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Application of the 5E Model in Teaching Sciences in Vietnamese Secondary School under STEM Education Orientation

Do Thi Quynh Mai[1]✉, Nguyen Mau Duc[2], Pham Thi Bich Dao[3]

[1] Email: maidtq@hnue.edu.vn, Hanoi University of Education (VIETNAM)

[2] Email: nguyenmauduc@dhsptn.edu.vn, Hanoi University of Education (VIETNAM)

[3] Email: daoptb@vnies.edu.vn, The Vietnam National Institute of Educational Sciences (VIETNAM)

✉ Corresponding author

ABSTRACT: *STEM education has become an educational trend of great interest in many countries worldwide, and Vietnam is no exception. Based on the research of STEM education operating process, the 5E model, and the analysis of Science subjects curriculum at secondary school, the paper proposes the principle of designing contents for teaching and learning activities using the model 5E under the STEM education orientation, and designing and organizing teaching activities in teaching Science subjects in secondary school. The paper also gives an illustrative topic of applying knowledge to create a "Simple rocket" after learning basic theory in the "Acetic acid" lesson - 9th grade Chemistry. Research methodology was carried out on 80 students in grade 9 of experimental and control classes at 2 secondary schools in Nha Trang and Thai Nguyen province. Through the implementation of these activities, students acquire knowledge of a number of STEM subjects, apply them to solve practical problems, and enhance their interest in learning science subjects, contributing to the formation and development of what competencies necessary to meet the requirements of reforming general education in Vietnam.*

KEYWORDS: **5E model, secondary school, STEM education, sciences teaching.**

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1. Introduction

In many countries worldwide, the implementation of STEM education has greatly developed. STEM education originated in the United States nearly two decades ago. This is considered as a breakthrough of the United States education. So far, many countries have pursued STEM education programs because of their righteous and indispensable direction in the context of economic competition among countries around the world (Xie et al., 2015; Bybee, 2013).

STEM oriented educationis well suited to the educational innovation requirement in Vietnam (Le, 2017). The general education program has identified goals that need to be formed and developed for secondary school students with common core competencies for all subjects: self-reliance and self-study, communication and collaboration, problem solving and creativity, language and social and natural capacity, aesthetics, physical ability, information and communication technology use and specific competencies for each subject (MOET, 2018). Science subjects, in addition to providing students with fundamental knowledge about the transformation of substances, life, energy, and movement, demonstrate the relationship between people and the physical world, the natural world, which is closely related to connected sciences including Physics, Chemistry, Biology, Technology, and, most importantly, the reality of human life. Therefore, the combination of teaching science subjects via situations and problems in daily life not only contributes to help students develop necessary capabilities (ability to solve problems and creativity, capacity for communication and cooperation), but also stimulates interest in the subject (Xie, 2015; Siew, 2015).

The 5E Model (The 5E Model of Instruction) was developed by Rodger W. Bybee (2006) based on the SCIS model by J. Myron Atkin and Robert Karplus (1962) - a model used to improve

the Science subject's curriculum for elementary school students. The 5E model is based on a constructivist theory of learning in which students build knowledge from their experiences. Model 5E is a positive teaching method through activities of interest, stimulation, problem-making, proactive discovery, interpretation, and evaluation that helps students develop their capacity (Bybee, 2009). By understanding and reflecting on the activities that have been experienced, from both personal and social perspectives, students can combine new knowledge with previously known concepts. The 5E model has a profound impact on many other science subjects, such as Physics, Chemistry, etc... This model has also spread to many regions of the world and to many different levels of teaching (Bybee, 2009; Tezer & Cumhur, 2017).

Today, some authors are very interested in the 5E model and consider it a relatively effective teaching method for STEM education. In Vietnam, some authors have studied the 5E model, such as Le Xuan Quang, Pham Thi Bich Dao, Vu Thi Minh Nguyet mentioned using this model in teaching science subjects (Le, 2017; Pham & Vu, 2016). However, the application of this model to the program of Sciences subjects in 2006 has not been adequately mentioned.

