FOSTERING PROBLEM-SOLVING AND CREATIVE ABILITY FOR STUDENTS THROUGH TEACHING THE STEM TOPIC "ACID SOIL TREATMENT" IN NATURAL SCIENCE FOR GRADE 8

BỒI DƯỠNG NĂNG LỰC GIẢI QUYẾT VẤN ĐỀ VÀ SÁNG TẠO CHO HỌC SINH THÔNG QUA DẠY HỌC CHỦ ĐỀ STEM "XỬ LÍ ĐẤT CHUA" MÔN KHOA HỌC TỰ NHIÊN 8

Vuong Cam Huong*, Nguyen Huy Hoang, Pham An Binh

Pham Van Dong University, Vietnam

*Corresponding author: vchuong@pdu.edu.vn

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Abstract - The General Education Curriculum for Natural Science is oriented toward methods of forming and developing students' natural science competence. Teachers are encouraged to implement STEM education to develop students' integrated competence in applying knowledge and skills in natural science, technology, engineering, and mathematics to solve real-world challenges. This paper proposes a teaching procedure for the STEM topic "Acid Soil Treatment" based on five activities and conducts pedagogical experiments in teaching Grade 8 Natural Science at two lower secondary schools. The results show that students' problem-solving and creativity competence improved significantly. Thus, the application of teaching the STEM topic "Acid Soil Treatment" contributes to fostering students' problem-solving and creativity competence and can be used in Natural Science teaching practice at lower secondary schools.

Key words - STEM education; STEM topic; ability; problem solving

Tóm tắt - Chương trình giáo dục phổ thông môn Khoa học tự nhiên (KHTN) định hướng về phương pháp hình thành, phát triển năng lực KHTN, giáo viên được khuyến khích triển khai giáo dục STEM nhằm phát triển năng lực tổng hợp và vận dụng kiến thức, kỹ năng trong các lĩnh vực KHTN, công nghệ, kỹ thuật và toán học của học sinh để giải quyết những thách thức trong thực tiễn. Trong bài báo này, chúng tôi đề xuất xây dựng tiến trình dạy học chủ đề STEM "Xử lí đất chua" theo 5 hoạt động và tổ chức thực nghiệm sư phạm trong dạy học môn KHTN 8 tại 2 trường trung học cơ sở. Kết quả cho thấy, năng lực giải quyết vấn đề và sáng tạo của học sinh có sự cải thiện đáng kể. Như vậy, việc áp dụng dạy học chủ đề STEM "Xử lí đất chua" đã góp phần bồi dưỡng năng lực giải quyết vấn đề và sáng tạo cho học sinh và có thể sử dụng trong thực tiễn giáo dục KHTN ở trường trung học cơ sở.

Từ khóa - Giáo dục STEM; chủ đề STEM; năng lực; giải quyết vấn đề.

1. Introduction

In the context of profound global transformations in technology, economy, and society, the development of students' comprehensive competences, particularly creative thinking, problem-solving, and the application of knowledge to practice, has become an urgent requirement. In the context of the European Union, the development of STEM competence through innovation in STEM education is considered a topic of considerable interest in the fields of education, economy, and politics [1]. Research has focused on analyzing trends in the STEM labor market and providing policy recommendations to encourage the training of STEM human resources to meet the increasing demands of the market.

The importance of integrating interdisciplinary knowledge and skills to solve complex problems in daily life has been widely recognized worldwide, and STEM has become increasingly relevant to advocating interdisciplinary approaches to teaching and learning [2]. Studies on learners and teaching in STEM subjects have increased significantly over the past decade [3–4]. According to previous studies, students' perceptions and learning attitudes have a significant influence on their learning motivation [5–6]. These are factors that teachers need to consider when implementing STEM education. Several studies in Germany, Australia, and the United States have indicated that teachers are a decisive factor in the process of fostering students' STEM competence [7–8].

