HNUE JOURNAL OF SCIENCE DOI: 10.18173/2354-1075.2021-0203
Educational Sciences 2021, Volume 66, Issue 4E, pp. 220-234
This paper is available online at http://stdb.hnue.edu.vn

ORGANIZATION OF STEM LESSON ON "*MAKING A SMART EPOXY NIGHT LIGHT*" TO DEVELOP CREATIVE AND PROBLEM-SOLVING CAPABILITY FOR HIGH SCHOOL STUDENTS

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Abstract. Developing students' creativity and problem-solving capability is a necessary, important, and long-term goal in high schools. Integrating STEM topics into the high school curriculum through interdisciplinary integration of subjects to solve real-life problems helps learners create practical products with useful application. Thanks to the STEM topics, learners are encouraged to apply their acquired knowledge to solve specific problems in real life, from which many different competencies are formed and developed for students especially problem-solving and creativity. The article presents the impact of applying STEM topics in teaching Chemistry to the development of students' creative and problem-solving abilities, the process of designing STEM topics in teaching Chemistry, the steps to implement the topic, product evaluation criteria, evaluation criteria for component competencies of creativity and problem-solving capability, and the results to develop students' problem-solving and creative capability through experimental teaching activities in high schools. The data obtained from the teacher's assessment and the students' self-assessment showed obvious development of students' creative and problem-solving capability in the experimental class.

Keywords: STEM education, problem-solving skills and creativity, chemistry teaching, high school students, smart epoxy night light.

1. Introduction

Problem solving and creativity are the most important skills that high school students need to form and sharpen in the learning process [1]. Therefore, the education program that promotes students' qualities should focus on problem-solving and creativity skills.

"STEM education is an interdisciplinary approach to learning, where academic knowledge is closely combined with practical lessons through the application of scientific knowledge including Technology, Engineering, and Mathematics into concrete contexts, creating a connection between schools, communities, and businesses that allows learners to develop STEM skills and increase competitiveness in the new economy" [2]. A considerable number of countries have focused on STEM. STEM has been beneficial for high school students to develop their qualities, especially creativity and problem-solving capability.

Ngày nhận bài: 16/8/2021. Ngày sửa bài: 17/10/2021. Ngày nhận đăng: 24/10/2021.
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In the world, STEM education is focused on investment and development through many programs and projects. These programs aim to guide teachers to effectively apply teaching methods in teaching STEM topics, taking learners as the center, students actively occupying knowledge, developing competence and skills for students in directing students towards STEM fields, to develop a qualified workforce in STEM fields, which is one of the main objectives of the STEM education reform. Hui Hui Wang [3] illustrated the need for teachers to plan dialogic, authentic interaction with students to build shared meanings about scientific concepts to enhance STEM learning. Engin Karahan *et al.* [4] found that the STEM career maturity program that was designed and implemented herein has positive impacts on the career counseling competencies and performance indicators of the participants, as well as their knowledge and awareness of professional STEM areas.

In Vietnam, Le Xuan Quang [5] has paid much attention to STEM education, defined the concept of STEM education, built STEM education programs as well as experimented with the possibility of STEM education. Chu Cam Tho studied the lessons on changing teacher training/retraining from STEM and open math day in Vietnam [6]. Nguyen Thi Thuy Trang presented terpene topics - advanced grade 11 chemistry in STEM model [7]. Do Thi Thu Thuy [8] focused on clarifying the basis of problem-solving and creativity and how to assess students' ability through teaching *Nitrogen group* lessons. However, until now, the development of problem-solving and creative skills for high school students through building STEM topics in chemistry has drawn little attention from the education program. Therefore, the research of STEM in Chemistry that has interdisciplinary integration with other subjects to develop creativity and problem-solving abilities for high school students should be focused more. In this paper, a study on the organization of the lesson on "Making a smart epoxy night light" to develop creativity and problem-solving capability for high school students has been presented.

2. Content

2.1. Some concepts

According to the concept of General education program 2018, STEM education is an educational model based on an interdisciplinary approach, helping students apply science, technology, engineering, and math knowledge to solve several practical problems in specific contexts [1]. STEM education helps students: Realize the importance of S-T-E-M knowledge and skills in solving practical problems and designing and manufacturing products; recognize the need for life-integrated, interdisciplinary insights and the power of S-T-E-M fields in today's economy and society; be equipped with skills of global citizens in the 21st century such as critical and creative thinking, expression and presentation skills, exchange and collaboration skills; have a positive impact on the ability to choose a future career when there are many opportunities to acquire hands-on experiences in many areas of life [9].

