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Stem-education Project: Automatic Light in Response to Ambient Light for 11th Graders to Develop Creativity and Problem-solving Competency

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Abstract

In this article, we present a study on the design and organization of STEM-topic teaching on making an automatic light in response to ambient light to develop creativity and problem-solving competency – one of the General Education Program 2018's general competencies. We will provide students with a portion of the knowledge from Symposium 11.3 – "Introduction to electronics" in the Physics Program 2018 in this topic. The Engineering Design Process was used to create the lesson plan because it requires students to overcome obstacles while solving real-world problems. As students engage in learning activities, their creativity and problem-solving competencies grow.

Keywords: STEM-topic, Engineering Design Process, creativity and Problem-solving Competency

Introduction

Many countries throughout the world, including the United States, Finland, and South Korea, have integrated electronics, AI, and robots in their curricula, but understanding helps students catch up with the Industrial Revolution 4.0. We in Vietnam can no longer avoid this trend. The Ministry of Education and Training released the Physics Program in 2018, which included numerous adjustments to student growth goals as well as revised knowledge content. Symposium 11.3 is a brand-new section of the program that teaches students about sensors and some electronic gadgets. There is currently no research on this symposium, according to our study. So that we conducted this research to generate a STEM topic, and by engaging in this topic, we want to develop an important competency in the 21st century: creativity and problem-solving – one competency needs to have.

STEM-education Concept

STEM stands for Science, Technology (Technology), Engineering, and Mathematics, and is frequently used when discussing development policies in these fields. STEM integrated education, or STEM education, is a sub-category of integrated education. STEM education, on the other hand, is an educational perspective that incorporates S - Science (scientific knowledge), T - Technology (technology knowledge), E - Engineer knowledge (technical knowledge), and M - Mathematical knowledge (mathematical knowledge) into a lesson, a topic, or an experienced activity.

Nguyen Thanh Nga and colleagues also hold a positive view of STEM education as an interdisciplinary concept: "STEM education is an approach and discovery in teaching and learning between two or more STEM subjects or between a STEM subject and one or more other school subjects" [1].

Former US President Barrack Obama once shared: "It's more than a school subject, or the periodic table, or the properties of waves. It is an approach to the world, a critical way to understand and explore and engage with the world, and then have the capacity to change that world, and to share this accumulated knowledge."

Some foreign authors also have different ways of defining STEM education:

- + A true STEM education should increase students' understanding of how things work and improve their use of technologies [2].

- + STEM education is an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy [3].
- + STEM is formed from 4 fields Science (science), Technology (technology), Engineering (engineering), Mathematics (mathematics), in which engineering and technology are considered secondary factors compared to other fields. science and math. STEM education is the integration of teaching and learning of theoretical and practical content of mathematics and science through the integration of relevant engineering and technology elements [4].

In this article we use the definition of stem education mentioned in the 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 a number of practical problems in a specific context" [5].

Creativity and Problem-solving Competency

Nguyen Ngoc Duy in his research: " Thiết kế bộ công cụ đánh giá năng lực giải quyết vấn đề và sáng tạo cho học sinh các tỉnh miền núi tây bắc thông qua dạy học dự án trong môn hóa học [Designing a toolkit to assess creativity and problem-solving competency for students in the northern mountainous provinces through project-based learning in the chemistry subject]" has outlined the concept. The concept of creativity and problem-solving competency is: "A unique individual competency to independently, effectively use cognitive processes, actions and states, motives, and emotions. to solve situations, learning and implementation problems where conventional processes, procedures, and solutions are not available, and at the same time, new ideas can be formed and implemented" [6].

In the General Education Program 2018, the Ministry of Education and Training does not give a specific definition, but creativity and problem-solving competency is defined through 6 component competencies, including: Realizing new ideas; Detect and clarify problems; Forming and implementing new ideas; The output, the solution. Organizational design and operations; Independent thinking [7].

In this article, we propose to define creativity and problem-solving competence as follows: Creativity and problem-solving competency is the ability that an individual student has independently or in cooperation with others, mobilize knowledge, skills, states, motivations, emotions to generate and solve situations and problems in learning and practice for which there is no available process or solution. At that time, students need to configure and realize new ideas to find optimal, creative, and highly applicable problem solving.

