

DEVELOPING STUDENTS' PRACTICAL COMPETENCE IN TEACHING NATURAL SCIENCE FOR 8TH GRADERS USING STEM EDUCATION ORIENTATION

Hoang Huy Le,
Giang Truong Nguyen⁺

Thai Nguyen University of Education, Vietnam
⁺Corresponding author • Email: gianghoa47b@gmail.com

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ABSTRACT

STEM education is a direction chosen by the Ministry of Education and Training in recent years to train learners with the necessary skills of the 21st century, which helps learners meet the increasing demand for human resources. In the 4.0 era, the problem of developing students' abilities is an urgent matter. The competencies that students need to develop include general and specialized competencies. In the specialized competencies, the capacity to practice has a particularly important role. Developing the capacity to practise natural sciences of 8th graders is an urgent issue to improve the quality of current education in Vietnam to meet the reform's requirements of the general education program.

1. INTRODUCTION

Practical competence is the ability to perform experiments successfully and safely and to use knowledge to scientifically explain observed phenomena to conclude. Practical competencies include the ability to conduct experiments; the ability to observe, describe, explain experimental phenomena, and the ability to process information related to the experiment (Bernd Meier & Nguyen Van Cuong, 2014; Nguyen Thi Thanh et al., 2014).

In Vietnam, there is only a small number of practical research and development works, and studies have suggested that this is one of the most important factors to be trained to improve the quality of chemical teaching. Up to now, there has been no systematic study of specific measures to develop the competence of natural science practice towards STEM-oriented for 8th graders.

2. LITERATURE REVIEW

The United States is one of the first countries to study STEM education and has a strategy endowed with STEM. The government has supported high schools with an innovative STEM network, regardless of target groups (Nguyen Thi Ngoan, 2017).

In the UK, STEM has been studied for a long time. An important education program related to STEM is *Twenty First Century Science Textbook* (GCSE) (Nguyen Van Bien, Tuong Duy Hai, 2019).

Five main areas of STEM education identified in the action strategy are: capacity improvement and participation in STEM; level of participation and aspirations; increasing teacher capacity and the quality of STEM education; supporting STEM educational opportunities in school systems; facilitating effective cooperation with universities, businesses and industrial companies (Nguyen Mau Duc, 2017).

In Southeast Asia, Thailand is one of the first countries to implement the STEM education model. Thailand's STEM education is carried out through the STEM education network including: National STEM Education Center (NSEC), Regional STEM Education Center (RSEC), STEM Education Network, STEM Ambassador (Vietnam Ministry of Education and Training, 2019).

In Vietnam, from the 2014-2015 school year, the Ministry of Education and Training has issued a document guiding the experimental organization of STEM education. Since then, STEM education has been deployed in many provinces and cities (Vietnam Ministry of Education and Training, 2019).

The Ministry of Education and Training officially announced the new general education curriculum on December 27, 2018. In this program, the subjects of Mathematics, Physics, Chemistry, Biology, Informatics and Technology contribute to promote STEM education (Nguyen Mau Duc, 2017).

3. RESEARCH METHODS AND RESULTS

3.1. Research methods

Competence is the ability to responsibly and effectively apply actions to solve tasks and problems in changing situations in the fields of occupation, society, or individuals based on knowledge, skills, and experience as well as a willingness to take the action (Do Huong Tra et al., 2015).

Students' competencies can be understood as: "the ability to master age-appropriate systems, knowledge, skills, attitudes... and connect them appropriately in successful implementation of learning tasks, effectively solve problems posed for students in life" (Nguyen Cong Khanh, 2013).

Practical competence is one of the most important abilities that need to be dealt with from the beginning of learning natural science (Michael Robert Greenhoe, 2013).

The expressions of scientific practice capacity of 8th graders are determined according to the following level (Nguyen Thanh Nga et al., 2017):