According to [1, 10] creative and problem-solving competence is an individual's ability to solve problematic situations for which conventional processes, procedures, solutions are not available or can skillfully solve problems with their own unique features and in a constantly innovative way that is consistent with reality, valuable and socially meaningful.

2.2. Designing a STEM-based teaching process "*Making smart epoxy night light*" for high school students

The content of a STEM lesson or topic must meet six criteria [2, 11]. After consulting several documents on the STEM teaching process [2, 12-16], our STEM topic to develop problem-solving and creativity for high school students have been formulated in five steps:

- ***Step 1***: Select teaching content: There are many types of epoxy night lights on the market today. However, the prices for these products are very high, which is not suitable for the mid-range market segment. Based on an interdisciplinary combination of knowledge of Informatics, Physics, Mathematics, Technology, and Biology, students can make a smart epoxy night light with low cost, very little electricity consumption to help meet the customers' needs.

- ***Step 2***: Identify the problem to be solved: For students to clearly define the problem to be solved, we suggest the 4W + 1H questionnaire. Students learn knowledge and information to give their own answers, then discuss in groups to identify problems to be solved.

- ***Step 3***: Develop product criteria/problem-solving solution: We discussed building several criteria for the product and came to a consensus on the criteria that must be based on factors like production cost, product size, usability, sourcing of materials, and product effectiveness.

- ***Step 4***: Design the teaching process: The teaching topic consists of 6 lessons in class (45 minutes each lesson) and the project implementation time at home is 3 weeks. To effectively develop students' competencies, especially problem-solving and creativity, when designing teaching activities, we used some active teaching methods and techniques such as project-based learning method (PBL), a problem-solving method, group discussion methods, KLEWS, mind mapping and brainstorming techniques. In each teaching activity, we clearly stated the time to perform the activity, objectives, content, expected learning products that students must complete, and assessment methods in each of those activities.

- ***Step 5***: Evaluation: To assess the impact of the topic on the development of problem-solving and creativity for students, we based the evaluation on the process and results of the project.

2.3. Lesson plan on the topic of "Making smart epoxy night light"

Based on the EDP engineering design process (Figure 1) [16, 17], we build a STEM-themed teaching design process "Make a smart epoxy night light" including activities performed in sequence the following (Figure 2).

