



Original Article

# Designing Teaching Process for Stem Topic “Traffic Signal Lights” for Upper-secondary School Students

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**Abstract:** In this paper, we propose a new STEM topic in the automation field for upper-secondary school students, which is the topic "Traffic signal lights". This STEM education is designed to be relevant to the current general education curriculum in subjects as Physics, Technology, and Informatics. Based on the 6E learning model, the teaching process is built for this topic, in which two factors of technical design and practice (programming and assembly of circuits) are emphasized in STEM-oriented teaching for upper-secondary school students.

**Keywords:** 6E teaching process, automation, upper-secondary school, STEM education, traffic signal lights.

## 1. Introduction

STEM education has been widely applied in developed countries. The knowledge that this educational model brings to students is the fundamental foundation for the younger generation to adapt to the era of the Industrial Revolution 4.0. STEM education is a teaching model that is encouraged to be implemented in the new general education curriculum issued in 2018 [1]. Later, STEM topics were designed

and organized based on the content of the current curriculum issued in 2006 [2-4]

The STEM theme "Traffic signal lights" is designed to create opportunities for students to explore, and apply the electrical, electronic and programming knowledge learned in subject of physics, technology, and informatics in the current general education curriculum to design traffic signal lights using Arduino, an open-source hardware and software platform. The knowledge content in this topic has met the requirement of the new physics, technology, natural sciences curriculum issued in 2018 for upper-secondary students. Therefore, traffic signal lights are the topic for being both

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practical and feasible in both the main curriculum and extracurricular experience activities. In addition, we also apply the 6E teaching process to design the teaching process for this topic to exploit the ability, to explore knowledge, and design techniques for students.

In 1980, the 5E process was launched to help students practice their necessary skills for the 21st century, such as environmental adaptability, social skills, problem-solving skills, self-management, thinking abilities [5]. The 5E teaching process consists of 5 phases (stages) applied to the teaching process design of a particular lesson/topic, including: i) Engage; ii) Explore; iii) Explain; iv) Enrich; v) Evaluate. From the 5E model, the technical practice factor (eNGINEER) was implemented, and became the 6E *model* [6]. The 6E model is student-centered teaching which emphasizes the combination of design and discovery. The use of the 6E model in teaching has also been studied and developed in [4].

## 2. Research Questions and Methodology

We conduct research to address the following two questions: The compatibility of the STEM topic "Traffic signal light" with the general requirements of the current general education curriculum? How is the acceptance of teachers and students/effectiveness when designing the teaching process?

We conduct documentary research, material analysis and synthesis to learn the connection between the content of the topic and the content of related subjects in the current upper-secondary school curriculum. On the basis of the theory of the 6E teaching process, we design the appropriate teaching process.

In this work, we use two main research methods. The first is to note the concepts of STEM education, 6E teaching process. The second is to implement the experiments. We design and fabricate traffic signal lights based on single electronic components and arduino microcontroller, then build algorithmic

flowcharts and scratch programming to control traffic lights. Next, we use the scientific observation method to collect research data on the proposed STEM topic.

## 3. Results and Discussions

### 3.1. Traffic Lights

#### 3.1.1. Topic Description

The topic "Traffic signal lights" helps students solve the problem of designing and automatically controlling traffic lights using Arduino. With the use of some simple electronic components such as transistors, LEDs, resistors, batteries, LCDs, and Arduinos, students can learn the structure, working principle, assembly and programming for controlling traffic lights. Through learning activities, students can practice basic electronic circuit design and assembly skills.