Process

In addition, we also refer to some STEM organization processes as follows:

- • + 5E intructional model is an integrated teaching process introduced in the 1980s, including 5 stages: Engage; Explore; Explain; Elaborate; Evaluate. (2 & Scotter, 2006)
- + 6E learning by design™ model is a process that develops from the 5E intructional model and strongly develops technical design elements, although in the 5E intructional model, it has not been really cared for properly, so the 6E process was born. This process includes 6E: Engage; Explore; Explain; eNGINEER; Enrich; Evaluate. (Burke & March, 2014)
- + Engineering Design Process (EDP) The steps of the Engineering Design Process (EDP) based on the Massachusetts' Curriculum Frameworks. A few feedback loops are indicated by arrows within the circle, although additional sub-loops can occur between any two steps. There are 8 steps: Identify the problem/need; research and rank objectives and constraints; develop possible solutions; select best solution with constraints; construct a prototype/model solution; test/evaluate the solution; communicate the result; reasses and revise.

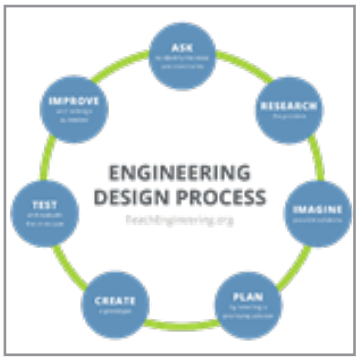


Figure 1: EDP process ("Engineering Design Process,")

EDP is still, in our opinion, one of the best procedures for organizing the topic "Automatic light in response to ambient light" we see several parallels between the procedures described above: first, the educator or teacher will lead the students into the problem to be solved or the situation/context so that the students are aware of the problem to be solved; second, students will work in groups and focus on thinking to find solutions by associating and applying knowledge related to the problem; third, students participate in activities organized by instructors to apply their solutions/products to the problem in order to address the original problem; finally, after fixing the problem, teachers and students generalized the problem and dug deeper to come up with more effective solutions/products.

Active Learning Techniques

Tablecloth Technique

The "Tablecloth" technique is a form of organizing cooperative activities that combine individual and group activities to stimulate and promote active participation, enhance independence, learner responsibilities and develop a model of learner-student interaction [8].

In the "Tablecloth" technique, the teacher will assign the problem to the group, the group members think and record their opinions, evaluations, and choices on their paper. Then, the whole group summarizes the ideas, discusses, evaluates, and selects the best idea, the secretary records the group 's general opinion on the problem that the teacher assigns in the middle of the paper.

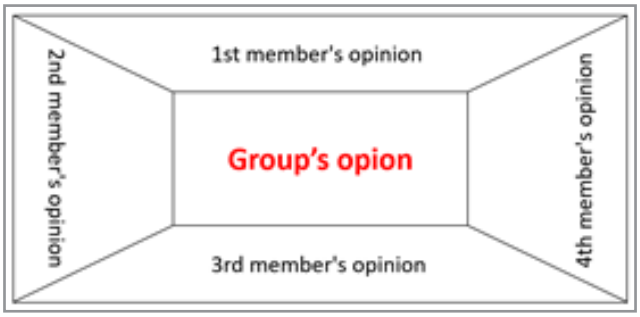


Figure 2: Paper for student use in "Tablecloth" technique

KWL Chart Technique

KWL (K - Know, W - Want to know, L - Learned) chart technique is a teaching organization technique that helps students start by brainstorming everything they already know about the topic of the lesson; this information will be recorded in column K. They then make a list of questions about things they would like to know more about the topic, which will be recorded in column W. During the research process, studying documents and studying, students will answer the questions recorded in column W, this information will be recorded in column L.

Table 1: KWL table

K - Know	W - Want to know	L - Learned

Gallery Walk Technique

Gallery walk technique can be used for individual or group activities.