The paper proposes using the 5E STEM-oriented education model to teach several content in the curriculum of science subjects in order to develop students' capacity. It also illustrates the application of knowledge after learning the Carbon lesson - 9th grade chemistry and instructing students to create a "simple rocket".

2. Methodology

This section covers research model, participants of the research

2.1. Research Method

In this research, we have used the method of case study as it enables us to examine a particular group in depth and to assess the data obtained through data collection tools without being concerned about generalization.

2.2. Participants

The research team conducted a pedagogical experiment with 2 classes at in 2 different schools including 40 students in the experimental class (Grade 9A7, Nha Trang Secondary School) and 40 in the control class (Grade 9C, Trung Vuong Secondary School), in. Grade 17, Nha Trang Secondary School, and 9C, Trung Vuong Secondary School, Thai Nguyen, Thai Nguyen Province. The experimental class and the control class selected students with similar qualifications.

3. Situation and problems

3.1. Concept

There are many views related to the ability to apply knowledge and skills into practice. Trinh Le Hong Phuong highlighted that "the ability to apply knowledge and skills into practice is the ability of learners to use the knowledge and skills learned in class or learned through practical experience in real life to solve the problems posed in diverse and complex situations in life effectively and with the potential to transform them. The ability to apply skills and knowledge into practice shows the quality and personality of people in the process of operation to satisfy the need to dominate knowledge" (Trinh, 2014, p.120).

In this article, we use the above definition to determine set of criteria for assessing this capacity.

Some manifestations of the capacity to apply skill knowledge into practice (MOET, 2018)

According to Curriculum in Natural Science Subject at Secondary School. (MOET 2018), Some manifestations of the capacity to apply skill knowledge into practice included:

- Discovering and explaining some applications of scientific knowledge with different issues and areas of practice.

- Discovering and explaining some practical problems related to the field of sciences.

- Applying subject knowledge and interdisciplinary knowledge to explain some natural phenomena, application of natural knowledge in life.

- Ability to analyse and synthesize knowledge in the field of sciences to critically evaluate the

effects of a practical problem.

- Innovation: Applying general knowledge to propose some new methods, measures, model designs, or problem-solving plans.

- Having appropriate behaviours in situations related to health issues of oneself, family, and community, behaving in accordance with nature with the requirements of social sustainable development and school environmental protection.

3.2. 5E model under STEM teaching orientation

There are many processes for integrating STEM. Rodger W. Bybee's 5E instructional model can be effectively used in teaching sciences subjects. The 5E is one of the most effective teaching models for science subjects in the laboratory, practice, or interactive discussion activities (Bybee et al., 2006; Ternel et al., 2013).

The 5E model consists of 05 main stages (Bybee, 2009; Tezer & Cumhur, 2017). The contents of the 05 stages can be summarized ins Figure 1.

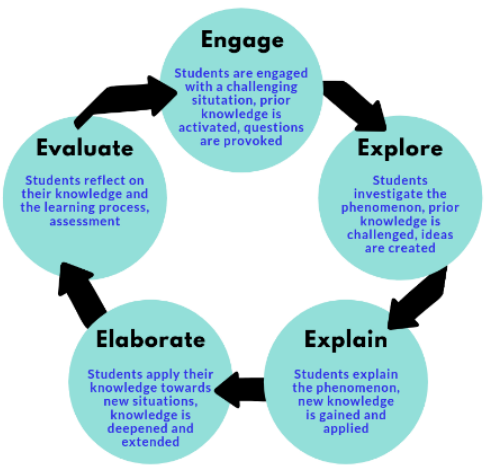

Figure 1. The 5E teaching model

Engage: In this stage, teachers need to identify the knowledge and skills that students have and draw the attention and interest of students using problems such as (ask questions, describe problems, interpret problems,...) pictures or stories in a book or through an experiential activity. Through this activity, the teacher learns the needs and concerns of students in order to stimulate learning motivation to achieve high results.