After students make their own plans to design the traffic signal control circuit, the teacher analyzes the advantages and disadvantages of the control circuit that the groups design. After that, the teacher needs to come up with a simple and cost-effective traffic signal control circuit, as shown in Fig. 1 (tools for fabricating this circuit is shown in Table 1). The traffic light consists of 5 blocks: 1. Arduino board; 2. LCD display; 3. Green, yellow and red LED lights; 4. Transistor; 5. 220 VAC–12 VDC power adapter. Basically, the working principle of this circuit is as follows: The three output pins of the Arduino A0, A1, A2 respectively are connected to the B terminal of the three transistors T1, T2, T3, and in turn will be connected to the red, yellow, green signal lights. Based on programming using Kidscode v3.0 software, we can set the state of pins A0, A1, A2 low (i.e., 0V) or high (i.e., 5V). In case an output pin is low, i.e., terminal B of the transistor connected to this pin has no current, so the transistor will not work, the traffic light connected to this transistor will turn off. And

vice versa, if an output pin goes upper-secondary, the traffic light connected to this pin via the transistor will light up. In parallel, we can program to display letters and numbers countdown on the LCD screen. The programming procedure therefore corresponds to the output shown simply as follows (note that the time of the lights and the display of

information on the LCD are fully adjustable by the programmer): 1. The green light is on for 30 seconds, and the LCD counts down from 30 to 0; 2. Yellow light flashes for 3 times, 1 second each time, and the LCD counts down from 3 to 0; 3. The red light is on for 30 seconds, and the LCD screen counts down from 30 to 0. Similarly, the process will continue to repeat.

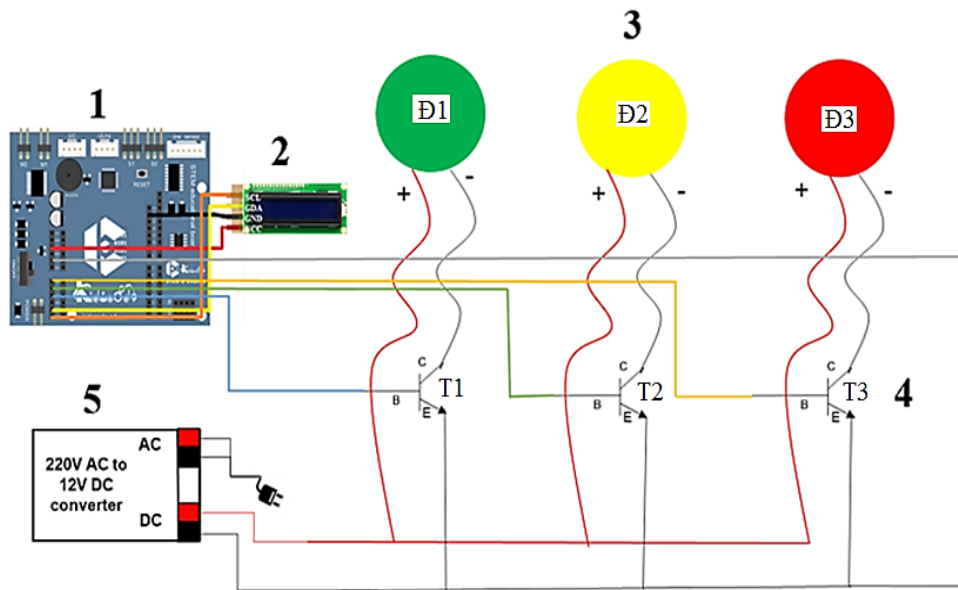

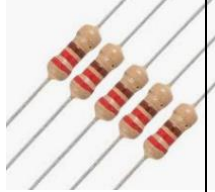
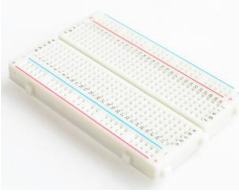

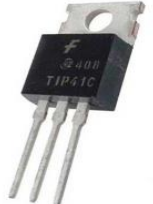



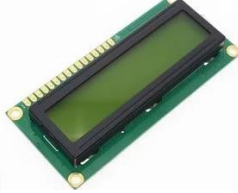





Fig. 1. Traffic light control circuit

Table 1. List of traffic signal light theme tools

Components (number)	Images	Components (number)	Images	Components (number)	Images
Blue, red, yellow Led lights (32 leds for each colour)		220Ω Resistor (20)		Test Board (01)	
Aluminum-plastic sheet 30 × 10 cm (01)		Transistor B13TIP41C (03)		Arduino Board (01)	