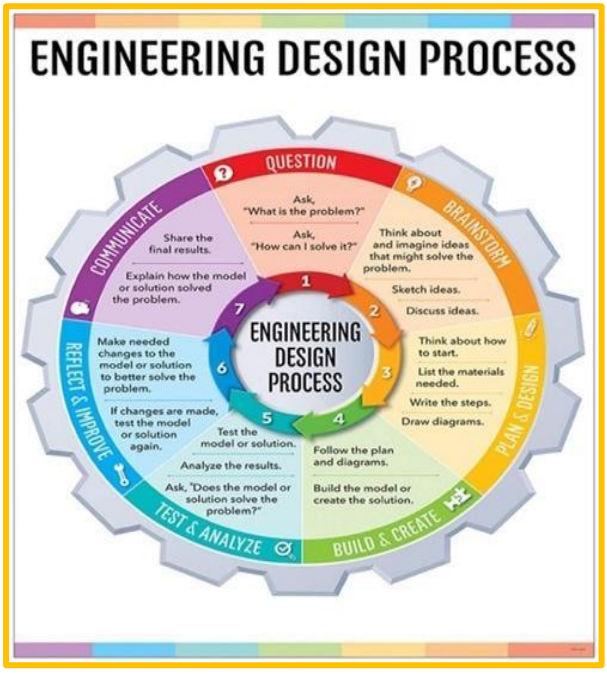

Figure 1. Engineering design process

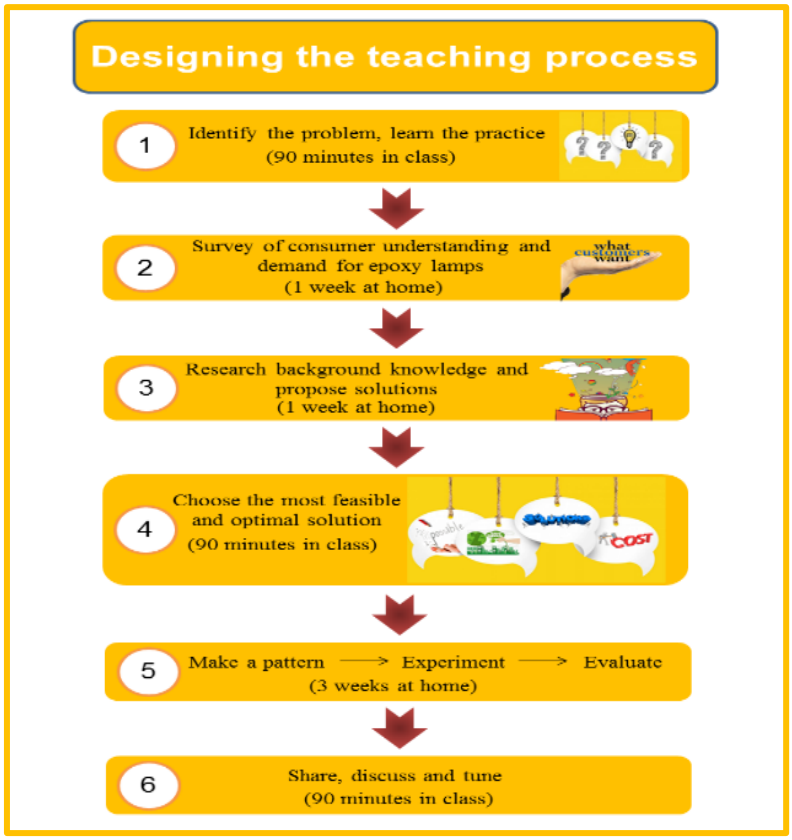

Figure 2. Designing the teaching process"Make a smart epoxy night light"

2.3.1. Identify the problem, learn the practice "*Make a smart epoxy night light*"

To make a smart epoxy night light based on a number of practical problems as follows: Epoxy night light is gaining popularity because it is compact, beautiful, convenient and made from environmentally friendly materials. However, the cost of an epoxy lamp is still very high for the Vietnamese consumer market; energy saving is a requirement that needs to be addressed as fuel sources are becoming increasingly scarce; a night light with a color suitable for the bedroom space brings comfort to the user; applying the development of science, technology and information technology as well as integrating smart features of epoxy lights on phones brings modernity and convenience to users.

2.3.2. Survey of consumer knowledge and demand for epoxy lamps

We distributed questionnaires to customers on "Consumer knowledge and demand for epoxy lamps". Due to the impact of the Covid epidemic, an online survey by sending questionnaires to a group of students' parents and all teachers at Thanh Mien High School was conducted. Amount of 116 people took part in the survey. The results obtained are as follows: There are 21.05% of respondents saying that their families are using epoxy night lights, this is a low number; Most of the respondents wanted to own a night light with a price of less than 300,000 VND (63.16%), only 3.51% of the respondents said that they wanted to own a night light that is more than 800,000 VND; There were many comments of consumers who wanted to own a night light controlled by phone (38.60%) or controlled by voice (48.25%); Most of the comments mention that consumers wanted to own an eco-friendly night light that is personally designed. Based on the survey results, we choose the options for manufacturing epoxy lamps that are the most suitable and best meet the needs of customers.

2.3.3. Research background knowledge and propose solutions

**** Background knowledge***

Science

- Chemistry: The bonding and curing ability of epoxy adhesives; heat resistance, strength, transparency, light penetration of epoxy resin; the ratio of epoxy glue and curing agent in volume or weight to create epoxy resin.

- Information technology: Use a laptop or smartphone to search for documents for the project; using WS2812B RGB LED combined with control and timer by smartphone via Blink software; Use ESP8266EX Wifi chip to control; C++ programming language and Arduino IDE software; using Word and Powerpoint tools to build plans for the project, design survey forms, design posters, project product reports; design process of the night light (base part).

- Biology: Effect of color and light intensity on sleep.

- Physics: Archimedes' principle (avoid the situation when pouring the glue, the woodblock floats on the surface of the glue mixture).

Technology (T)

- The process of creating epoxy night lights: The body part (made from epoxy glue) and the lamp part; the process of creating the lamp body.