Explore: This is the main stage of the cognitive process, requiring students to actively explore new concepts through specific learning experiences or manipulations of materials or equipment. Teachers can ask students to observe, experiment, design, collect, analyse and put together relevant information to arrange, reorganise and find directions for the tasks. Group activities, experimenting, analysing pictures, situations, or giving personal opinions take place during this stage. Students must be active, positive and creative to complete their tasks.

During this stage, the teacher guides, initiates activities, and provides time and opportunities for students to proactively and voluntarily explore objects, materials, and situations related to the problem (based on the students' ideas). Teachers can guide students when proposing explanations or solutions, as well as correct any misconceptions that students may encounter during the exploration process.

The explore stage is also an opportunity for students to interact, debate,... on core activities to improve communication and adaptability with different communication styles and characteristics of other students. In addition, students need to discuss their ideas to build a common understanding for the group about the problem and propose common solutions.

Explain: The idea of this stage is that students use reasoning to explain the problems in their own way, to present and interpret the meaning of terms related to the lesson. Initially, the teacher instructs students to put together their knowledge and asks questions (if they need further clarification) and, at the same time, creates conditions for students to present, describe, or analyse the experiences and observations that have been received... Besides, teachers can introduce additional terms, concepts, and new formulas, helping students connect with their previous experience. For this stage to be effective, teachers should create conditions for students to share what they have learned before introducing more detailed information directly.

Elaborate: This stage is to create a space for students to apply what they have learned by participating in deeper experiences such as manipulating, expanding, or discussing (concepts

and skills) in more details. The expansion phase is also an opportunity to place students in new situations and issues, broadening their horizons. Students have chance to practice , review, and apply in similar situations. This helps students acquire knowledge in a deeper way, practice skills more smoothly, and apply them to different situations and contexts.

Evaluate: This is the final stage of the 5E model, but it is not a continuation of the elaborate stage but an integration stage into all of the above stages. Students self-assess their own experiences of knowledge and skills or assess those of other students. Through this stage, teachers also assess students' progress in the learning process. The evaluation is conducted through the students' presenting solutions to the initial problems. The 5E model allows for formal (in the form of tests) and informal assessments (in the form of quick questions). Informal assessments can be made at the beginning of the teaching process. A formal evaluation is carried out after the elaborate stage. This is an important opportunity for students to use their acquired skills, evaluate their understanding, and have the ability to express their solutions.

3.3. Principles of designing teaching content under STEM education orientation

When designing teaching contents in accordance with STEM education orientation to be applied in teaching secondary school science subjects, the following principles should be ensured (Pham & Vu, 2016; Trinh, 2014):

a) The content of teaching should integrate knowledge of subjects in the field of STEM education.

The content is built on the basis of the inherent and natural relationship between the goals and the content of the subject (in the field of STEM) and necessarily avoids coercion and constraints. This is considered the first principle because, without content related to STEM fields, it cannot be called STEM education.

This principle is to ensure training in STEM skills and apply integrated knowledge to solve practical problems for students. Therefore, students are well aware of the effect of theoretical knowledge on real life. On the other hand, the implementation of learning tasks is an opportunity for students to not only revise and apply old knowledge but also acquire new knowledge, gain experiences, and develop career orientation in the future.

Depending on the degree of integration between subjects, it can be divided into two forms of incomplete STEM and complete STEM. Some characteristics of these two forms are as follows:

+ Complete STEM: learners need to apply the knowledge of all four areas of STEM to solve problems.

+ Incomplete STEM: learners do not have to apply their knowledge in all four areas of STEM to solve problems.

b) STEM educational content is appropriate for students.

In the process of designing experiments as well as applying them in the teaching process, teachers need to create challenges by increasing levels of difficulty, creating contradictions in students' perceptions, and suggest the need to solve problems and challenges.

"Suitable" here means that the teacher must set the difficulties so that under guidance, by the students' own efforts or by cooperation with other students, the problem can be solved.

