Figure 3).

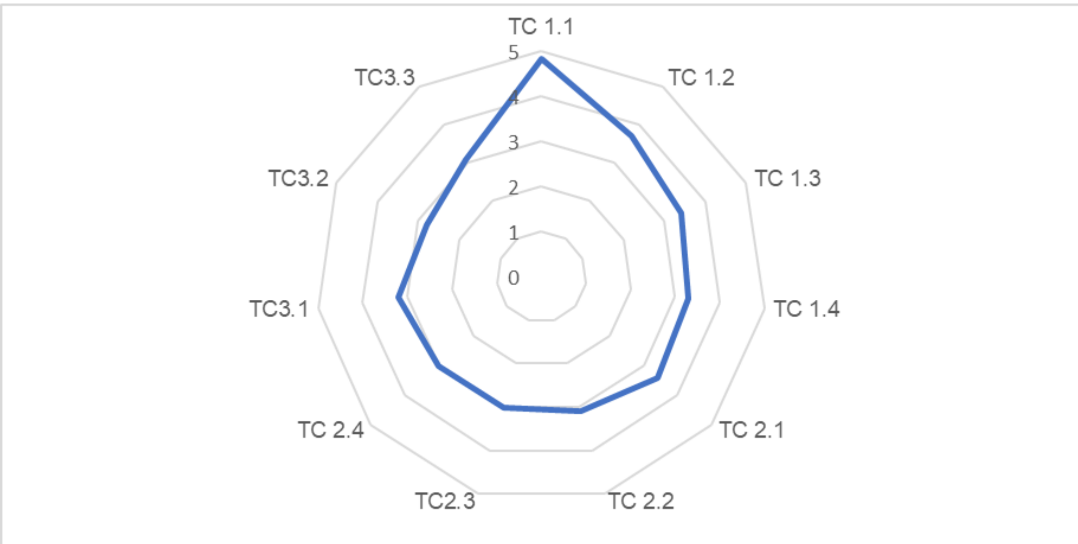


Figure 3. The level of the participants' goal achievement

The group of science awareness objectives had higher values than the other groups. This result is consistent with the current situation of teaching in schools. The interview data showed that the class that followed the Cambridge curriculum had experienced similar learning activities. Students of two classes explained that they are mainly taught science with their teacher being present, and by watching videos, and less on how to perform their tasks.

The analysis of variance (ANOVA) test results (Table 5) showed a difference in the average score of the target level between the three classes. Grade 6C2 (Cambridge) scores were higher than that of the others, with a statistically significant difference.

Table 5. ANOVA results

(I) class1	(J) class1	Mean difference	Std. error	Sig.
6A	6H		1.54583	.169
	6C2	2.14257	1.63684	.000
6H	6A	-14.49167	1.54583	.169
	6C2	-2.14257	1.66504	.000
6C2	6A	-16.63423	1.63684	.000
	6H	14.49167	1.66504	.000

However, the correlation results between the knowledge test score and the level of proficiency score showed a strong positive link between the two factors (Table 6). This result highlights the role of providing knowledge in competence development teaching.

Table 6. Correlation between participants' grades and science achievement

			Grade	Achievement
Grade	Pearson correlation		1	.500**
	Sig. (2-tailed)			.000
	N		49	49
Achievement	Pearson correlation		.500**	1
	Sig. (2-tailed)		.000	
	N		49	109
	** Correlation is significant at the .01 level (2-tailed)			

4. Discussion and Conclusions

Vietnam has been implementing the fundamental change in education from a content to a competence orientation. However, the change requires much effort from teachers to prepare and do research about new and suitable methods (Mai & Brundrett, 2022). The results of this study can be used for recommendations that help teachers to design and implement the new curriculum. Finding a teaching method suitable for competence development is one of the requirements set for Vietnamese education. The 5E model is one of the models that has been demonstrated through numerous studies on the appropriateness of science teaching and the development of students' science inquiry skills (Akar, 2005; Kaynar et al., 2009; Zhou, 2021). The 5E model and inquiry activities as proposed have been experimented, confirming its ability to provide context for students to develop their skills. Some Vietnam education research has shown the same findings (Becker & Quang, 2017; Tran, 2013). The findings also pointed out that students studying an international program have a higher level of skills than students who study the public curriculum when doing activities. The main reasons were that they are familiar with inquiry activities.

In this study, the proposed topic also showed the relevance of the 5E model to provide an environment in which students can perform the skills of scientific competence from awareness to inquiry and problem-solving. The study also showed the interest of students in experiencing scientific inquiry activities. The tool's reliability was confirmed to illustrate the suitability of assessment activities in the 5E model with the knowledge assessment activities. A limitation of the research was the lack of detailed qualitative information about the development of students' science competence. Future studies may implement the experiments with Grade 6 students for a more extended time to determine the effects on students when participating in the 5E learning model. Qualitative methods such as observations, case studies, and in-depth interviews may be applied to explain the quantitative data intensely. Using the model steps, teachers can design their own lesson plans that are suitable for the course learning outcomes and facilities.

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