- + The teacher raises the question/problem to the whole class or to groups.
- + Each member (individual activity) or groups (group activity) sketches problem solving ideas on a piece of paper and sticks them on the walls around the classroom as a picture exhibition.
- + Students in the whole class go to see the "exhibition" and can make comments or additions.
- + Finally, all the solutions are gathered, and the optimal solution is found.

Structure of Creativity and Problem-solving Competency

According to the General Education Program of the Ministry of Education and Training (December 26, 2018), the creativity and problem-solving competency of high school students consists of 6 basic components: recognizing ideas new; detect and clarify problems; forming and implementing new ideas; propose and select solutions; design and organize activities and independent thinking [7].

Topic Plan

Introduction

Currently, our country is advancing toward industrialization and modernization, but there are still many locations where electronics are not used, and dynamic electronic circuits still require people. On days when it becomes dark early, we might notice that the lamps have not switched on, making it impossible for everyone to walk, or that the park lighting system is often still illuminating even though it is now morning. This is a problem that need to be addressed since it wastes a considerable amount of power and pollutes the living environment. To solve this problem, we need a clear knowledge of our responsibility in preventing resource waste and pollution by simply turning on lights at the right times.

Teaching students' life skills in general, as well as required competencies in the twenty-first century, is a pressing need that necessitates a shift in content and approach from educators. Creating circumstances for kids to begin programming at an early age is another technique to help them develop a variety of competencies, including creative thinking, communication, teamwork, critical thinking, and so on. Scratch is a popular programming language that is growing in popularity across the world. Instead of needing to memorize instructions, kids may totally develop their knowledge in a variety of disciplines and topics by using this programming language, thus this is one of the instruments for youngsters to release their creativity and realize their ideas automatically, regulated, ...

For the reasons stated above, we decided to design and organize the STEM topic "Automatic light in response to ambient light" to help students develop their creativity and problem-solving competency while also contributing to their overall growth, part to improve students' awareness of energy use as well as to assist them in learning new programming languages and electronics.

Target on Creativity and Problem-solving Competency

Creativity and problem-solving competency

We establish particular goals for each behavioral expression of competence based on the 6 behavioral expressions of creativity and problem-solving competency described above, as well as the topic's target: "Automatic light in reaction to ambient light." Then, in the lesson plan, codify these competencies; each activity in the lesson plan will focus on the development of certain distinct competencies. Students would have completely developed creativity and problem-solving competency after actively participating in activities related to the topic.

Table 2: Behavioral expression and encoding of competence

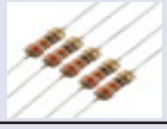
Elemental competency	Behavioral expression	Encode
Recognizing ideas new	Students identified that lights that automatically turn on/off according to ambient light are products that help reduce environmental pollution which students learn some electronic components.	GQVD-ST-1.1
	Students have new ideas to improve their group's automatic lighting products by suggesting tools/knowledge they want to learn more about; such tools/knowledge are feasible in the classroom space and suitable for high school students.	GQVD-ST-1.2

Detect and clarify the problem	Students analyze the inconvenient situation when the urban lighting system turns on/off at the wrong time.	GQVD-ST-2.1
	Students raised the problem that needs to be solved, which is the need to replace the normal lighting system with an automatic light system that turns on/off according to the ambient light.	GQVD-ST-2.2
Forming and implementing new ideas	Students propose design ideas and realize them by designing lights that automatically turn on/off according to the ambient light.	GQVD-ST-3.1
	Students form ideas to improve/overcome limitations of their group's light products.	GQVD-ST-3.2
Propose and select solutions	Students can suggest ideas, suggestions and improvements for other team's designs and products.	GQVD-ST-4.1
	Students choose a plan to improve their group's product to be effective and overcome the most limitations.	GQVD-ST-4.2
Design and organize activities	Plan to learn knowledge, prepare tools and assign tasks to members to perform automatic light manufacturing with high efficiency.	GQVD-ST-5.1
	Know how to adjust the tasks of each team member when having difficulty in implementing the design and manufacturing of the group's light products accordingly.	GQVD-ST-5.2
	Students presented the plan to improve and overcome limitations in light products with available tools and materials, short implementation time (about 30 minutes).	GQVD-ST-5.3
Independent thinking	Students learn to ask many valuable questions as they explore relevant knowledge in the topic.	GQVD-ST-6.1
	Students are willing to review and re-evaluate the limitations of the group's model when there are suggestions from friends or teachers.	GQVD-ST-6.2