In Vietnam, in 2018, education underwent a strong transformation from a system primarily focused on knowledge transmission to one aimed at the comprehensive development of learners' qualities and competences, in which problem-solving and creativity competence is one of the three general competences that need to be developed in students [9]. To respond to the trend of integrated teaching, the Ministry of Education and Training issued Official Dispatch No. 3089/BGDĐT-GDTrH on the implementation of STEM education in secondary education [10]. This document provides orientations for the organization and management of STEM education activities in schools, while also guiding the process of designing and implementing STEM lessons.

There have been numerous studies on the development and organization of teaching STEM topics in Natural Science at the lower secondary level, including the topic "Turning Dirty Water into Clean Water" for Grade 6 Natural Science following the STEM education orientation [11]; the current situation of managing Natural Science teaching activities oriented toward STEM education in lower secondary schools in Hoc Mon commune, Ho Chi Minh City [12]; and teaching the topic "Organisms and Environment" (Natural Science 8) through real-world problems to develop students' problem-solving competence [13].

With the aim of fostering students' problem-solving and creativity competence, in this study, we developed the STEM teaching topic "Acid Soil Treatment" in Grade 8 Natural Science and conducted experimental teaching at Tran Phu Lower Secondary School and Chanh Lo Lower Secondary School, Cam Thanh Ward, Quang Ngai Province.

2. Content

2.1. Research methods

- Theoretical research methods: Reviewing and synthesizing documents on STEM teaching, directive documents on the renovation of general education, the General Education Curriculum, and the Natural Science Curriculum.

- Practical research methods: Conducting pedagogical experiments at Tran Phu Lower Secondary School and Chanh Lo Lower Secondary School, Cam Thanh Ward, Quang Ngai Province; using questionnaires to survey 97 students' opinions on problem-solving and creativity competence before and after the experiment; observing students' behavioral manifestations and interviewing students during the learning process.

- Mathematical statistical method: The results of the pedagogical experiment were statistically processed using Microsoft Excel.

2.2. STEM education

STEM education has been approached by many researchers from different perspectives. According to Tsupros, STEM education is an interdisciplinary integrated teaching method in which students apply STEM knowledge and skills to solve real-world situations, thereby strengthening the connection between schools and the community [14]. Meanwhile, Moore argued that STEM education is the partial or complete integration of the fields of natural science, technology, engineering, and mathematics into teaching activities through linking subject content with real-world problems [15].

In the 2018 General Education Curriculum, the Ministry of Education and Training introduced the concept of STEM education as follows: "STEM education is an educational model based on an interdisciplinary approach, helping students apply knowledge of science, technology, engineering, and mathematics to solve certain real-world problems in specific contexts" [16]. Based on the STEM cycle, which includes the engineering design process or the scientific inquiry process, STEM education not only promotes learning in the fields of natural science, technology, engineering, and mathematics but also forms and develops learners' qualities and competences, especially the specific competence of Natural Science and STEM competence following an interdisciplinary orientation [17].

2.3. Designing the teaching procedure for a STEM topic

According to Official Dispatch No. 3089, the process of organizing the teaching of a STEM lesson or topic in secondary schools consists of five main activities, as shown in Figure 1.

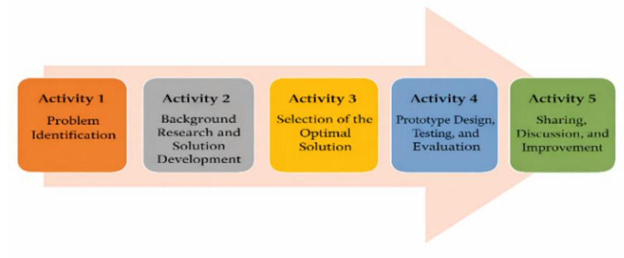

Figure 1. *STEM topic teaching activities*

2.4. Illustration of teaching the STEM topic "Acid Soil Treatment" in Grade 8 natural science

2.4.1. General information about the STEM Topic

a. Teaching content

The lesson belongs to the Grade 8 Natural Science Curriculum:

Lesson 9: Bases – The pH Scale, including the following contents: the concept of bases and their chemical properties; the pH scale and the meaning of pH values; and practice in measuring the pH of different types of soil.

b. Integrated STEM Elements

Science (S)	The concept of pH; the neutralization reaction between acids and bases; the harmful effects of acidic soil on crops.
Technology (T)	Using pH indicator paper to test the acidity of soil.
Engineering (E)	The soil improvement process; techniques for mixing CaO into soil at an appropriate ratio to achieve the target pH.
Mathematics (M)	Statistically processing pH measurements; calculating the required amount of lime based on area and actual pH; drawing a graph of pH variation.