220VAC-12VDC power adapter (01)		Steel racks (01)		LCD (01)	
Wire (02 m)		Arduino Jacks (01)		Arduino connection cord and USB port (01)	

3.1.2. Assembling and Operation Process

In this part, the assembly and operation process is divided into 4 parts: Part 1. Fabricating the lights (based on the knowledge learned about mixed circuits and under the guidance of the teacher, students can design the led matrix from single leds); Part 2. Power circuit (based on their knowledge of transistors and under the guidance of teachers, students design power circuits to control newly built

lights; Part 3. Arduino circuit and hardware (based on the learned knowledge about the integrated circuit and under the guidance of the teacher, students learn and master how to use it; Part 4. Code programming and loading for arduino (based on the learned loop and conditional structure and under the supervision of the teacher), students programmatically control traffic lights.


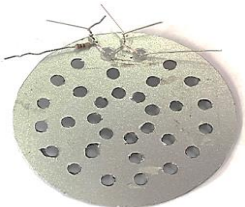

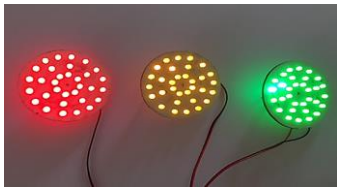
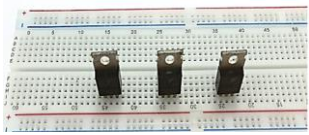
Steps	Illustrations
<b>Part 1. Fabricating the lights</b>	
Step 1: Cutting circles whose diameter is 8cm from Aluminum-plastic sheet.	Step 2: Cutting circles whose diameter is 8cm from white paper, draw concentric circles, mark the points to drill holes to attach the LEDs, then stick it on the aluminum-plastic sheet in Step 1 (see Fig. 2). 
Step 3: Drilling the marked holes.	Step 4: Assembling circuit of LEDs in series in order. The positive pin of the LED row (+) connects to the 220Ω resistor. The negative pin of the LED row (-) connects to the positive pin (+) of the neighbor LED row. Connecting five yellow (red) LEDs in series (a row of serial 5 LEDs). For green LEDs, connect 3 ones in series with a 330Ω resistor (a row of serial 3 LEDs) (see Fig. 3). 

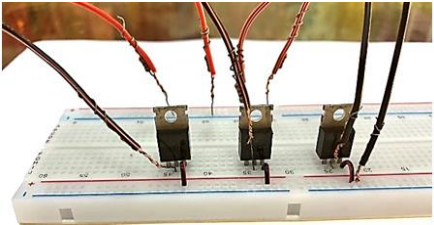
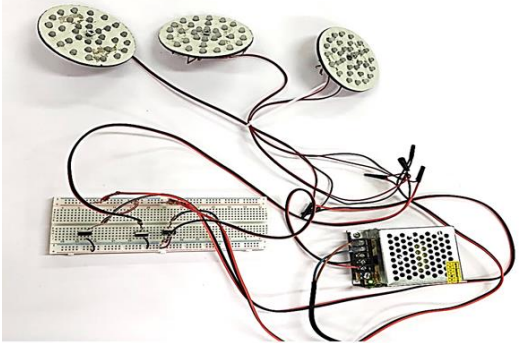
Fig. 2. Drilled aluminum-plastic.

Fig. 3. Assembling circuit of LEDs.

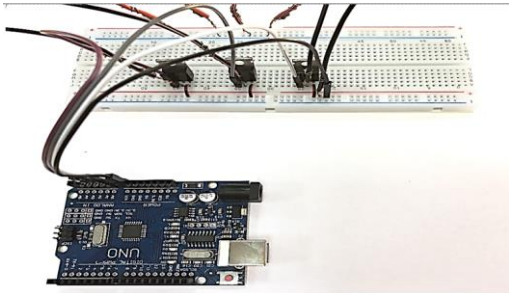
<p>Step 5: Connecting the (-) pins into a joint negative pin, and do the same with (+) pinpins of LEDs rows. As a result, we have (+) joint pin and (-) joint pin</p>  <p>Fig. 4. Making (+) joint pin and (-) joint (see Fig. 4).</p>	<p>Step 6: In order to test the lights, we use the 220VAC to 12VDC power adapter. Connect the pins (+), (-) of the LED rows to the pins (+), (-) of the adapter, respectively. Check the LEDs work normally (see Fig. 5).</p>  <p>Fig. 5. Power supply for led.</p>
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**Part 2. Power circuit**