Table 1. Development levels of competency in natural science

Type of competence	Development levels		
	A (completed)	B (developing)	C (unformed)
Ability to conduct experiments safely	Students can state and comply with the rules and safety of the laboratory.	Students can state and comply with the most simple part of the rules and safety of the laboratory.	Students are not able to state and comply with the rules and safety of the laboratory, even with the most basic ones.
	Students can identify and choose the correct chemicals to do an experiment.	Students can identify chemicals but may mistake some chemicals to do an experiment.	Students are not able to identify and choose the correct chemicals to do an experiment.
	Students can present the effects and structure of the tools and necessary chemicals.	Students can present the effects and structure of the tools and necessary chemicals in simple experiments.	Students are not able to present the effects and structure of the tools and necessary chemicals.
	Students can self-conduct some simple experiments.	Students can conduct some simple experiments with the teacher's support.	Students are not able to conduct some simple experiments without the teacher's support.
	Students can conduct some complicated experiments with the teacher's support.	Students can prepare tools, chemicals, and know all the steps to do the complicated experiments but cannot hand-on some notes to experiment successfully.	Students are not able to conduct some complicated experiments, even with the teacher's support.
	Students can do the experiments quickly and accurately.	Students can do the experiments exactly but exceed the limited time.	Students are not able to do the experiments quickly and exactly.
Ability to observe, describe, explain experimental phenomena	Students can observe and realize experimental phenomena.	Students can observe but not realize experimental phenomena.	Students are not able to observe and realize experimental phenomena.
	Students can describe experimental phenomena exactly and briefly.	Students can describe experimental phenomena.	Students are not able to describe experimental phenomena.
	Students can explain experimental phenomena reasonably.	Students can explain simple experimental phenomena reasonably, but not with complicated ones.	Students are not able to explain experimental phenomena.
	Students can write chemical equations and draw the necessary conclusions.	Students can write chemical equations.	Students are not able to write chemical equations and draw the necessary conclusions.

	Students can propose and conduct alternative experiments successfully.	Students can propose alternative experiments, but cannot conduct those experiments successfully.	Students are not able to propose and alternative experiments.
	Students can use experimental information basing on research methods, problem-solving, and verification.	Students can use experimental information basing on research methods and verification but cannot give and solve the problems.	Students are not able to use experimental information.
Ability to process information related to the experiment	Students can process, select, determine the scope of knowledge that needs searching.	Students can process, select, but not determine the scope of knowledge that needs searching.	Students are not able to process, select, determine the scope of knowledge that needs searching.
	Students can analyze and evaluate the experimental information.	Students can analyze but not evaluate the experimental information.	Students are not able to analyze and evaluate the experimental information.
	Students can orientate the tasks and information of the experiment that needs to be exploited.	Students can orientate only the tasks of the experiment.	Students are not able to orientate the tasks and information of the experiment.

Identifying 6 principles of developing the capacity to practice natural sciences for students is ensuring the peculiarities of chemistry; orientation; the objectives of the program; pedagogical nature; diversity and comprehensive; practicality and objectivity in evaluation. Proposing the process of developing the capacity of natural science practice for students can be demonstrated through 6 steps as follows:

Step 1: Prepare the contents of the natural science practice experiment at home.

Step 2: Conduct experiments in class.

Step 3: Organize students to work in groups to report group performance.

Step 4: Propose improvements to successfully conduct the experiments.

Step 5: Test and conclude.

Step 6: Draw experience from the experiment.

We propose 5 measures to develop the capacity of natural science practice for 8th graders including designing and using chemical experiment manuals; use of chemical experiments in combination with aggressive teaching methods; using teacher experiments to follow research and verify methods in teaching new lessons; use funny chemical experiments and experiments associated with practice in teaching practice and using experimental exercises, experimental exercises.

Developing an observation checklist to evaluate the development of natural science competency for students (**A - 3 points; B - 2 points; C - 1 point**) is shown below:

Type of competence	Manifestations	Point		
		3	2	1
Ability to conduct experiments safely	1. State and comply with the rules and safety of the laboratory			
	2. Identify and choose the correct chemicals for the experiment			
	3. Present the effects and structure of the tools and necessary chemicals			
	4. Self-conduct some simple experiments			
	5. Conduct some complicated experiments with the teacher's support			
	6. Do experiments accurately and quickly			
Ability to observe, describe, explain experimental phenomena	7. Observe and realize experimental phenomena			
	8. Describe experimental phenomena exactly and briefly			
	9. Explain experimental phenomena reasonably			
	10. Write chemical equations and draw the necessary conclusions			
	11. Propose and conduct alternative experiments successfully			

Ability to process information related to the experiment	12. Use experimental information basing on research methods, problem-solving, and verification
	13. Process, select, determine the scope of knowledge that needs searching
	14. Analyze and evaluate the experimental information
	15. Orientate the tasks and information of the experiment that needs to be exploited

Summary

Highest score

45

The student's natural science capacity development score is based on the capacity scale: from 15 to 25 - Low level; from 26 to 35 - Average level; from 36 to 45 - High level (UNESCO, 2002).