The suitable characteristics must also match with the age range characteristics. Each age is associated with the accumulation of cognitive and social experiences, with the dominant activity of that age. As students grow up, their intellectual needs and cognitive interests also change.

c) STEM education content must have practical significance, suitable for students' lives and experience

Teachers need to streamline academic knowledge, enhance practical knowledge, and create conditions for learners to experience and explore knowledge. Teachers themselves need to master the knowledge system in the field of STEM and its application in daily life.

To implement this principle, teachers need to:

- Select the content and basic knowledge in the field of STEM, suitable to the conditions, practical circumstances, and students' experiences.

- Ensure that learners must understand theoretical knowledge, see clearly the origin of such knowledge, and the role of scientific knowledge in practice.

3.4. Proposing some content for teaching science subjects in the context of STEM education

After analysing the content of the Sciences subjects programs: Chemistry, Physics, Technology, and Secondary Biology, applying the 5E model and STEM education orientation, teaching contents with STEM education-oriented learning are proposed as follows:

The above teaching content is applicable during one lesson or extracurricular activities and clubs requiring more engaging learning materials.

Table 1. Contents of STEM education-oriented in teaching Sciences subjects at lower secondary level

No.	Product	Related knowledge		
		Content	Field of reference	
			Lesson	Grade
1	Mini rocket	Acetic acid is more acidic than carbonic acid.	Lesson 29 (Carbonic acid and carbonate salt) Lesson 45 (Acetic acid)	Chemistry 9th grade
		Effect of concentration, surface area on the reaction rate.	Lesson 13 (Chemistry reaction)	Chemistry 8th grade
		The imbalance force exerted on the bottle stopper inside the bottle and atmospheric pressure	Lesson 5. The balance between Force - Inertia	Physic 8th grade
		The difference in pressure in a bottle with atmospheric pressure	Lesson 9. Atmospheric pressure	Physic 8th grade
		Mechanism of operation of missiles in practice	Technology	
2	mini water filters	Adsorption capacity of charcoal (C)	Lesson 27 (Carbon)	Chemistry 9th grade
		Liquid pressure affects the filtration rate and the factors that affect fluid pressure	Problem 8 (Liquid pressure - Flasks)	Physic 8th grade
		The principle of operation of the water filter	Practical knowledge	
3	conductivity measuring devices	Conductivity of metals	Lesson 25 (Physical properties of metals)	Chemistry 9th grade
		Electrical conductivity of graphite	Lesson 27 (Carbon)	Chemistry 9th grade
		Serial circuit	Lesson 4 (Serial circuit)	Physic 9th grade
		Use electrical tape	Lesson 33 (Electrical safety)	Technology 8th grade
4	Design furniture from plastic	Thermoplastics flows into a liquid under high temperatures and hardens when cooled.	Lesson 54 (Polymer)	Chemistry 9th grade
		technical drawings	Lesson 2 (Projection) Lesson 9 (Detailed drawings) Lesson 13 (Mounting drawings)	Technology 8th grade
		Plastic bottles made from PP (thermoplastic)	Practical knowledge	

4. Results and discussion

An example of teaching with the 5E model under the STEM educational orientation

The 5E Model is appropriate for teaching some content of science subjects (via experiments, practice, etc.) in the context of STEM education. This model was applied to the teaching organization of the proposed content.

Below is an example showing the steps of organizing teaching to create a "Graphite circuit" product in after-school hours - 1st semester - 9th grade Chemistry. Teachers can also guide students to self-study at home after teaching Carbon lesson - Chemistry class 9 (Le, Cao & Ngo, 2020).

ACTIVITIES TO CREATE PRODUCTS "A SIMPLE ROCKET"

Objectives of the activity: The activity helps students

- Find out about the structure, operating principles of a simple rocket.