2.4.2. Objectives

a. STEM competence

Scientific competence: Students are able to present the concept of pH; state the harmful effects of acidic soil with pH < 5; explain the reaction using lime to neutralize acid in soil through chemical equations; and solve neutralization problems involving acid and lime.

Technological competence: Students are able to proficiently use pH measuring tools, such as litmus paper and color charts.

Engineering competence: Students are able to measure the pH of a simulated acidic soil sample, apply techniques for treating acidic soil, and verify changes in soil pH after treatment.

Mathematical competence: Students are able to calculate the required lime ratio and analyze pH data before and after the experiment through charts.

b. General competences

- Problem-solving and creativity competence: Students actively contribute ideas, coordinate activities, and support group members in conducting the simulated acidic soil treatment experiment, thereby finding an optimal solution for cultivated soil affected by acidity or alum contamination.

- Communication and collaboration competence: Students actively cooperate with group members and properly fulfill the requirements when conducting chemical experiments and discussing the chemical equations of bases, specifically reactions between acids and bases; they also collaborate in measuring pH and presenting reports.

- Self-control and self-learning competence: Students voluntarily study, explore, and apply knowledge about bases, the pH scale, and methods for treating acidic soil through textbooks, the internet, and other materials.

c. Qualities

- Honesty: Students accurately record the measured pH values and report the products.

- Responsibility: Students demonstrate responsibility in the rational use and protection of soil resources, contributing to environmental preservation.

2.4.3. Teaching procedure

Activity 1: *Identifying the problem*

The teacher asks the following question: In many rural areas, farmers often apply powdered lime, whose main component is CaO, to cultivated soil in order to improve acidic soil conditions. Based on your chemistry knowledge, explain this practice.

The teacher summarizes: When CaO in powdered lime comes into contact with water, it forms $Ca(OH)_2$. Owing to its basic property, $Ca(OH)_2$ neutralizes acids present in the soil, thereby reducing acidity and improving the quality of cultivated soil.

* Situation: The teacher shows images of rice plants with yellow leaves and gradual withering in alum-affected soil areas.

The teacher guides students to formulate possible solutions through a system of guiding questions:

Question 1: Why does the soil in those areas make it difficult for plants to grow?

Question 2: What is the ideal pH value of agricultural soil?

Question 3: How can those plots of land be "rescued" in the most economical way?

* Task: Sketch and develop an experimental model for treating simulated acidic soil using quicklime, CaO.

Activity 2: *Studying background knowledge and proposing solutions*

- Students apply the background knowledge learned in Lesson 9, Bases – The pH Scale, and consult materials such as books and the internet to answer the following questions:

+ What is the pH scale? What pH range does acidic soil fall into?

+ Which chemical property of quicklime enables it to neutralize acidity?

Groups discuss and propose solutions for treating acidic soil. Students may refer to the following suggestions to complete the worksheet shown in Figure 2.

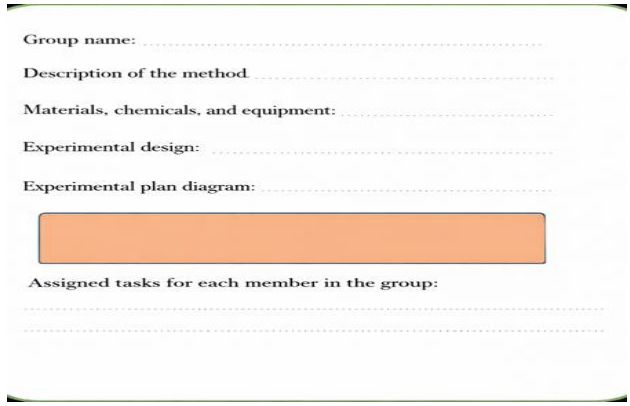
Group name: ....
Description of the method ....
Materials, chemicals, and equipment: ....
Experimental design: ....
Experimental plan diagram: ....
Assigned tasks for each member in the group:
....