<p>Step 1: Plug three transistors on the board test in order. Note: The distance between transistors (see Fig. 6).</p>  <p>Fig. 6. Assembling transistors.</p>	<p>Step 2 Connect C pin of the transistor to the negative pin of light (-). Similarly, we do with the other the lights and transistors.</p>
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<p>Step 3: Plug the positive pin (+) of the lights and positive pin (+) of the adapter on the positive line on the test board (see Fig. 7). We then have the completed circuit as shown in Fig. 8.</p>  <p>Fig. 7. Wiring for transistors.</p>	 <p>Fig. 8. The completed circuit.</p>
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**Part 3. Arduino circuit and hardware**

<p>Step 1: Using the connection wire of the Arduino set, connect the B pin of the transistor (corresponding to the red light) to arduino's A0 pin. Similarly, the A1 pin connected to the yellow light transistor, the A2 pin connected to the green light transistor. Using the connection wire, plug the Arduino's GND pin to the common E pins of the transistors in the power circuit (see Fig. 9).</p>	 <p>Fig. 9. Connecting Arduino.</p>
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Step 2: Plug in the SCL pin of the LCD monitor with the A5 pin; Plug in the SDA pin of the LCD monitor with the A4 pin; Plug in the VCC pin with the 5V hole of the Arduino board; Plug the GND pin with the GND pin of the Arduino board (see Fig. 10).

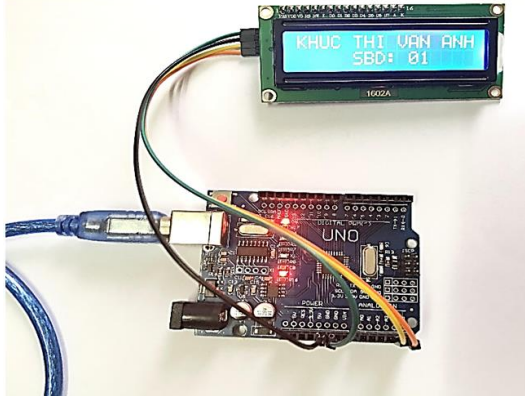


Fig. 10. Connecting LCD.

Step 3: Drill the holes at the center of the lights and the crossbar of the pillar, then fix the lights and crossbar; Using 2-way adhesive tape to attach the power circuit, arduino circuit on the wooden base (see Fig. 11).

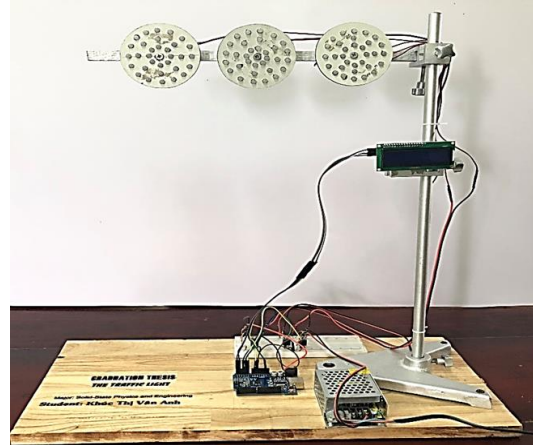


Fig. 11. Finished hardware.

**Part 4. Code programming and loading for arduino**

Step 1: On the toolbar of Kidscode software, go to the connection → Select the serial port → Left double click selects the COM port.

Step 2: Program the traffic light control program using Kidscode v3.0 software, then proceed to load the program code into arduino (see Fig. 12).

