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Developing the Ability to Apply Knowledge and Skills for Students under Stem Education

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Abstract STEM education is becoming a trend in many countries, including Vietnam. In the general education program, reduce the content of academic theoretical knowledge, instead of knowledge associated with reality and life, while emphasizing STEM education to meet the requirements of the 4.0 technology revolution. The article presents an overview of STEM; STEM-oriented teaching; Research the status and solutions for STEM activities in high school of Vietnam. From there, design the topic of Producing vinegar from sugar and fruit in teaching Carbohydrate chapter-Chemistry 12 under STEM orientation, to develop the ability to apply knowledge and skills to students.

Keywords: *STEM education, organic chemistry 12, Vinegar eating, ability to apply knowledge and skills*

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1. Introduction

Previously, when talking about Vietnam, people remembered the Vietnam War. After the end of the Third Indochina War in 1989, Vietnam has become a more dignified and beautiful country. In the process of building and defending the country, Education and Science - Technology play a very important role and are considered as the top national policy. Vietnam is the 15th most populous country in the world and the third one in Southeast Asia. Vietnamese people's average income in 2019 is about 3000 USD per year, which is lower than the world average. Human resources are the keys to promote the sustainable development in Viet Nam. Therefore, the role of Education is really important. To meet the renovation requirements of Education towards training high-quality human resources for society in the era of the industrial revolution 4.0, not only Vietnam but other countries in the world are also concerned about STEM education. STEM is an abbreviation for Science, Technology, Engineering and Math (Mathematics). The question is why STEM education can meet the above requirements? According to the National Science Teachers Association (NSTA), STEM education is an interdisciplinary approach in the learning process, in which the conceptual academic concepts are integrated with real-world lessons, where students apply their knowledge in science, technology, engineering, and math to specific contexts, helping to connect schools, communities, and workplaces with global organizations, thereby developing capabilities in the STEM field, and at the same time being able to compete in the new economy. This also shows that STEM education orientation is the key direction of world education in the Industrial Revolution 4.0 period. In Vietnam, the general education program issued in 2018 puts much focus on STEM education because it has full STEM subjects: Mathematics; Natural Sciences; Technology; Information Technology. STEM topics in the curriculum of integrated subjects at the basic education stage such as Natural and Social subjects, Science, Informatics and Technology (in elementary schools), Natural Science subjects (in high schools); Orientation for innovating educational methods outlined in the general education curriculum are suitable for STEM education at the integrated teaching level under interdisciplinary topics, applying cross-disciplinary knowledge to solve practical problems. In addition, STEM education topics in grades 11 and 12 are expected to be experiential activities in the form of science research clubs including STEM-oriented research activities. The openness of the program allows some STEM educational contents to be developed through local programs, school education plans; STEM programs and activities implemented and organized through educational socialization activities [1].

However, in Vietnam, STEM and STEM education in particular has not been deeply studied. There are few articles and documents on STEM education discussing the theoretical basis of STEM education and its application to teaching. In particular, in Chemistry there are few STEM teaching topics are few, especially ones associated with the practice [2].

Vinegar is a very popular ingredient in Vietnamese cuisine. Producing vinegar from common available materials, such as sugar and fruits, and so on…helps students both apply their knowledge about carbohydrates in real life situations and create their confidence and excitement in learning. This also makes students feel that Chemistry is close to life, and there is a close connection between theoretical knowledge and real life.

The article briefly presents STEM education, procedures to teaching STEM-oriented Chemistry. Basing on these procedures, the topic "Producing vinegar from sugar and fruit" in the Carbohydrate chapter - Chemistry 12 in the direction of STEM education to develop the capacity to apply knowledge and skills for students was developed.

2. Research Content

2.1. Overview of STEM Education

STEM is the abbreviation for the term Science, Technology, Engineering and Mathematics. The term STEM was originally used when referring to US development policies on Science, Technology, Engineering, and Math. This term was first introduced by the United States Science Foundation (NSF) in 2001 simply as an abbreviation for these fields [5].