- Analyse information, select simple and suitable materials and tools for making rockets based on the gas evolution reaction of acetic acid;

- Survey a number of factors affecting the movement, high airspeed, and far airspeed of the rocket

(i) Increase learning motivation and engagement

The teacher shows a video about the rocket launch process and asks students questions (questions to promote curiosity). Use brainstorming to get students to present as many ideas as possible. Sample questions include:

How can rockets go up?

State the properties of a chemical reaction that can be used to create rocket flight.

What factors will affect the high airspeed and far airspeed of the rocket?

This raises the problem of designing a simple rocket using a reaction involving acetic acid.

To answer these questions, students need to apply the knowledge they have learned about

Physics: understanding of rocket operating principles: (a rocket engine works by the jet principle: when the fuel burns in the combustion chamber, it creates a pressure on the combustion chamber wall balanced in all directions. In the nozzle position, the pressure is reduced, the (unbalanced) pressure on the opposite side will push the rocket forward).

Chemistry: acetic acid reacts with carbonate salts to form gas.

Engineering: Factors affecting the rocket's high airspeed and low airspeed are: pressure in the "reaction chamber,", air resistance, size and shape of the rocket, weather,…

(ii) Explore

In this section, participants are given time to think, plan, investigate, and organize collected information.

The teacher divides the class into groups, each group has 4-6 students.

Guide students to conduct experiments and discuss them according to the worksheet.

WORKSHEET NUMBER 1

Task 1: Investigation of the amount of carbon dioxide gas produced in the reaction between acetic acid and baking soda

– There are 2 balloons with two different colours: blue and red. Put 5g of baking soda into the blue balloon and 10g of baking soda into the red balloon, respectively

– Use the graduated cylinder to measure the vinegar into the bottle with the volumes as shown in the table below and number the bottle in order

	Bottle 1	Bottle 2
Volume of vinegar	150ml	200ml

Lift the balloon upright so the baking soda falls, make sure that the balloon does not bounce when the reaction occurs.

Result of the experiment: Compare the size of 2 balloons.

Task 2: Based on the information about the necessary parts of the rocket, draw the simplest structural model of the rocket that can still ensure its flight function. (note clearly the actual role, dimensions and expected materials of each part)

Hints for doing task 2:

Which part will be the place to store the vinegar and baking soda solution? (mark on the drawing above)

What shape should the rocket have to make it easy to move?

Task 3: Make the rocket according to the design, test and record a video about the manufacturing process, report it to the class.

(iii) Explain

After doing the task on the worksheet, students continue to answer the questions posed by the teacher.

Suggest some questions

- When can rockets fly?

- How do you determine the amount of $NaHCO_3$ and vinegar that you need? Explain?

- How do rockets fly straight without tilting or deflecting?

- How does the generated gas spray out to give the rocket propulsion without the two reactants falling apart before the reaction takes place? (note the states of the two reactants: solid, liquid)

- How to reduce the drag of the air when the rocket goes up?

(iv) Elaborate

In order to deepen and expand students' knowledge, the teacher asks some questions that require students to apply their knowledge and experiences to find the answers.

Suggest some questions

Question 1: How to make the gas generate faster and reduce the waiting time of the reaction?

(v) Evaluate

The teacher assigns a representative of each group to report the result, and the representative of other groups ask the questions.

Other groups participate in discussing the results of the reporting group.

After students report the results and answer the questions, the teacher evaluates students based on a number of criteria, such as:

- The rocket is capable of flying at least 3 meters above the ground.

- Performance of students in class: students' answers on worksheets, students' attitudes during conducting experiments (teachers observe and record)

5. Results analysis

5.1. Qualitative analysis results

Testing of the 05 above-mentioned items at 04 secondary schools obtained the following results:

About students: The survey results show that most of the students actively participated in the activities of the lesson. They had many opportunities to participate in educational activities under the STEM educational orientation under many various forms. They were able to express their opinions and creative ideas and propose solutions to solve common learning tasks. In general, most students were interested in and want to learn about STEM-oriented education. This promises the convenience of implementing STEM-oriented teaching at high schools in Vietnam in the future. This is reflected in the students' products at each stage of the 5E model in the operation to create a simple rocket product.