Material

The following are some of the bare-bones tools and resources that we utilize in our educational experiments, the majority of which are simple to come by, low-cost, and reliable teaching aids. We recommend that teachers prepare electronic gadgets for students since they are unknown and first-hand to them; the rest of the simple mechanical tools and recyclable materials can be provided by themselves or the school.

Table 3: List of material for topic

Number	Materials	Quantity	Number	Materials	Quantity
1	Laptop		13	Voltage booster circuit 5V	
2	Arduino Uno R3 + iniUSB-USB wire		14	Wire stripper	
3	Compact light 220V		15	Stand for 1 battery	
4	Male - male wire		16	100 Ohm resistor	
5	Male-female wire		17	220 Ohm resistor	

6	Connector wire – female		18	Carton	
7	Bread board		19	Candle glue gun	
8	Light sensor module		20	Hot stick glue	
9	Compact light holder		21	Scissors	
10	Power plug 220V		22	Aluminum ruler	
11	Double wire 0.75x2		23	Paper knives	
12	Relay 5V				

Pedagogical Experiment

Location and student

The students of our pedagogical experiment in this STEM topic are class 11B09 of HOA SEN Middle and High School, semester II, school year 2021:

- + **Number of students participating in the topic:** 32 students.
- + **Students' characteristics:** this is a class with a mix of social orientations; therefore, their technological knowledge and competencies are still lacking. They are still perplexed, inactive, and in need of direction while participating in production or design tasks. The creativity and problem-solving competency have not yet manifested itself clearly.

Disadvantage and Advantage

Advantages

- The Hoa Sen Middle and High School management board, as well as the Physical team, helped us organize a pedagogical experiment, allowing us to contact the target population.
- Hoa Sen Middle and High School is well equipped with the necessary facilities, utensils, and equipment, making STEM-topic classes a breeze to plan.
- Students in the experimental class are engaged, have good study habits, and a strong desire to learn about manufacturing.
- The teacher in charge is a teacher with professional competence, good experience in teaching and classroom management, and enthusiastic advice and support for us in the process of organizing pedagogical experiments.

Disadvantages

- The educational experiment introduces a completely new and unexpected quantity of knowledge to the students' present curriculum, leading to confusion, a lack of attention, and a lack of comprehension of the significance of knowledge.
- The tools used to create goods for students are electrical components, which the school has not completely prepared; we must prepare all for students to assure genuine advancement.
- It is important to prepare and carefully watch and record teachers to discover and evaluate the growth of students' competencies.
- Some youngsters are still active or quiet, affecting the structure of instructional experiments.

Student Assessment Results

The subjects of the experiment are social-oriented students, they have not been exposed to STEM topics before, have never done design drawings, or activities related to technical factors. Therefore, when we organized a pedagogical experiment, we found that there were activities that children performed very poorly, but in manufacturing activities, they performed well because they all had skills in making products.

During the experiment, we were not able to perform the assessment on all students. Because the children have not been familiar with answering the worksheets in each activity, most of the worksheets are not satisfactory, not clearly showing their ability.

In addition, the observation and monitoring ability of the classroom teacher is also limited, so it is not possible to focus on observing the performance of all students.