Basing on the determination of teaching objectives, we have developed 03 topics to teach Natural Sciences towards STEM education (outlining 3 topics). Here are the details of the topic "REVEALING THE MYSTERY OF LAKE NYOS".

3.2. Research results

3.2.1. Name of the lesson: MOL AND DENSITY OF GASES

3.2.1.1. Name of the topic

REVEALING THE MYSTERY OF LAKE NYOS

(Period: 03 periods – Grade 8)

3.2.1.2. Objectives

- Present the definition of moles (Atom, molecule).
- Calculate the weight of moles (M); be able to convert between moles (n) and mass (m).
- Present the definition of density, write the formula to calculate the density of gas.
- Compare whether one gas is heavier or lighter than another based on the formula for density.
- State the concept of the molar volume of a gas at the pressure of 1 bar and 25°C.
- Apply the formula: $n(mol) = \frac{V(L)}{24,79(L/mol)}$ to convert between moles and volume of gas under standard

conditions: pressure 1 bar at 25°C.

- Students understand the concept of a gas density.
- Students can prepare CO₂ from simple tools and chemicals.
- Students can design a model and explain the mystery at Lake Nyos.
- Students can make presentations and can provide critical thinking about their team's designs as well as other groups in the class.
- Students can evaluate the strengths and weaknesses of the designed model.
- Students are equipped with personal work skills; teamwork skills.

3.2.1.3. Topic description

On August 21, 1986, in a tragedy that destroyed an entire village, one of the most bizarre and mysterious natural tragedies in history occurred in the Lake Nyos area - a lake formed on the crater of a decommissioned volcano in Northeastern Cameroon. Suddenly, without warning, the lake bed created a cloud of death that covered an entire land within a radius of 25 km (16 miles), traveling with a race of nearly 100 km / h. The cloud's dead hand drained the oxygen of the air, scattering corpses along its path, killing 1,746 people and more than 3,500 living beings within minutes. The disaster is depicted exactly like the doomsday scene of the Bible, with people and objects dying in pain for unknown reasons, without a trace. Many villagers from the villages of Cha, Nyos, and Subum, under the influence of the lake, died in their sleep.

Students will act as scientists revealing the mystery.

To implement this lesson, students need to apply knowledge:

- Mathematical knowledge: How to calculate model cost and measure model size, process data,...
- Physical knowledge: degree solubility, gas density and gas collection.
- Chemical knowledge: preparation and testing of carbon dioxide properties.
- Biological knowledge: biological activity of carbon dioxide.

Subjects: 39 students in 8C

Setting: Trung Vuong Secondary School – Thai Nguyen city

3.2.1.4. Preparation

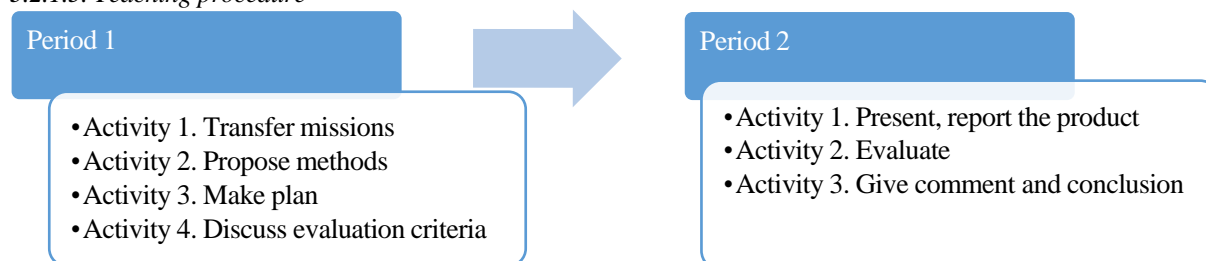
Teacher

- Model of Nyos village, chemicals to make out CO₂, PowerPoint, supporting information system.
- Group chat Facebook/Zalo.
- Learning materials.

Students

- Read the tutorials, make the models.

3.2.1.5. Teaching procedure

**Period 1. Transfer mission****Activity 1: Transfer mission (30 minutes)****A. Objectives**

- Students discover the reasons for the disaster.
- Students obtain basic knowledge to explain the mystery.
- Students build up a model, find out the explanation for the mystery.
- Students draw the experience for self-protection when facing dangers from CO₂.

B. Students' expected products

When finishing the activity, students will be able to hand on:

- Some ways to explain the disaster at Lake Nyos.
- A report on the strengths and weaknesses of each ways of explanation.

C. Teaching and learning approach

Teacher divides students into groups with their duties.