- How to create lamp molds, design patterns, lamp styles.

- The process of using a programming language to make LED lights, integrating control software on the phone.

Engineering (E)

- Selection of materials (selection of glue, molding materials) to design the lamp body, selection of materials and decorative materials for the lamp.

- Fabrication of the lamp body.

- Application of the mixing ratio between the glue part (Denoted as A) and the curing agent part (Denoted as B) according to the ratio of volume or weight to best cure the glue in the shortest time.

- Application of programming language, advanced knowledge of informatics to design LED night lights as required.

- Usage of tools and laboratory equipment.

Math (M)

- Use formulas to calculate the volume of cubes, prisms.

- Calculate the amount of glue needed to create the lamp frame, and the necessary cost to create an epoxy night light.

**** Proposing solutions***

Some solutions proposed by the groups are as follows:

- Solution 1: Make a simple epoxy night light, in which the LED part is submerged in the middle of the glue.

- Solution 2: Make an epoxy night light in which the lamp part and the lamp part are separate, the lamp has only one color with manual on/off control like conventional night lights.

- Solution 3: Make an epoxy night light with integrated smart features such as light color control, brightness intensity control on phones or devices with a wifi connection.

2.3.4. Choosing a solution

The teacher organized a 90-minute session for students to report in class on the production options of epoxy lamps, analyze the advantages and disadvantages of these methods and choose the optimal solution to ensure what will work best for the students.

- Teachers and students analyzed the solutions and agreed not to make epoxy lights according to the first solution because when the LEDs are broken, the product can no longer be used, which means the lifespan of the product is not long.

Table 1. Criteria for evaluating the project "Make smart epoxy night lights"

Criteria		**Level 1 (1 point)**	**Level 2 (2 points)**	**Level 3 (3 points)**	**Level 4 (4 points)**
1. Costs		δ 1,000,000 VNĐ	δ 500,000 VNĐ	δ 400,000 VNĐ	δ 200,000 VNĐ
2. Functionality		Only night light.	- Night light. - Decorative light.	- Night light. - Decorative light. - Controlled by touch screen on the mobile phone.	- Night light. -Decorative light. - Controlled by touch screen on the mobile phone.
3. Size		- Height ε 30 cm - Length, Width ε 15 cm	- Height > 20 cm - Length, Width > 12 cm	- Height δ 20 cm - Length, Width δ 12 cm	- Height δ 15 cm - Length, Width δ 10 cm
4. Material availability	*Lamp body*	Buy whole part and hard to find.	- Easy to search but buy the whole part.	- Easy to search, buy only parts of the materials.	Easy to find, and fully craftable.
	Light box	Buy the whole part.	Craft partially and buy the rest.	Craftable under the guidance of experts.	Fully craftable.
	LED light	Buy the whole part.	Craft partially and buy the rest.	Buy materials then craft under the guidance of others.	Fully craftable from simple materials.
5. Efficiency		The light can work but it is not stable (sometimes the light is on, sometimes the light is off), when there is a problem, it takes a long time to fix.	Lights work normally, but still have problems and take a long time to fix.	Lights work fine, (problems happen sometimes but can be fixed).	The lights work well, no problems.

- Teachers and students jointly divided tasks based on student's abilities and interests:

+ Group I: Manufacturing epoxy lamps according to option 2 proposed above from available materials.

+ Group II and group III, each group builds an epoxy lamp body.

+ Group IV: Students with in-depth knowledge of Informatics, using C++ programming language to design LED lighting systems that can control color, brightness intensity, on and off switches on phones or other electronic devices that can connect to Wifi. This lighting system is fitted into group II and group III lamp body parts to create a complete smart epoxy night light.

- After selecting the solution, the teacher and students agreed on the product evaluation criteria. The finished product is evaluated based on the established criteria. The higher the evaluation score is, the better quality the product possesses.

2.3.5. Prototyping, testing and evaluation

Students spent 3 weeks working from home to complete the product. Students worked from home in assigned groups with the support of the teacher, students complete the assigned tasks according to the plan (Figure 10). The making of epoxy lamps includes the following steps:

***Step 1*:** Select raw materials and materials: epoxy glue, fillers, decorative materials, LED lights.

***Step 2*:** Make the lamp body from epoxy glue.

Figure 3. Steps to make the lamp body

Step 3: Make the lamp base: Choose the LED box to fit the size of the lamp body, then make the LED.