Figure 2. *Proposed experimental design*

Activity 3: *Selecting solutions*

Task 1: Each group presents its ideas and experimental arrangement plan. After the presentation, the groups exchange ideas and discuss to agree on the design procedure and experimental steps. Other groups use the criteria in Table 1 to comment on, evaluate, and propose adjustments to improve the plan.

Task 2: Based on the agreed plan, the groups develop an implementation plan for the experiment, clearly assign roles to each member, and prepare all necessary materials, chemicals, tools, and equipment for the implementation process.

Table 1. *Criteria for evaluating experimental plans*

Criteria	**Requirements**
Materials, chemicals, and tools	Full components: acidic soil, quicklime CaO, water, plastic cups, pH measuring tools, such as indicator paper, etc.
Experimental design	Clearly identify the control sample, 0 g of lime, and the experimental samples with gradually increasing lime mass variables, namely 1.4 g, 2.8 g, and 5.6 g.
Experimental procedure	Logical implementation steps: weighing soil → measuring initial pH → mixing lime → waiting for the reaction → measuring pH again.
Drawing of the experimental plan	A clear layout diagram of the experimental cups is provided, with labels to distinguish the samples.
Presentation of the design plan	The design content is presented scientifically and coherently, while appropriate illustrative actions are used to clarify the ideas.
Interaction with listeners	Feedback from others is received and recorded.

Activity 4: *Testing and evaluation*

The groups implement the plan after receiving feedback from the teacher and making improvements.

Preparation:

- Tools: plastic cups, plastic bottles, plastic spoons, stirring rods, and pH indicator paper.

- Chemicals:

+ Acidic soil: Soil with an acidic environment, in which the concentration of H^+ is higher than that of OH^- in the soil solution and which often contains many free Al^{3+} and

Fe^{3+} ions. Further information about acidic soil and soil improvement can be found in Grade 10 Technology, Lesson 4.

+ To illustrate the measurement-based experiment, a simulated acidic soil sample containing 4.9 g of H_2SO_4 is prepared.

+ Additional chemicals: water and quicklime CaO.

- Materials: acidic soil and cotton wool.

Procedure:

Step 1. Measuring the pH of the acidic soil sample

Take the acidic soil sample, mix it with 20 mL of distilled water, stir thoroughly, and filter the liquid. The filtering process is conducted as follows: cut a plastic bottle into two equal parts. Then place the bottle neck downward into the bottom part of the plastic bottle. Put cotton wool inside, then pour the mixture of acidic soil and water into the plastic bottle to filter out the liquid.

Dip the pH indicator paper into the filtrate and observe the color change of the pH paper. Compare it with the color chart to record the pH result of the acidic soil.

Step 2. Treating acidic soil

- In practice, farmers have many methods for treating acidic soil, such as applying agricultural lime, adding organic matter and microorganisms, and washing away salinity and alum. In addition, automatic deacidification systems may be used, such as automated alkaline solution dosing or automated lime application using IoT technology.

- Conduct the treatment of simulated acidic soil by mixing acidic soil samples with quicklime CaO at different masses:

+ Sample 1: acidic soil sample + 1.4 g CaO; then mix with 20 mL of distilled water.

+ Sample 2: acidic soil sample + 2.8 g CaO; then mix with 20 mL of distilled water.

+ Sample 3: acidic soil sample + 5.6 g CaO; then mix with 20 mL of distilled water.

Step 3. Measuring the pH of the treated soil

Filter the liquid from the soil samples and measure the pH of the treated soil in the same way as in Step 1.
Record the pH results of the soil in Samples 1, 2, and 3; explain the results; and draw conclusions about the environment of the soil samples after treatment.

Activity 5: *Sharing, discussion, and adjustment*

- Groups draw a column chart showing the change in pH according to the amount of lime applied.