The term STEM is used in many different contexts such as "STEM education" (STEM education), "STEM careers" (STEM industry), "STEM workforce" (human resources in STEM field), "STEM learning" (learning in STEM field), and "STEM integration" (STEM integration) [6]. Currently, STEM education is concerned by educators in many organizations. Therefore, the concept of STEM education also has different interpretations. Currently, there are three main ways of understanding STEM education:

- According to the US Department of Education, "STEM education is a program that provides support, enhancement, and education in Science, Technology, Engineering and Mathematics at elementary and secondary to tertiary level" [5].

- According to Sanders: "STEM education is an interdisciplinary education model that helps students apply scientific, technological, technical and mathematical knowledge to solve some practical problems in a specific context" [5].

- According to Tsupros, Kohler and Hallinen, the American Association of National Science Teachers: "STEM education is an interdisciplinary approach to learning where academic knowledge is closely coupled with practical lessons through the application of students' knowledge of Science, Technology, Engineering and Mathematics into specific contexts that create the connection between schools, communities, and businesses that allow learners develop STEM skills and increase competitiveness in a new economy " [6].

STEM in the context of education STEM is essentially understood as equipping learners with the ability to apply the necessary knowledge and skills related to the fields of science, technology, engineering and math. STEM education is bridge the gap between school and life, create competent people to work in an environment of creativity and use the mind in the work of the era of technology revolution 4.0.

2.2. Actual Situation of Organizing STEM Teaching Activities in High Schools

In the past years, some authors have researched on STEM teaching activities in high schools, such as: Kieu Thi Hai [7]: Developing the ability to apply skill knowledge through teaching STEM of Carbon - Silicon chapter (Chemistry 11); Ngo Thi Toan [8]: Developing the ability to apply knowledge, skill through STEM teaching in Non-metallic Chemistry class 11; Tran The Sang [9]: Building and using some STEM themes to develop the problem-solving and creative capacity for 10th-grade students in High school According to the actual investigation of these authors: Most teachers know about STEM and STEM education, but it is only a brief and inadequate understanding. However, most teachers have found that STEM education has an important role in teaching Chemistry so they want to find out more information about it. Developing competency for students is very necessary, especially the ability to apply knowledge and skills, problem-solving and creative capacity. Students are very interested in STEM; the methods of teaching that promote their abilities and strengths. To understand and navigate the process of designing organizational processes and selecting contents of STEM activities, the author of the study conducted a study on the situation of teaching organization of STEM activities and students' needs in the activities of STEM in high school. The study surveyed from July 2019 to September 2019 with 30 teachers teaching Chemistry at such schools as Son Tay High school; Phuc Tho High School; Ngo Quyen High school; Thang Long High school in Hanoi, 520 students from grade 12 of Son Tay High school and 560 students from grade 12 of Phuc Tho High School. The survey results show that: For teachers: In teaching process, teachers organize STEM educational activities, but the frequency is still low (Figure 1a), the rate of regular use is very low (accounting for 2%), the proportion never used quite high (25%). The cause is thought to be:

+ Firstly: Teachers must follow a fixed teaching plan, while STEM activities are quite time-consuming for both teachers and learners.

+ Secondly: The assessment and examination process in Vietnam is still heavy on knowledge, not focusing on ability assessment.

+Thirdly: Many teachers have not been specifically instructed to design STEM activities, to organize STEM educational activities, and to evaluate students' performance.

- For students:

+ During learning process, the students were very excited to observe an experiment and they really wanted to conduct an experiment or use a specific technical application to make practical products.

+ They were very interested in the STEM festival, the exhibition of scientific products.

+ They also had many practical questions that needed to be answered.

+ Most of the students were interested in the lessons with STEM elements or STEM activities (93% of the respondents). This is a motivating factor and also a favorable factor for the author to conduct pedagogical experiments (Figure 2).