Students' activities	Teacher's support
Students watch a video.	<ul style="list-style-type: none"> - Teacher shows slides, video to give the problems and provide knowledge about the physical properties, modulation, biological activity of carbon dioxide; - Teacher: leads students to the problem, let students act as scientists to reveal the mystery.
Students propose approaches.	<ul style="list-style-type: none"> * Make out CO₂ - With HCl and CaCO₃/Na₂CO₃; - With coke and mentos; - With effervescent tablet C and water; - By burning fossil fuels. * Collect CO₂ - Move the air and let the bottle's mouth up; - Move the air and let the bottle's mouth down; - Move the water. * Propose models and ways to check CO₂ - Model 1: Using fire to check; - Model 2: Using hoppergrasses or crickets to check;
Discuss the approaches proposed by the students.	<ul style="list-style-type: none"> - Teacher lets students discuss, gives comments and orientation to the students.

Activity 2: Designing model to reveal the mystery at Lake Nyos (30 minutes)**A. Objectives**

- Students can design a model of Nyos village and the effects of CO₂ on living in the village.

B. Students' expected product

- The design of the model of Nyos village and the effects of CO₂ on living in the village.

C. Teaching and learning approach

Students' activities	Teacher's support
<ul style="list-style-type: none"> - Work in group, design model of Nyos village and work out the effects of CO₂ on living in the village. - Report, discuss about the designed model. - Self-question and give the most suitable approach. 	<ul style="list-style-type: none"> - Give some clues on students' designing. - Ask students from different group to stand in the front and report on what they have found out. The others listen, give questions and comments on the presented model.

Activity 3: Make a plan (20 minutes)

A. Objectives

Students discuss and arrange the duty for each member reasonably.

B. Students' expected product

The plan of each member's duties.

C. Teaching and learning approach

Teacher divides students into groups with their duties.

Students' activities	Teacher's support
Listen.	Teacher: We have discussed and agreed on the model of Nyos village and the effects of CO ₂ on living in the village.
Arrange the tasks in their group.	Now work in a group and share your work equally.
Each group has a student come to the board and report; The others listen and adjust their plan suitably	Teacher: gives students the checklists of tasks arrangement and plan.
	Teacher: determines the plan with each group.

Activity 4: Determine evaluation criteria (10 minutes)

A. Objectives

- Give the evaluation criteria for students to base on and have an appropriate implementation plan;
- Get the appropriate model basing on design criteria.

B. Students' expected product

Evaluation criteria transcript.

C. Teaching and learning approach

Teacher divides students into groups with their duties.

Students' activities	Teacher's support
Students help build up the evaluation criteria	Teacher and students discuss evaluation criteria. Give students the prepared checklists
Students take note to adjust their evaluation criteria	Gives conclusion about evaluation criteria

Expected checklist:

No.		Criteria	Maximum	Score
1	Product	Product reveals the mystery	3	
2		Creativity	2	
3	Report	Clearly explain the work process	1	
4		Applying knowledge during working	2	
5		Presentation and answering questions	2	
Total			10	

Period 2. Present, report on product, evaluate

Activity 1: Report, discuss (25 minutes)

A. Objectives

- Students operate the Nyos village model and the effects of CO₂ on life in the village.
- Students can present reports on the group's products.
- Students can present their knowledge and how to operate the model.

- Students have experience when encountering similar cases in life.

B. Students' expected product

- The design of the model of Nyos village and the effects of CO₂ on living in the village.
- A report on the product.
- An individual report.

C. Teaching and learning approach

Students' activities	Teacher's support
Come to the board to reveal the mystery and present about the product. Report should include difficulties and strengths of the product as well as the use of the product.	Asks students to come to the board to reveal the mystery and present about the product. Let other students ask some questions. Teacher as the manager, focus on certain issues:
Students answer the questions.	<ul style="list-style-type: none"> - Which knowledge did you base on to design this model? - Can you describe the model in details? - How does this work? - How can we prepare and collect CO₂? - Do you gain any experience after designing the model?

Activity 2: Evaluate (10 minutes)

A. Objectives

- Evaluate students' products.
- Help students consolidate basic knowledge.
- Help students find solutions to improve products.

B. Students' expected product

- A report on weaknesses and how to improve the model.
- Strengths and the usefulness of the model.