- Students answer the question: Is it beneficial to apply too much lime, resulting in pH > 8? Why?

- Students propose an optimal deacidification procedure for an actual local soil sample through the following practical problem: A field has an area of 200 m². Analysis shows that every 10 m² of soil contains 9.8 grams of sulfuric acid, H_2SO_4, which causes acidity. How many grams of quicklime, CaO, are needed to completely neutralize the amount of acid in that field?

- The teacher comments on and evaluates each group's presentation results based on the criteria in the evaluation sheet, as shown in Table 2.

Table 2. *Evaluation sheet*

Criteria	Level A, 8.5–10	Level B, 7.0–8.4	Level C, 5.5–6.9
pH measurement technique	Standard procedure, accurate measurement, and no contamination of the sample.	Correct procedure and accurate measurement, but the process is still slow.	Able to measure, but the results show large errors.
Explanation of how the amount of lime used in the experiment affects the pH measurement results; calculation of the practical problem	Clearly explains the amount of lime needed to neutralize the acid and the pH environment to be measured. Correctly calculates the amount of lime needed in the practical problem.	Explains the amount of lime needed to neutralize the acid but does not explain the measured pH environment. Correctly calculates the result of the practical problem.	Explains the amount of lime used in the experiment, but the explanation is incomplete and inaccurate. The calculation for the practical problem is inaccurate.
Report and discussion	The report and column chart are clear, with complete annotations.	There is a report and a column chart, but the annotations are incomplete.	Only ideas and data are provided, with no chart.

2.5. Pedagogical experiment

2.5.1. Purpose of the pedagogical experiment

The study evaluates the feasibility of using the STEM topic "Acid Soil Treatment" to foster students' problem-solving and creativity competence.

2.5.2. Design of the pedagogical experiment

a. Experimental participants

Table 3. *Description of the sample in the pedagogical experiment*

Class – Lower Secondary School	Number of Students	Student Teacher	Teaching Time
8C10 – Tran Phu Lower Secondary School	48	Nguyen Huy Hoang	Week 24
8C7 – Chanh Lo Lower Secondary School	49	Le Thi Xuan Hoa	Week 25

We conducted the pedagogical experiment in the second semester with 97 Grade 8 students from Tran Phu Lower Secondary School and Chanh Lo Lower Secondary School.

b. Assessment tools and data processing methods

- Assessment tools: Monitoring and recording students' manifestations in learning activities; discussing with and interviewing several students before and after their participation in the STEM topic; evaluating group products based on the developed set of criteria; and surveying students' opinions using questionnaires before and after the implementation of STEM teaching.

- Data processing method: The data collected from the survey were synthesized and statistically processed using Microsoft Excel.

2.5.3. Results of the pedagogical experiment

The pedagogical experiment was conducted according to the teaching procedure of the STEM topic with a sample of 97 Grade 8 students from Tran Phu Lower Secondary School and Chanh Lo Lower Secondary School, as shown in Figure 4. The development level of students' problem-solving and creativity competence was measured after they studied the STEM topic "Acid Soil Treatment". The teacher surveyed students' opinions using questionnaires before and after implementing the STEM topic to assess the formation and development of problem-solving and creativity competence, as presented in Table 4.

Table 4. *Survey results on the components of students' problem-solving and creativity competence*

	Level	Experimental results	
		Before	After
A. Problem identification, Skill 1	1	42.3%	15.5%
	2	38.1%	36.1%
	3	19.6%	48.4%
B. Proposing and selecting solutions, Skill 2	1	64.9%	10.3%
	2	19.6%	35.1%
	3	15.5%	54.6%
C. Planning, implementing, and evaluating solutions, Skill 3	1	38.1%	18.5%
	2	40.2%	36.1%
	3	21.7%	45.4%
D. Presenting reports, Skill 4	1	11.3%	7.2%
	2	30.7%	24.7%
	3	56.7%	68.1%

Table 5. *Values of statistical parameters*

Skill	Mean, Pre-test	SD, Pre-test	Mean, Post-test	SD, Post-test	t	p
Skill 1	1.77	0.76	2.33	0.73	4.713	0.00001
Skill 2	1.51	0.75	2.44	0.68	8.277	$7{,}34.10^{-13}$
Skill 3	1.84	0.76	2.27	0.76	3.987	0.00013
Skill 4	2.46	0.69	2.61	0.62	1.557	0.12268

The statistical data show that students' problem-solving and creativity competence changed positively after the pedagogical experiment. This change is clearly reflected in the increase in the percentage of students achieving Level 3 in all skills, while the percentage at Level 1 decreased significantly.