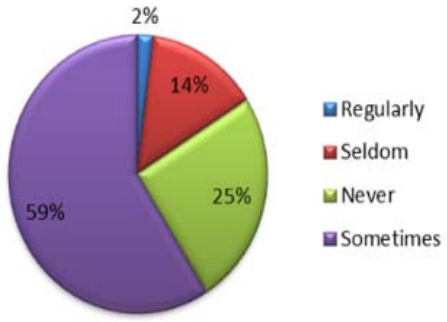

Figure 1a. Chart of teachers' frequency of STEM organization

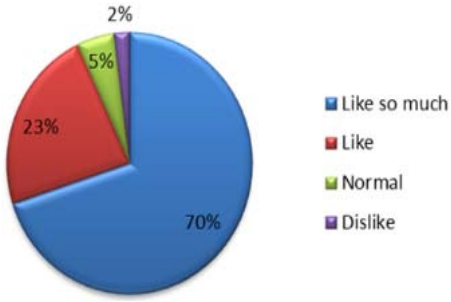

Figure 1b. Chart of students' interest in STEM activities

2.3. Designing the Topic "Producing vinegar from Sugar and Fruit" under STEM Education-oriented

2.3.1. Rationale of the Project

Chemistry is the science that studies the substance, the metabolic method and its application in life; it is a subject very close to human life. Chemistry helps students with knowledge and skills related to the natural world, people through lessons and practice sessions of chemistry. Under the pressure of examinations, most high school students in Vietnam has studied Chemistry only to pass exams, so they do not really paying attention to the practicality of chemistry. Besides, a number of teachers are not aware of the role of chemistry in real life knowledge of chemistry, so most of the lessons are conveying theory from textbook with little attention to the use of that theoretical knowledge in real life activities. In the general chemistry program, students already know that acetic acid is a substance in the composition of vinegar. Vinegar is a popular spice used in processing many dishes of Vietnamese families, but recently the press has reflected many cases of using industrial acetic acid to make it into vinegar. The action raises concerns for consumers about this spice. We have to think about applying knowledge of chemistry to make vinegar for our family. We are the chemistry teacher, with the desire to improve the effectiveness of teaching and learning Chemistry by having students do life-relating experiments to help students learn chemistry in an easy-to-understand and practical way which may bring chemistry closer to life and more appealing to students, we conducted the teaching project: "Producing vinegar from sugar and fruit".

2.3.2. Aims of the Project

- About knowledge:

+ Students point out: Physical properties, the molecular structure of the natural state, applications of saccharose, glucose, starch, and cellulose.

+ Students explain: Why does saccharose have no fermentation reaction but fruits, sugarcane containing saccharose for so long have a sour taste?

+ Students present the main ingredients of vinegar, apply the knowledge they have learned to make vinegar.

- About skills:

+ Students write a chemical equation illustrating the properties of sucrose, glucose, starch, and cellulose.

+ Students get the main chemical equation that occurs during the vinegar fermentation.

+ Students practice thinking in scientific research through performing experimental activities.

+ Students can think independently; ability to build hypotheses, observe experimental phenomena, make comments and conclusions; group activity capabilities, information gathering, and reporting.

- Attitude and capacity are formed:

+ Active learning actively, love scientific research.

+ Ability to apply knowledge of chemistry to live: Discover the content of knowledge of chemistry about carbohydrates that are applied in life's problems; Identify life problems related to carbohydrate properties and use knowledge of chemistry to explain; Independent creativity in handling practical problems.

2.3.3. STEM Knowledge in the Topic

The STEM knowledge in the topic are shown in Table 1.

Table 1. The STEM Knowledge in the Topic

STEM	Related knowledge
Science (S)	- Glucose (Lesson 5 - Chemistry of grade 12); - Saccharose, starch, and cellulose (Lesson 6 - Chemistry of Grade 12); - Nutrition, material and energy metabolism in microorganisms (Lesson 22– Grade 10 Biology); - Reproduction of microorganisms (Lesson 23– Grade 10 Biology); - Growth of microorganisms. (Lesson 25– Grade 10 Biology).
Technology (T)	Application of microbiological technology in the production of vinegar.
Engineering (E)	Process of producing vinegar
Math(M)	Calculates the amount of sugar and fruit needed to make vinegar

2.3.4. Conducting activities

Activity 1: Determining requirements for making vinegar

• Step 1: Set the problem, transfer tasks

On the basis that the teacher has assigned the student to go home to find out information about edible vinegar, benefit of vinegar and ingredients for vinegar, the teacher asks questions for students to answer: What is vinegar, what is the use of vinegar, and what are the ingredients for vinegar?