Stage 1: Researching the lamp's software and hardware.

Stage 2: Fabrication of LEDs.

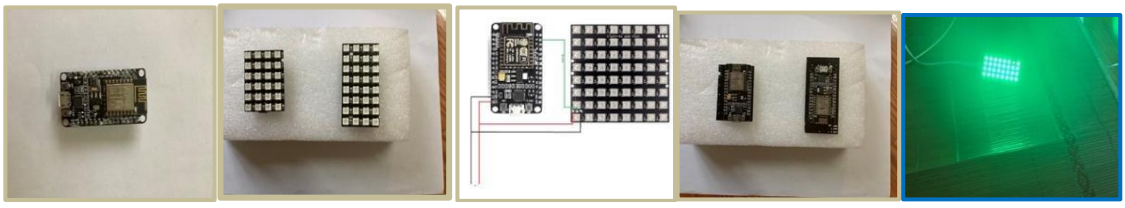

Figure 4. LED fabrication and testing

Stage 3: Software development

Stage 4: Complete hardware and overcome some difficulties in the process of hardware completion.

Stage 5: Overcoming software defects; changing hardware to match each lamp; uploading software to the node.

Stage 6: Connecting to Wifi to control lights via phone or computer.

Figure 5. Students make the lamp body

Figure 6. Students make LED lights that connect to Wifi and control via smartphone

Figure 7. Students process data and make product reports

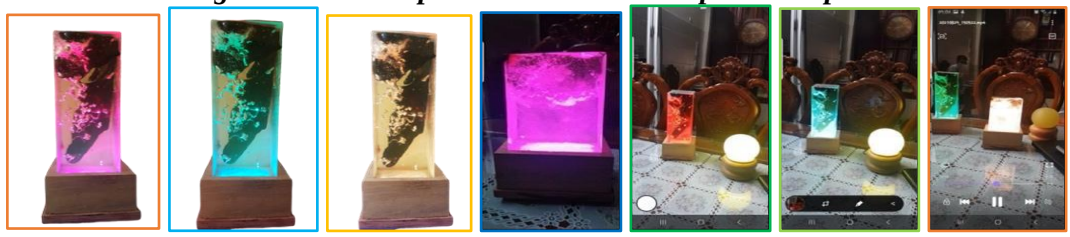

Figure 8. Finished epoxy lamp product

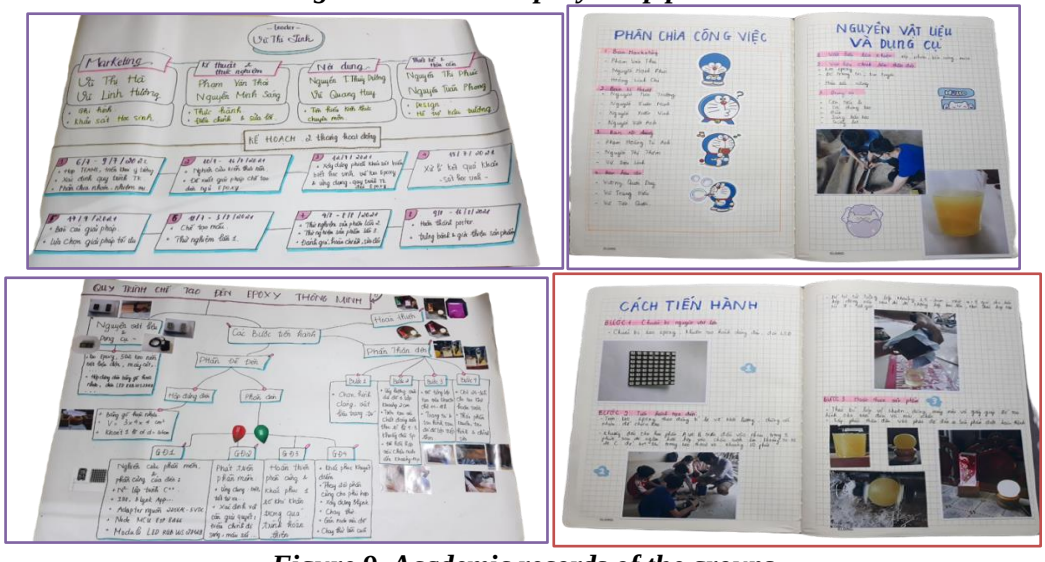

Figure 9. Academic records of the groups

2.3.6. Sharing, discussing, and adjusting

After completing the project product, the teacher gave the students the following reports:

- Summary report of the entire smart epoxy lamp manufacturing project (Illustrated through the introduction poster, Figure 10).