C. Teaching and learning approach

Students' activities	Teacher's support
Students listen to the comments.	Give comments on the models basing on the evaluation criteria
Students self-assess and assess others members in the group.	<ul style="list-style-type: none"> - Teacher gives a conclusion on strengths and weaknesses, then give solutions for students to improve - Basing on students' reports and models, gives comments, and assesses students. Complies, improves, and perfects the products - Lets students assess and self-assess The teacher assesses the products according to the evaluation criteria

Activity 3: Comment, conclude (10 minutes)

A. Objectives

- Students understand the knowledge applied to model design.
- Students grasp the shortcomings to overcome the model they have designed.

B. Students' expected product

- Report on comments content.
- Gain knowledge and solutions to improve.

C. Teaching and learning approach

Students' activities	Teacher's support
Students listen to the evaluation.	Teacher publishes his evaluation, self-evaluation and mutual-evaluation will be show afterwards.

3.2.2 Name of the topic: Density of gases

3.2.3 Topic: Air – Burning

3.2.4. Comparison of the obtained results

At the end of each lesson, the teacher assesses the development of students' practical natural science competence and evaluate the note of each student after every practice lesson

The results after assessing and processing by EXCEL are shown below:

Table 2. Results from the control group and experimental group

Group	Number of subjects	Score X_i											Average score
		0	1	2	3	4	5	6	7	8	9	10	
Σ Experimental	50	0	0	0	0	13	11	9	7	6	4	0	5,88
Σ Control	50	0	0	0	3	16	13	6	6	4	2	0	5,32

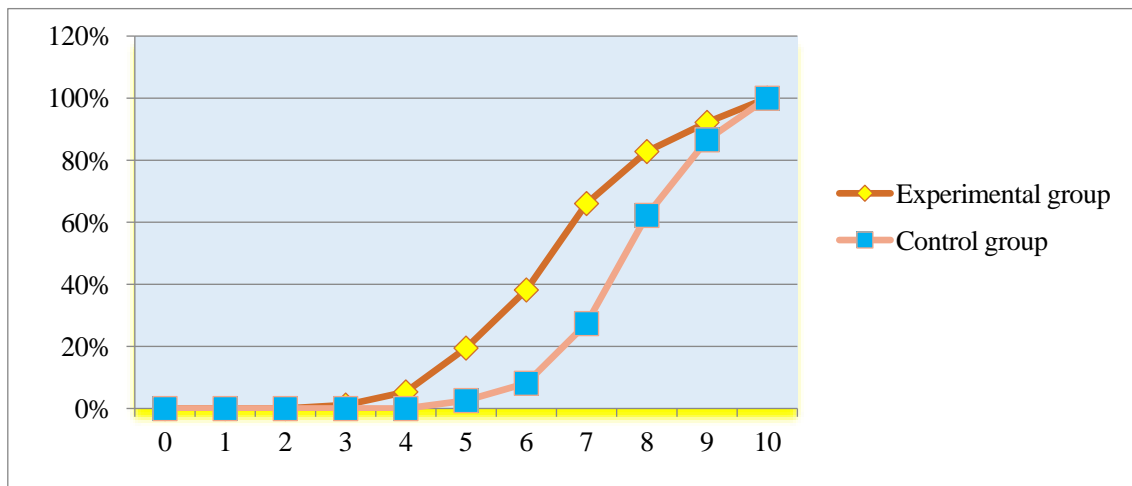


Chart 1. The results of assessing the Control group and Experimental group

Table 3. Statistical description and comparison

Statistics	Mean	Experimental group	Control group
Description	Mode	6	6
	Median	6	6
	Mean	5,88	5,32
	Std. Deviation	1,31	1,67
Comparison	p-value	$1,23 \cdot 10^{-27}$	
	Correlation	0,82	

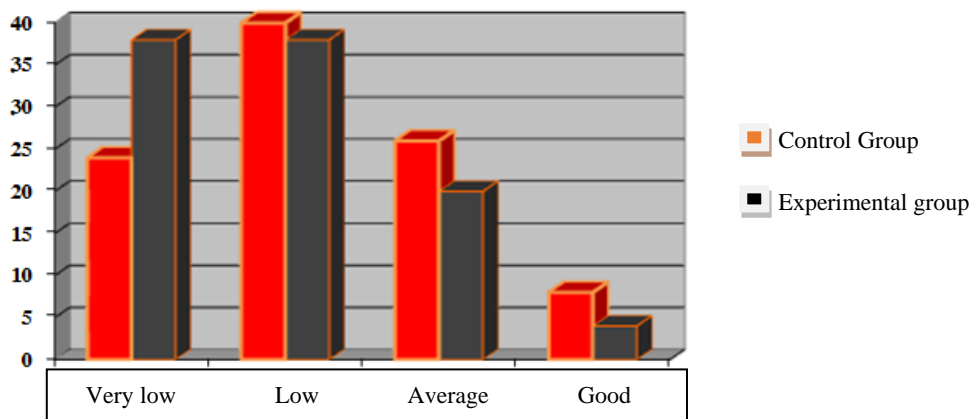


Chart 2. An overview of the results of assessing the Control group and Experimental group