5.2. Quantitative analysis results

To assess the students' ability to develop the ability to apply their knowledge and skills through STEM activities in the topic "Simple rocket".based on the goal of developing the capability to apply skills for students, the research team made an initial comment: STEM activities can develop the capability to apply skills in the real life of the learners. From there, the research team built a practical questionnaire to learn about the difficulties and practical needs of students in STEM educational activities. Based on the results, the research team built a system of STEM activities and proposed the process of organizing these activities with the goal of developing the capability to apply knowledge and skills to students. The effect will be important in the assigned task.Analysing the impact results will help answer the question: Can students develop the ability to apply their knowledge and skills through STEM activities? And how should STEM be organized to best develop students' ability to apply their knowledge and skills?

Figure 3. Designing household decoration items from plastic bottles

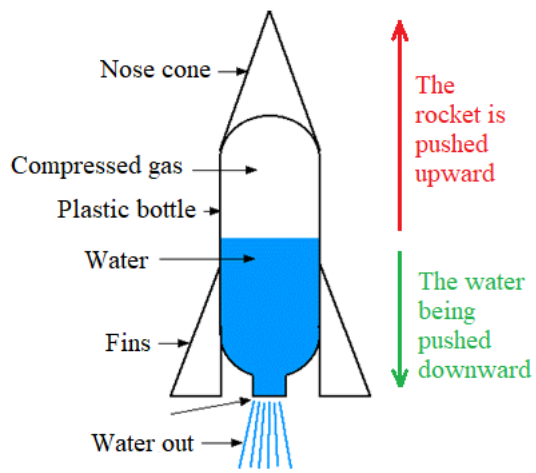

Figure 4. Simple rocket

After developing a system of STEM activities, to evaluate the development of students' ability applying their knowledge and skills in the process of performing assigned tasks, the research team built an observation checklist to evaluate the corresponding activity based on 9 criteria. Each level will specify the content that students can achieve by each step in the activities. Level 1 corresponds to 1 point, level 2 corresponds to 2 points, level 3 corresponds to 3 points, and level 4 corresponds to 4 points. The results are shown in Table 2 below.

According to the chart of the progress in assessing the capacity to apply knowledge and skills to students (Figure 3), each criterion of knowledge and skills application evaluated during the training of students is gradually increasing (shown in the left picture, the graph showing each line going up; in the right picture, the average points of the subjects after experiment are higher compared to the control class).

In Table 5, from the average value, it shows that when the experiment was conducted according to the STEM model, the observation point was much higher compared to the post-piloting student class (the difference in average point between the experiment class and the control class is 0.72). This proves that the application of STEM education has a great influence on developing the ability to apply knowledge of chemical skills to students.

Determination of impact level (ES): ES = 0.71. From the ES value, looking at the Cohen table, It shows that the use of the STEM model has a large impact on developing the capacity to apply knowledge and skills to students. The p-value between the class after the experiment and before the experiment was always <0.05, which shows a clear difference in the average scores between students applying skills and knowledge and students after the impact of groups of classes before and after experiments passed. Teaching STEM topic "Simple rocket" is not likely to happen randomly, demonstrating that the impact of the research has created a large impact on the experimental classes.

6. Conclusion

Table 2. Results of evaluating the capability of applying knowledge and skills based on the observation checklist on the topic "Simple rocket " (40 students)