- Report on the manufacturing process of smart epoxy lamps (Illustrated through the introduction poster, Figure 11).

- Product introduction report (Illustrated through the introduction poster, Figure 12).

At the end of the reports, students, experts, and teachers attended the product tour, asked questions about the product, made comments, and suggestions on how to make a better product.

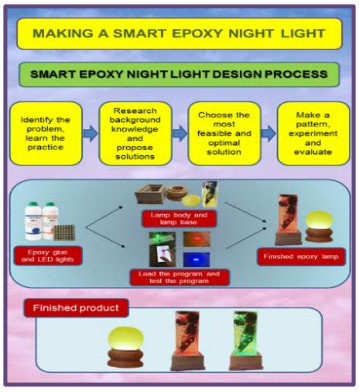

Figure 10. Poster summarizing the steps of designing lessons for making smart epoxy lights

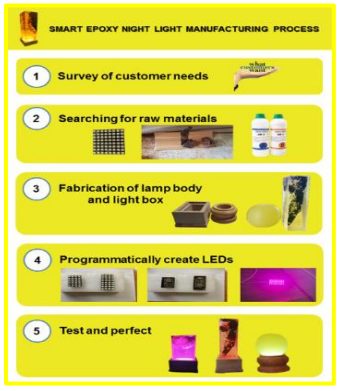

Figure 11. Poster introducing the process of making smart epoxy lights

Figure 12. Product introduction poster

Figure 13. Some pictures of the report and product introduction session

2.4. Assessing the development of students' creativity and problem-solving capability in teaching the topic "*Making a smart epoxy night light*"

Based on the criteria and manifestations of creativity and problem-solving capability [1, 8, 10], a Rubric is built to evaluate the component capabilities and presented in Table 2.

Table 2. Building criteria and assessment level of creativity and problem-solving competence

Criteria	Levels of accomplishment			
	Level 1	***Level 2***	***Level 3***	***Level 4***
1. Data Collection and analysis from different sources to	Rely on others for information. Unable to analyze data.	Show minimum capability of collecting and analyzing to reveal trends	Capable of collecting data from different trusted sources. Analyze data for	Show great capability of collecting and processing data. Analyze the

reveal and evaluate possibility and reliability of ideas.	Data may not be reliable.	and ideas. Data may not be cohesive.	the possibility and reliability of the ideas. Data may not be clear.	possibility and reliability of the ideas. Data is trustworthy and cohesive. Relevant knowledge is clearly stated.
2. Recognize and state situations where the problems emerge during the study process or in practice.	Only capable of recognizing the *situations that have problems* (SHP) under the instruction of teachers. SHP may not be fully understood and well stated.	Capable of recognizing SHP during the learning process and in practice. Show minimum capability of stating SHP.	Possess a good level of recognizing SHP. Capable of stating SHP. SHP may not be clearly understood and stated.	Master at recognizing SHP in both study and practice. Fully understand and clearly state SHP.
3. Analyzing the SHP in study and practice.	Only capable of recognizing the problems under the instruction of teachers. Unable to analyze the problems.	Capable of recognizing problems during the learning process and in practice. Show minimum capability of analyzing the problems.	Possess a good level of recognizing problems in both study and life. Capable of analyzing the problems. Problem may not be fully analyzed.	Fully recognizing problems in both study and practice. Problems are clearly stated and well analyzed.
4. State ideas in a new way of thinking, be creative based on different existing ideas. Capable of connecting ideas, researching solutions for real problems. Capable of risk evaluation and a backup plan.	Capable of finding some ideas in study under the instruction of teachers. Show a new way of problem-solving but unable to connect the ideas and research them. May not have any backup plan and risk evaluation.	Capable of finding some ideas in study and life. Show limited capability of problem-solving in a creative way. Capable of researching solutions for simple problems. May not have any backup plan and risk evaluation.	Capable of finding some ideas in study and life. Show capability of problem-solving in a creative way. Capable of researching solutions for problems. Limited backup plan and risk evaluation.	Great capability of finding ideas in study and life. Show limited capability of problem-solving in a creative way. Capable of researching flexible solutions for problems. Detailed backup plan and risk evaluation.