Teacher summarizes and adds, points out:

- Edible vinegar is a solution of acetic acid (CH_3COOH) in water with a concentration of about 2%-5%, formed from the fermentation of ethyl alcohol or sugar water.

- Edible vinegar is a very familiar spice in Vietnamese cuisine. Some studies also show that if used with the right amount of vinegar still has healing effects.

• Step 2: Assign tasks to students and set up product requirements

The teacher stated the task: Based on the findings, the groups will implement the project "producing edible vinegar from sugar and fruit".

Edible vinegar products should meet the following requirements:

✓ Edible vinegar has a natural aroma of fruit

✓ Sweet and sour taste

✓ Cloudy and colored according to the material, shaking the bottle the foam slowly dissolves dissolving

✓ The volume is about 250 -500 ml.

Vinegar prepared from acetic acid Homemade vinegar

Figure 2. Vinegar from acetic acid and homemade

Figure 3. Reporting process for making vinegar

• Step 3: Teachers approves on implementation plan

Table 2. The Lesson Progress

Main activities	Duration
Activity 1: Assigning project tasks	45 minutes
Activity 2: Research background knowledge and reporting	90 minutes (Students study at home in groups, report in class about 45 minutes)
Activity 3: Prepare product designs to report, select and report design plans	45 minutes
Activity 4: Making and testing products	1 week (students do at home in groups)
Activity 5: Exhibition, product introduction.	45 minutes

Activity 2: Research on the structure of glucose, saccharose, starch, cellulose and other factors affecting vinegar fermentation

Students learn and discuss at home to learn the assigned knowledge:

Content 1. Glucose

Content 2. Saccharose

Content 3. Starch - Cellulose

Content 4. Factors affecting the vinegar fermentation

Students self-study and discuss in groups to agree on relevant knowledge. In class, students report in groups. Teacher and other group students evaluate. At the end of the lesson, the teacher will assign tasks to the groups about making vinegar. After students report, cross-evaluate, teachers summarize and guide students to apply the learned knowledge to the next task through the following questions:

- Starch hydrolysis reaction
- Vinegar fermentation reaction
- Factors affecting the vinegar fermentation.

The teacher assigns the following task: Base on the knowledge they have learned, students have to design the process of making vinegar from sugar, fruits ... Requires a product poster containing the following contents:

- Diagram of steps to make vinegar
- Expected raw materials (including the quantity of sugar, the number of fruits, fermentation time, fermentation conditions)
- Chemical reactions occur.

Activity 3: Designing, presenting and defending fruit and vegetable vinegar-making plans

Step 1: The teacher organizes for groups of activities to present the blueprint and select the blueprint for the group.

Step 2: Each group in turn presents the design plan for 5 minutes. The remaining groups pay attention to.

Step 3: The teacher organizes the remaining groups to ask questions, comment on the design plans of your group; the group presented answers, defended, received comments, gave appropriate corrections.

Step 4: The teacher comments, summarize and standardize relevant knowledge, finalize issues that need attention and editing of groups.

Step 5: The teacher assigns teams to deploy to manufacture products according to the design.

Activity 4: Producing vinegar from sugar and fruits, testing products

(Students work at home or in the lab)

Step 1. Students search and prepare the ingredients

Step 2. Students make vinegar according to the design

Step 3. Students test the quality of vinegar, comparing with the product evaluation criteria (Evaluation form). Students readjust the design, record the adjusted content and explain the reason (if need to adjust)

Step 4. Students complete the list of ingredients to produce products

Step 5. Students complete the product; Prepare product introduction.