In this topic, we organize for the whole class to perform, but prioritize the assessment of some students, the students are assessed into 3 groups:

Table 4: Results analysis of group 1

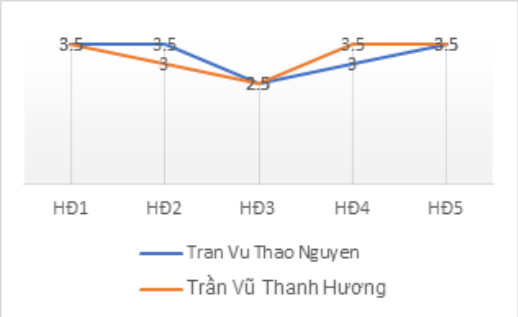
<table>
<tr><td rowspan="2">Group 1</td><td>Tran Vu Thao Nguyen</td><td rowspan="2">Product: Urban lights automatically according to the ambient light</td></tr>
<tr><td>Tran Vu Thanh Huong</td></tr>
<tr><td colspan="3"> 
</td></tr>
<tr><td colspan="3">• Analysis of experimental results</td></tr>
<tr><td colspan="3">In activities 1 and 2, Huong and Nguyen both performed well, they have social knowledge, spirit and sense of learning. Both children understood and realized that the topic task was “Design and manufacture lights that automatically turn on/off according to ambient light”</td></tr>
<tr><td colspan="3">   </td></tr>
<tr><td colspan="2">Activity 3, when we made the design, we noticed that the children were very confused when doing it. Both children do not know their role in this activity, do not understand the meaning and implementation of the blueprint. The teacher had to assist in explaining that both children understood the implementation and the meaning of the design, but the results were still not good.</td><td>  </td></tr>
<tr><td colspan="2">In manufacturing activities, the children showed their skills and ingenuity through products. However, because the design they made was too sketchy and lacked details, the finished product was far different from the design. While manufacturing, we also noted Thanh Huong's opinion on the position of the light sensor so that it is aesthetically pleasing but still works stably</td><td>  </td></tr>
<tr><td colspan="2">With community sharing activities, both children had a relatively convincing and clear presentation of their products. Thanh Huong raised her hand to give her opinion on how to place a light sensor for group 3, Thao Nguyen had suggestions on how to make a support frame for group 2.</td><td>  </td></tr>
</table>

Table 5: Results analysis of group 2

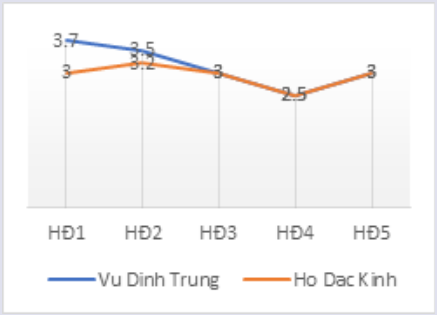
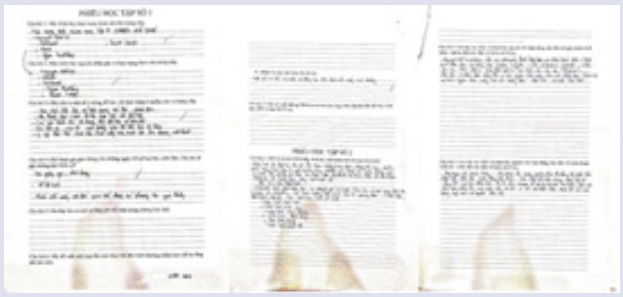
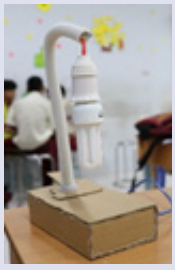
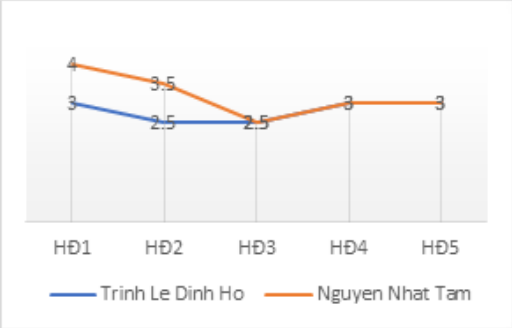
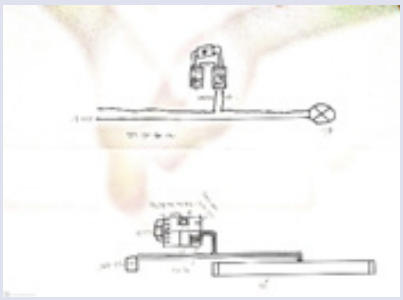
<table>
<tr><td rowspan="2">Group 2</td><td>Vu Dinh Trung</td><td rowspan="2">Product: Desk lamp automatically turns on/off according to the environment light</td></tr>
<tr><td>Ho Dac Kinh</td></tr>
<tr><td colspan="3"> 
</td></tr>
<tr><td colspan="3">• Analysis of experimental results</td></tr>
<tr><td colspan="3">Similar to Thanh Huong and Thao Nguyen in group 1, Dinh Trung and Dac Kinh in group 2 also have a good, active learning sense and good background knowledge. Both students highlighted the task in this topic, but the group asked the teacher's permission to make the lamp for a different purpose than Group 1, which is to make a desk lamp that turns on/off according to the ambient light.</td></tr>
<tr><td colspan="3">   </td></tr>
<tr><td colspan="2">During the design process, Trung and Kinh performed better than the two students in group 1. They were able to list the necessary tools in the design. However, the design is still sketchy and flawed. We realize that this is a feature of the whole class, they have never done the design before, so they faced many difficulties when doing it.</td><td>  </td></tr>
<tr><td colspan="2">This is a group of boys, so they don't make the product as beautiful and skillful as the girls, but they also tried to make the product as close to the design as possible. During the implementation process, the two children had difficulty in making the body of the lamp because the chicken intestine was not strong enough to hold the light bulb, they tried many things but failed.</td><td>  </td></tr>
<tr><td colspan="2">After presenting their group's products, the children received suggestions from Thao Nguyen that they used coiled wire as a support frame for the chicken intestine. They have recorded and perfected their group's lamp product more reliably. These two children also did not have any comments or suggestions for the group of friends; They only focus on overcoming their limitations.</td><td>  </td></tr>
</table>