5.Collect and clarify information related to problems, recommend and analyze solutions to problems.	Collecting limited amount of information under the instruction of the teachers. Information may not be well analyzed. Unable to recommend solutions.	Collecting limited amount of information independently. Information may not be cohesive. Unable to recommend solutions.	Collecting limited amount of information. Information is analyzed fully. Unable to recommend solutions.	Work independently to collect and organize information. Utilize information effectively to create multiple solutions in different fields.
6. Evaluating advantages and drawbacks of solutions and choosing the best.	Randomly choose one of the available solutions	Ask teachers about different solutions, then choose one.	Independently evaluate different ideas to choose one. Solutions may not be thoroughly evaluated.	Using different skills to compare different solutions to choose the most feasible and effective solution.
7. Put the solutions selected into practice	Applying the solution in a given way, not an effective one.	Changing small parts under the instruction of teachers.	Capable of working independently to change small parts. The changes may not be major or creative.	Applying the solutions in a flexible and creative way.
8. Evaluating recently applied solutions and improving them.	Capable of evaluating the solution but unable to recommend ideas to improve.	Capable of evaluating the solution. Show limited capability to recommend ideas to improve.	Capable of evaluating the solution. Show capability to improve the solution. The improvement may not be in major part.	Capable of evaluating the solution. Show capability to improve solutions effectively in new situations.
9. Valuable questions. Evaluating the information objectively.	Ask some questions under the instruction of teachers. Easy to accept any ideas even biased ones.	Capable of asking questions related to the problem. Limited critical thinking skills. Show little skills attention to theory related to the problems.	Capable of asking questions related to the problem. Not easy to accept one-sided information. Show attention to theory or ideas related to the problems.	Capable of asking questions related to the problem. Not easy to accept one-sided information. High level of critical thinking. Show attention to theory or ideas

				related to the problems. Ready to review the entire problem if necessary.
10. Evaluating the problems, ready to consider related ideas and reconsider the problem.	Only care if the product work or not. Little attention to the advantages or disadvantages of the solution.	Evaluating the product's advantages and disadvantages. Unable to prove advantages and disadvantages.	Evaluating the solution thoroughly. Advantages and disadvantages are carefully analyzed. Capable of recommending some improvements	Make comparisons with existing products. Recommend solutions to improve and make product competitive,

To evaluate the feasibility and effectiveness of the proposed teaching process, we conducted a pedagogical experiment in class 12A (43 students) of Thanh Mien High School (Hai Duong). The development of students' problem-solving and creative capability before and after participating in the project is assessed by the teacher and by the students' self-assessment through a toolkit that includes a criterion-based assessment sheet (for Teachers), rubrics, KLEWS diagrams, topic product evaluation sheets, topic performance evaluation sheets. The experimental data were processed and presented in Table 3.

It can be seen in Table 3 that through teachers' evaluations, the scores according to the criteria of problem solving and creativity of the criteria after the impact are higher than that of the time before the impact, especially within criteria 8, 9, 10. This once proves that the STEM-based teaching method has had a positive impact on the development of students' problem-solving skills and creativity.

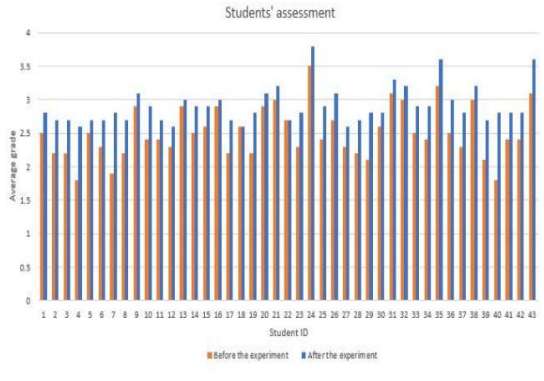

Figure 14. Graph of developing the problem-solving and creative ability of students in grade 12A after impact versus before impact through student assessment