Activity 5: Presenting edible vinegar products made from sugar and fruit

- Students display products. Representatives of other groups and teacher check, try the products, and score on the evaluation card.

- Students of each group to present the processes and chemical reactions that occurred.

- Teacher gives comments and publishes the product grading results as required by the evaluation sheet.

- Teacher asks questions to clarify the steps and chemical reactions that took place to inculcate knowledge related to the topic.

+ Compare edible vinegar made from different ingredients.

+ Which type is formed faster, explained?

- Encourage the group to raise questions to the other groups.

- Teacher summarizes the activities of the groups; Instruct groups to update their study points. Teacher gets feedback via a questionnaire:

Table 3. Student Questionnaire on the Level of Achievement of the Ability to Apply Knowledge and Skills

Full name:……Class:……Group……

Content name: ……

Opinions of students / Question	Totally agree	Agree	Disagree	Absolutely not agree
1. You understand the lesson and apply the knowledge to discover and explain practical problems.				
2. The task of learning is fit for you.				
3. You can practice more than the regular lessons.				
4. You can exchange, communicate and cooperate with friends better.				
5. Lessons help you develop your ability to apply knowledge and skills.				
6. You know how to plan the implementation of the topic and propose solutions to solve problems in the learning content.				
7. You participate effectively in developing learning products.				
8. You know how to evaluate the results obtained from performing a learning task.				
9. Lessons help you develop logical thinking				
10. You feel more love chemistry.				

Activity 6: Evaluation and summary

- Teacher designs self-evaluation sheet for groups, evaluation forms commented by the teacher, the questionnaire about students' interest after finishing the project. This is a very significant and necessary activity when closing the STEM project.

- The points of each group are calculated by the average points evaluated by the student's group and teacher themselves.

2.4. Pedagogical Experiment Results

We conducted pedagogical experiments naming: "*Producing vinegar from sugar and fruit*" with 77 students of experimental classes of grades 12A1 and 12A2 of Son Tay High school, and control classes with 81 students in two classes 12A1, 12A2 of Phuc Tho High school in the school year 2019-2020. We have designed the lesson plan and carried out the activities, evaluated the products of the student groups. All groups have good products. The results are calculated by the average points of students' self-assessment sheets and teachers' ones. After building a system of STEM activities, the authors of the study developed an observation checklist to assess the development of students' ability to apply knowledge and skills in the process of performing assigned tasks, corresponding to each separate activity such as:

- Applying knowledge of chemistry to explain and prove a practical problem.

- Detect and explain chemical applications with different problems and fields in practice.

- Detecting and explaining practical problems related to chemistry

- Applying knowledge of chemistry and interdisciplinary knowledge to explain some natural phenomena and applications of chemistry in life.

- Ability to analyze and synthesize knowledge of chemistry to critically evaluate the impact of a practical problem.

- Evaluation: apply general knowledge to critique and evaluate the impact of a practical problem.

- Innovation: Applying general knowledge to propose some new methods, measures, model design, and problem-solving plan.

- Having appropriate behavior in situations related to health problems of yourself, your family and society, and reacting to nature with the requirements of socially sustainable development and environmental protection.

Table 4. Evaluation sheet of ability to apply knowledge of chemistry

Full name of the assessed student: ……

Criteria	Level 1 (1 point)	Level 2 (2 point)	Level 3 (3 point)	Level 4 (4 point)
1. Student discovers practical problems				
2. Student mobilizes knowledge related to practical issues and proposes scientific hypotheses				
3. Student explores chemical knowledge related to the practice				
4. Student solves practical problems, evaluate practical problems				
5. Student proposes measures, solves practical problems and propose new problems				

Experimental results are shown in Table 5.

Analyze the development level of the ability of applying the knowledge based on the above results:

- The results of handling the competency criteria the ability to apply skills knowledge in students after the topic evaluated by teachers show that the p-value is <0.05, the ES impact level is 0.76. From the ES value, it shows that the above experimental results have a medium impact level, that is, the impact has a moderate impact, and this study can be replicated.