Table 6: Results analysis of group 3

<table>
<tr><td rowspan="2">Group 3</td><td>Trinh Le Dinh Ho</td><td rowspan="2">Product: The wall light automatically turns on/off according to the ambient light</td></tr>
<tr><td>Nguyen Nhat Tam</td></tr>
<tr><td colspan="3"> 
</td></tr>
<tr><td colspan="3">• Analysis of experimental results</td></tr>
<tr><td colspan="2">In activity 1, we noted Tam's superiority compared to other children, Tam knew how to propose knowledge to learn in the topic.</td><td>  </td></tr>
<tr><td colspan="2">When making design drawings, both Ho and Tam were confused with the drawing of the circuit diagram and the principle of operation, both of them focused on designing the circuit to be the most beautiful and compact, but did not show it. get the shape of the product that I will make.</td><td>  </td></tr>
<tr><td colspan="2">Although the design is still deviating from the original orientation, the students have done quite well in the manufacturing process. The product is somewhat fancy, the light sensor is placed in a calculated and hidden position, but still does not limit the ability to operate. This is also the group with the shortest crafting time in the class.</td><td>  </td></tr>
<tr><td colspan="2">Because the children finished their crafting activities early, they had time to observe and give suggestions. During the reporting process, we recognized the contribution of Ho to group 2 on sensor placement and Tam to group 1 on how to make the stand.</td><td>  </td></tr>
</table>

Activities

We will provide a description of the activities arranged in the topic below, as well as further comments on the competency coding given in Table 3. As a result, readers will have a better understanding of the author's concepts and how they are implemented in each activity.