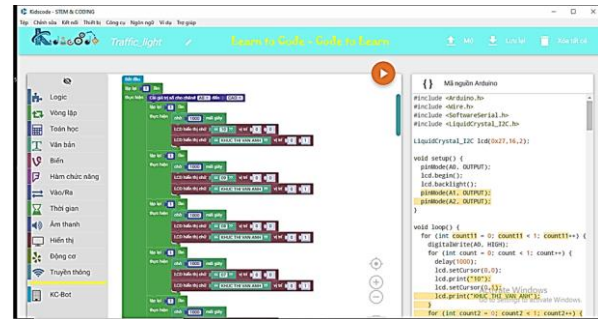


Fig. 12. Code program.

Step 3: Check if the program has been loaded into arduino successfully, left click on Arduino IDE Output at the left lower corner of Kidscode software v3.0.

**3.2. Analyze the Content of Knowledge in the Topic Corresponding to the Current General Education Program**

In this part, based on knowledge in physics, technology and informatics subjects, we extract some content of knowledge that are served for the proposed STEM topic, and are shown in Table 2. Based on the above table, it can be seen that the content of knowledge that students have learned

in physics, technology and informatics subjects can be fully exploited to serve the proposed STEM topic. Through this topic, students can both re-create knowledge and practice some practical skills to create new products that can be applied in life. Based on the content of the practical exercises in the main program, students can accept it well and the practice conditions are appropriate.

Subjects	Class	Lesson	Content	Notes
Physics	11th Grade	Lesson 7: Steady current. Power supply	Content 1: The power supply is capable of supplying current to the devices. Content 2: Electric battery is power supply	Learned and applied knowledge by students
		Lesson 13. Electric currents in metals	Content 3. Conductor is made of metal capable of conducting electricity.	Learned and applied knowledge by students
		Lesson 17. Electric currents in semiconductors	Content 4. The P-N junction in light-emitting diodes (LEDs) and transistors are made of semiconductors.	Learned and applied knowledge by students
		Lesson 18. Practice: Investigation of rectification properties of semiconductor diodes and amplification properties of transistors	Content 5. Transistors can be used as an electronic switch.	Skills trained
Technology	12th Grade	Lesson 2. Resistors - Capacitors - Inductors	Content 6. Resistors are used to limit and regulate current, and for voltage division in electrical circuits.	Learned and applied knowledge by students
		Lesson 3. Practice: Resistors - Capacitors - Inductors	Content 7. Determine the value of the resistance through the color code on the resistor body.	Skills trained
		Lesson 4. Semiconductors and ICs	Content 8. LED is a light-emitting diode, consisting of a P-N junction, used as a signal light in power supplies, equipments, ... when power is on. Content 9. Transistor is composed of 2 P-N junctions assembled together, used as an amplifying element or electronic switch.	Learned and applied knowledge by students
		Lesson 5. Practice: Diodes - Thyristor - Triac	Content 10. Identify electrodes A, K of diodes.	Skills trained
		Lesson 6. Practice: Transistor	Content 11. Determine the electrodes B, C, E of the transistor.	Skills trained
		Lesson 13. The concept of electronic control circuits	Content 12: Electronic control circuit can automate the machinery.	Learned and applied knowledge by students
		Lesson 14. Signal control circuit	Content 13: Traffic signal lights is based on a signal control circuit thanks to having enough blocks: Receiving - Processing - Amplifying - Executing.	Learned and applied knowledge by students
Informatics	11th Grade	Season 9. Branching structure	Content 14. Conditional statement structure is if <condition> then < command 1 > else <s command 2 >	Skills trained
		Article 10. Loop structure	Content 15. The loop statement structure is for <count variable>:= <start value> to <end value> do <statement>	Skills trained

3.3. Designing the Teaching Process Traffic Signal Light Theme

General process

The topic is conducted in 3 lessons (see Fig. 13), specifically as follows: i) Making lights; ii) Power circuit; iii) Arduino circuit and hardware finishing; and iv) Code programming and loading for arduino.