Table 5. The Results of Assessing the Ability to Apply knowledge skills based on the observation checklist

Criteria	Experimental class					Control class				
	The number of students score				Criteria average point	The number of students score				Criteria average point
	1.0	2.0	3.0	4.0		1.0	2.0	3.0	4.0	
1	5	5	35	32	3.22	20	22	21	18	2.46
2	4	6	33	34	3.25	21	24	20	15	2.33
3	3	8	30	36	3.38	17	24	23	17	2.49
4	3	4	31	39	3.38	25	21	19	16	2.32
5	5	15	27	30	3.06	22	20	23	16	2.41
The average point of experimental class = 3.24						The average point of control class =2.41				
The difference of average point = 0.83										
The standard deviation of experimental class = 0.91						The standard deviation of control class= 1.09				
Allow independent verification test p= $1.82.10^{-6}$										
ES level = 0.76										

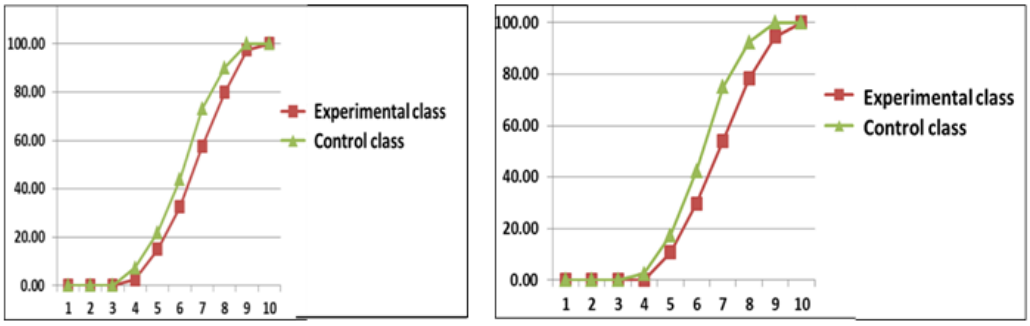

Figure 4. Cumulative test score for students of Son Tay & Phuc Tho High School

- The average score of the criteria to evaluate the ability to apply skills knowledge in the experimental class after the impact is higher than the experimental class before the impact. The difference of that average value is 0.83, showing that STEM-oriented teaching methods have a great impact on developing the ability to apply knowledge and skills for students.

- According to the progress chart, the ability to apply the knowledge and skills of the experimental class after the impact increases gradually during training, shown in the graph above, each criterion goes up.

In addition, we design special tests and build answers to assess students' ability to apply their knowledge.

From the experimental results, we have the following assessment: Experimental class has a good percentage of students better than the percentage of students who are quite good at the control class. In contrast, the rate of weak students and average students in the control class is higher than the percentage of weak and average students in the experimental classes. Thus, the experimental plan has a positive impact on the experimental class, students have the skills to solve practical problems, practical skills, meeting the requirements of the STEM topic.

The graph of accumulated test scores of experimental class is always on the right and below the cumulative lines of the control class. This proves that the students of the experimental classes meet the requirements and goals of the teaching topics oriented to STEM better than students in the control class.

3. Conclusions

From the results of the pedagogical experiment, the following conclusions can be drawn:

(1) It can develop the ability to apply students' skill and knowledge through STEM activities.

(2) In order to create conditions for students to develop the ability to apply the knowledge and skills, it is necessary for the teachers to select and design STEM activities that are practical, close to the students' life in order to create excitement and motivation for student's learning. Besides, teacher should create a safe and friendly learning environment, always encourages students to raise questions, create and propose ideas in learning.

(3)The project "Producing vinegar from sugar and fruit" has contributed to students' confidence, excitement and developed their ability to apply knowledge and skills. This makes chemistry closer to life, combining theoretical knowledge with real life. This is a learning activity helps students formulate their experimental capacity, the ability to apply knowledge into practice, the ability to solve problems, stimulate intelligence, curiosity, and absorb new knowledge and increase motivation in chemistry learning.

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