Table 7: Summary of activities

Encode	Activities	Content
GQVD-ST-1.1, GQ-VD-ST-2.1, GQ-VD-ST-2.2	Activity 1: Create a situation to create a problem	- Students were shown some clips with the content of Light Pollution and some pictures showing the waste of electricity of the daytime urban lighting system from which to propose a light that turns on only when necessary. and turn off when ambient light is sufficient. - Students participate in online classes created by teachers. - Students propose knowledge that needs to be studied to implement problem-solving products.
GQVD-ST-3.1, GQ-VD-ST-6.1	Activity 2: Research background knowledge and propose design ideas	- Students receive materials and study part of the necessary knowledge at home. - In class, the teacher will explain more advanced knowledge and perform exercises to apply knowledge. - Students discuss in groups according to the tablecloth technique and apply their knowledge to make the design of automatic lights.
GQVD-ST-4.1, GQ-VD-ST-5.1	Activity 3: Protect the blueprint	- Students perform the gallery walk technique to present their group's design to the class. - Students give each other feedback while listening to the presentation. - Students edit the design according to the suggestions of friends and teachers.
GQVD-ST-1.2, GQVD-ST-3.2, GQVD-ST-4.1, GQVD-ST-4.2, GQ-VD-ST-5.3, GQ-VD-ST-5.2	Activity 4: Prototyping the product and testing it	- Teachers provide materials and mechanical tools for students to perform. - Students work together to create product prototypes. - Students and teachers test product prototypes together. - Students come up with ideas and suggest more tools to improve/overcome the limitations of the product. - Students make product improvements.
GQVD-ST-6.2	Activity 5: Topic evaluation and community sharing	- Students complete the KWL chart worksheets that have been partially done in Activity 1. - Students discuss in groups and make a report about their products. - Each group of students presents to the class about their group's lamp products. - The whole class together vote and evaluate a best product to share with the community.

Discuss the Results of the Pedagogical Experiment

The children showed various stages of development during each activity, yet they all made significant contributions, ideas, and plans. We discovered that the youngsters had acquired problem-solving and creative competencies after reviewing the trial findings and graphs. Initially, our plan was to structure the two themes as described, with activities that were somewhat comparable, so that the children's progress could be seen more clearly. These are only a few examples of how the component competencies in creativity and problem-solving competency express themselves in behavior. Fully and consistently developing students' competency is a long-term process that requires students to participate in a variety of activities so that they may demonstrate and express their competency. Furthermore, there are some students in the class who do not have a strong feeling of learning and simply participate in the topic's activities superficially. Because the scores received did not reflect their real competence, we chose not to examine those students.

Conclusion

Based on the results obtained from the process of pedagogical experimentation, compared with the set tasks, we have solved the following theoretical and practical problems:

- Research the theoretical basis of STEM education, apply the technical design process to design lesson plans suitable for students and external conditions.
- Researching the theoretical basis for the development of students' problem-solving and creative competencies. From there, we built a toolkit to assess students' creativity and problem-solving competency.
- Build a system of knowledge units that need to achieve the content of "Algorithm Amplification" - Physics 11, Physics Program 2018.
- From the theoretical basis and the required knowledge units, combined with practical problems, we build the content of 2 STEM topics: Automatic light in response to ambient light and Design create an electronic room thermometer to contribute to the development of problem solving and creativity in students (because topic 2 is not eligible for implementation, we decided not to present it).
- Applying the process of the built topic, we conducted an experiment on the topic Automatic light in response to ambient light in high schools and evaluated the overall feasibility of the project in developing students' creativity and problem-solving competency.

- Due to the conditions of time, competency, and framework of the report, we only built two STEM topics and experimented with one topic. Besides, although we organized the topic with the whole class, we only conducted the assessment with a few students. We will continue to research to expand the scope, ability to evaluate and improve the built topic to suit current teaching conditions.

We built a Stem topic using active learning techniques approaches and the Engineering Design Process, and the topic has transmitted plenty of the information of Symposium 11.3 – "Introduction to electronics" in the Physics Program 2018. Furthermore, when students participate in the topic, they develop an interest in physics and practice a variety of design and production abilities. Not only that, but the topic's aim is still fully realized when we see how the students' creativity and problem-solving competency have grown, even if the amount of growth is still insufficient. The equality of students, however we feel that if both intended themes can be implemented, students' competency to solve issues and be creative will grow equally and thoroughly, establishing the groundwork for them to pursue further education.

Acknowledgement

To design and organize effective STEM topics, teachers need to have understood in many fields, regularly update social issues, and integrate them into topics, and design lesson plans. teach so that activities in which students play a leading role and have conditions to reveal and develop common competencies, especially problem solving and creativity.

To evaluate students' creativity and problem-solving competency, it is necessary to have a set of tools with clear criteria, close to the topic and the students' ability to express themselves.

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