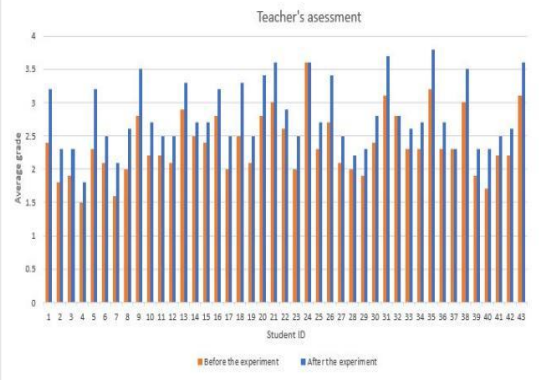

Figure 15. Graph of developing the problem-solving and creative ability of students in grade 12A after impact versus before impact through teacher assessment

The graphs in Figure 14 and Figure 15 show that through the assessment of teachers and students, the scores of students' problem-solving and creative abilities according to the following criteria have increased significantly compared to the time before the impact. From the analysis results, it is shown that students' problem solving and creativity are developed after students participate in the project, this change is not due to randomness but due to impact. The ES value from the evaluation questionnaire of teachers shows that the project has a great influence on the development of problem-solving skills and creativity of students ($0.8 < ES = 0.94 < 1$). In addition, since the p-value in the T-Test ($p = 7.00.10\text{-}5$) is always less than 0.05, it shows that the obtained data is reliable and the project is significant in developing and problem-solving skills for students. This reflects the development of problem-solving skills and creativity in students through the experimental process.

Table 3. Results of the assessment form on the level of development of problem-solving and creativity of students of grade 12A before and after participating in the project (assessment by the teacher)

Criteria	**Number of students who scored (Ex: Experiment)**								**Average score on the criteria of problem solving and creativity capability**	
	Level 1		***Level 2***		***Level 3***		***Level 4***			
	Befor Ex	After Ex	Before Ex	After Ex	Before Ex	After Ex	Before Ex	After Ex	Before Ex	After Ex
1	0	0	9	3	27	26	7	14	2.95	3.26
2	0	0	8	2	28	31	7	10	2.98	3.19
3	0	0	11	7	27	29	5	7	2.86	3.00
4	0	0	26	23	15	16	2	4	2.44	2.56
5	7	2	21	15	13	23	2	3	2.23	2.63
6	2	1	28	22	13	17	0	3	2.26	2.51
7	5	5	26	24	10	10	2	4	2.21	2.3
8	16	1	18	21	9	20	0	1	1.84	2.49
9	4	0	32	1	6	32	1	10	2.09	3.21
10	10	0	30	10	3	26	0	7	1.84	2.93
The average score on the criteria of problem solving and creativity capability									**2.37**	**2.81**

Table 4. Results of the analysis of the evaluation form on the level of development of problem-solving and creative ability of students in grade 12A before and after participating in the project (reviewed by teachers)

Mode	Teacher		Student	
	Before the experiment	*After the experiment*	*Before the experiment*	*After the experiment*
	2.3	2.5	2.2	2.8
Median	2.3	2.7	2.4	2.8
Mean	2.37	2.81	2.51	2.91
Standard deviation	0.46	0.50	0.38	0.28
Level of influence ES	0.941831063		1.031970403	
Pair test T – test	$7.00.10^{-5}$		$4.324.10^{-7}$	

3. Conclusion

Based on theoretical research on the process of building a STEM topic combined with building criteria for evaluating component competencies of problem-solving and creativity, we have designed activities and organized teaching STEM topic "*Making a smart epoxy night light*" through PBL and problem-solving methods to develop the problem-solving and creative capability for high school students. Through the process of experience, students can apply interdisciplinary knowledge and STEM skills to creatively solve practical problems. Students not only acquire knowledge by themselves but also develop problem solving and creativity thereby forming a passion for scientific research and school subjects, as well as promoting self-discipline, proactiveness, and creativity in the learning environment and life. Students also can interact in society, playing the role of members of society, creating a foundation for the formation of skills to adapt to future careers. Based on the results of the survey, the learning records, and observations, we see a clear effect of applying STEM topics in teaching and learning to develop students' problem solving, creativity. In our opinion, to evaluate the effectiveness of the application of STEM topics more objectively as well as the application of scientific research in teaching Chemistry, it is necessary to develop and expand this topic, to be more diverse than other topics and provide more testing in teaching practice in high schools.

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