Criteria No.	Experiment class					Control class				
	The number of students have scores				Average	The number of students have scores				Average
	1	2	3	4		1	2	3	4	
1	2	4	16	18	3.25	6	14	14	6	2.50
2	2	4	18	16	3.20	8	12	14	6	2.45
3	2	2	18	18	3.30	6	16	10	8	2.50
4	2	4	18	16	3.20	8	12	10	10	2.55
5	4	4	14	18	3.15	8	10	12	10	2.60
6	2	6	16	16	3.15	8	14	12	6	2.4
7	4	4	18	14	3.05	8	12	12	6	2.3
8	4	4	16	16	3.10	12	10	10	8	2.15
9	4	6	14	16	3.05	8	16	12	4	2.3
The average score of capacity to apply knowledge and skills of experiment class = 3.16						The average score of capacity to apply knowledge and skills of control class = 2.44				
The difference of average point = 0.72										
The standard deviation of experiment Class = 0.85						The standard deviation of control class = 1.02				
Allow independent verification test p = 1.31.10-4										
ES level = 0.71										

** Look up the name of the criteria by number: 1. Identify practical problems; 2. Identify knowledge in the study of sciences related to practical applications; 3. Searching and discovering knowledge related to practical issues; 4. Explain, analyse and evaluate practical issues; 5. Proposing and analysing a number of feasible solutions; 6. Selecting the most appropriate solution; 7. Successfully implementing the solution according to the selected plan; 8. Evaluate the effectiveness of the chosen solution accurately and concisely; 9. Apply the solution in a similar context or new situation.*

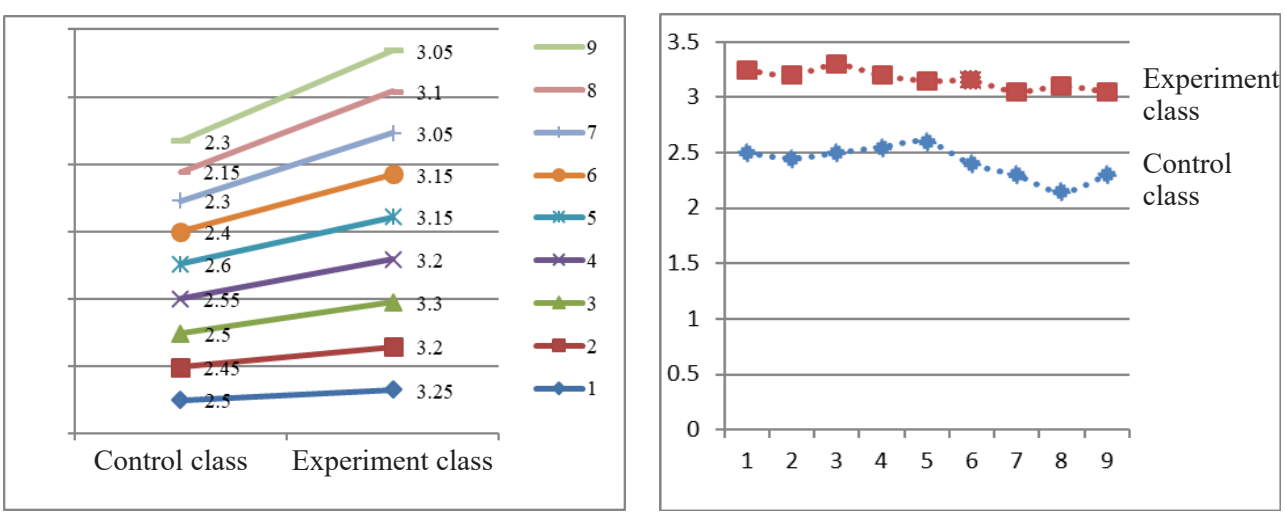

Figure 5. assessment results of students' capability in the topic "Simple rocket"

The teaching content each lesson/ topic is designed according to the 5E process so that students can explore by themselves and expand their knowledge. STEM-oriented content creation can help connect the knowledge of many subjects and apply that knowledge to

solve practical problems. Based on the learned knowledge and experiences of students in learning in general and science subjects in particular, as a basis for exploiting and guiding students into new and deeper discoveries about the surrounding life. Through the implementation of these activities, students are found proactive and actively creative to increase their interest in learning science subjects, thereby forming their passion for science and promoting their positive, self-conscious and mastery to create the premise to form the adaptive skills.

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