For problem identification, Skill 1, before the intervention, the number of students at Level 1 accounted for a relatively high percentage, 42.3%, whereas Level 3 accounted for only 19.6%. After the intervention, the percentage at Level 3 increased sharply to 48.4%, while Level 1 decreased to 15.5%. This demonstrates that students were better able to detect and identify problems than before. The mean value increased from 1.77 to 2.33; the paired-samples t-test produced a result of $p < 0.05$. The test result indicates that the difference between the two time points was not due to random factors.

For Skill 2, proposing and selecting solutions, students' progress was most evident. Before the intervention, most students were concentrated at Level 1, 64.9%, while only 15.5% reached Level 3. After the intervention, the percentage at Level 3 increased to 54.6%, while Level 1 decreased sharply to 10.3%. The mean score increased from 1.51 to 2.44. The p-value of 7.34×10^{-13} shows that the difference before and after the intervention was highly statistically significant. This result reflects that students developed the ability to search for information, think independently, propose ideas, and implement ideas during the learning process.

For Skill 3, the percentage of students achieving Level 3 increased from 21.7% to 45.4%, and Level 1 decreased from 38.1% to 18.5%. The mean score increased from 1.84 to 2.27, indicating that students' ability to plan and implement solutions improved markedly. The test result shows that the difference between the two time points reached statistical significance, with $p < 0.05$.

For report presentation, Skill 4, students already had a relatively high percentage at Level 3 before the intervention, 56.7%. After the intervention, this percentage continued to increase to 68.1%, while Level 1 decreased from 11.3% to 7.2%. However, the increase was not as large as that of the other skills; the mean score increased only from 2.46 to 2.61, and the test result was $p > 0.05$. This indicates that the improvement in Skill 4 did not reach statistical significance. The reason may be that students initially had a relatively good foundation in report presentation skills, leaving less room for further development.

In addition, we evaluated problem-solving and creativity competence by observing students' behavior while learning the topic, combined with interviews with students. The results showed that students' interest in and enjoyment of the subject were clearly demonstrated. Students shared that after participating in the STEM lesson "Acid Soil Treatment" in Grade 8 Natural Science, learning connected with practice helped them understand more easily and retain knowledge longer. The process of independently designing and conducting experiments also contributed to enhancing their confidence in problem-solving, while training their flexibility in handling arising situations.

Overall, the results of the pedagogical experiment demonstrate that organizing teaching through the STEM topic positively contributed to the development of students' problem-solving and creativity competence. However, it is necessary to continue adjusting the lesson structure toward allocating time and selecting methods appropriate to each stage of the process, thereby creating conditions for students to promote autonomy and flexibility in problem-solving and to have more opportunities to demonstrate the components of problem-solving and creativity competence.

Figure 3. *Images of the pedagogical experiment*

3. Conclusion

STEM education is becoming an educational orientation widely applied in many countries, including Vietnam. On that basis, this study developed and organized a pedagogical experiment on the STEM topic "Acid Soil Treatment", consisting of five activities in Grade 8 Natural Science teaching, with 97 students from Tran Phu Lower Secondary School and Chanh Lo Lower Secondary School in Quang Ngai Province. The results of the pedagogical experiment show that students' problem-solving and creativity competence improved significantly after participating in the STEM topic.

The study not only provides further evidence of the effectiveness of applying STEM education in teaching but also serves as a useful reference for teachers in the process of innovating teaching methods, thereby contributing to the achievement of the goal of developing learners' qualities and competences in accordance with the 2018 General Education Curriculum.

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