The results after assessing and processing by EXCEL are shown below:

Table 4. A summary on the level of development of students' practical natural science competence

Competence	Experimental group				Control group			
	Frequency			Mean	Frequency			Mean
1,0	2,0	3,0	1,0		2,0	3,0		
1	9	29	12	2,06	13	29	8	1,90
2	14	25	11	1,94	18	22	10	1,84
3	7	34	9	2,04	12	30	8	1,92
4	10	25	15	2,10	16	24	10	1,88
5	7	30	13	2,12	11	27	12	2,02
6	15	25	10	1,90	19	22	9	1,80
7	11	31	8	1,94	15	28	7	1,84
8	6	30	14	2,16	12	28	10	1,96
9	8	31	11	2,06	16	25	9	1,86
10	6	31	13	2,14	8	30	12	2,08
11	7	32	11	2,08	7	34	9	2,04
12	17	17	16	1,98	18	18	14	1,92
13	13	26	11	1,96	16	25	9	1,86
14	10	30	10	2,00	16	27	7	1,82
15	13	25	12	1,98	17	22	11	1,88
	Mean: 2,03				Mean: 1,91			
	Std. Deviation: 1,17				Std. Deviation: 1,21			
p-value: $3,36 \cdot 10^{-31}$								
Correlation: 0,88								

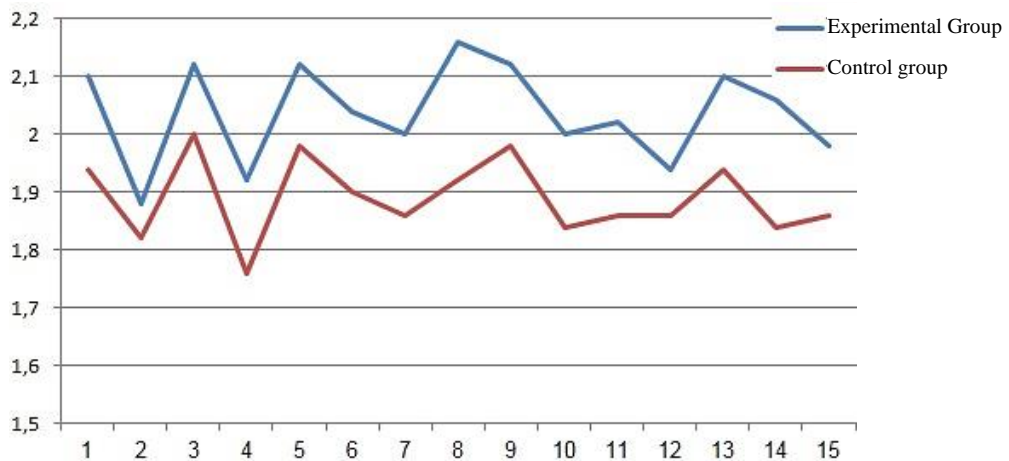


Chart 3. A summary on the level of development of students' practical natural science competence

*Comment:

Thus, the elemental capacities are developed, especially the competencies 7,8,10,14 develop faster because these are important competencies in the study of natural science. Students are still weak and have been trained with these abilities.

4. DISCUSSION AND CONCLUSION

The results of the pedagogical experiment have proven the feasibility of the process through 6 steps and 5 proposed measures to develop students' ability to practice natural science in 8th grade teaching. The students' natural science practice capacity has been trained under the current educational innovation goals, contributing to improving the quality of teaching, which is the driving force for our education to develop, to integrate with the education of advanced countries in the world.

We have designed lessons on topics “Revealing the mystery of Lake Nyos”, “Density of gases”, Air – Combustion” at secondary school, and it is indicated that students’ competencies have been enhanced after applying STEM lessons, especially important competences such as competence number 1, number 8, number 9, and number 14, in which great progress has been made.

Thus, applying STEM topics contributes to improving teaching quality and enhancing students’ competencies, especially in developing capacity to practice natural sciences. Moreover, it also helps in satisfying the innovation requirements of the high school education program.

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