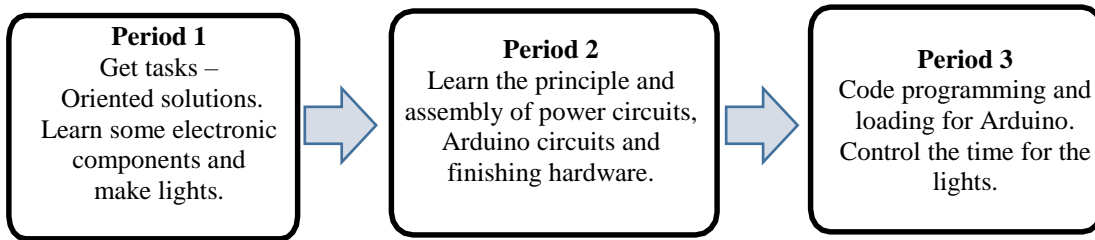


Fig. 13. General teaching process for the traffic signal light theme.

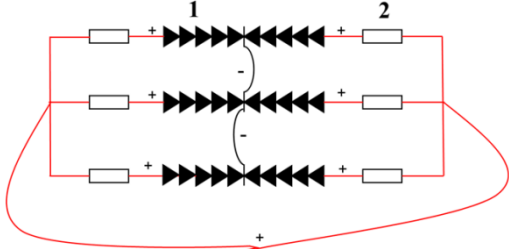
3.3.1. Student activity followed by 6E teaching process

Phase	Student activities	Periods
<b>Engage</b>	1. Students <i>emphasize</i> the important role of automation with electrical and electronic equipments, namely traffic lights. 2. Students <i>propose</i> approaches to automatically control traffic lights	1
<b>Explore</b>	3. Students <i>explore</i> the principle of operation of light-light diodes, transistor, direct current power, LCD, and Arduino. 4. Students <i>propose</i> an experimental plan to build an LED matrix from single leds and can light them using a 12VDC power supply. 5. Students <i>learn</i> how to use electronic components, direct power, LCD, and Arduino.	1+2
<b>Explain</b>	6. Students <i>explain</i> the basic principle of operation of the control circuit of traffic signal lights. 7. Students <i>present</i> the role of the main parts of traffic signal lights	1+2
<b>Engineering</b>	8. Students <i>determine</i> different electronic components and how to assemble and control them. 9. Students <i>use</i> tools for assembling between components. 10. Students <i>operate</i> traffic light control circuits and comment on product efficiency. 11. Students <i>program</i> to control blue, red, yellow signal lights, and displays on LCD on Kidscode v3.0 software developed on the basis of Google's open-source software, providing a drag-and-drop programming interface. 12. Students <i>design</i> green, red, yellow signal lights; and lampposts, the base of traffic lights.	2+3
<b>Enrich</b>	13. Students <i>think about</i> how to change the control time of the signal lights, and the implementation plan for non-stop light signal. 14. Students <i>propose</i> improvements for the done product	3
<b>Evaluate</b>	15. Students <i>present</i> products and discuss their groups' products. 16. Students <i>discuss</i> the implementation process of the students themselves, and their friends.	2+3



## 3.3.2. Teaching Process

The encrypted learning content (content 1, content 2,...) in section .2 is demonstrated in the student's learning activities according to the progress below.

Activities	Content progress	Contents
Period 1 – Designing and assembling green, red and yellow traffic signal lights		
Activity 1. Start [Engage] 4 mins	Each group of students in turn introduces the types of lights/signals used in road traffic that are commonly used. Students commented that automation plays an important role for traffic lights, especially in the future combined with driverless devices	Content 4 Content 8 Content 13 Content 12
Activity 2. Define the task [Engage] 4 mins	<i>Problem to solve:</i> How to be able to fabricate signal lights (blue, red, or yellow) is a matrix of many single LEDs? <i>Students work in pairs</i> to propose the plan. <i>Students work in pairs</i> "Designing and manufacturing a traffic signal light circuit consisting of multiple single LED lights"	Content 6 Content 8 Content 10
Activity 3. Learn about LED (light-emitting diodes). [Explore] 5 mins	<i>Teacher introduces</i> light-emitting diodes, assuming that we already know the rated current and voltage of LED and the source voltage is 12VDC, how to design a matrix of mixed LEDs in series or parallel that can work under the supply voltage of 12VDC (see Fig. 14). 	Content 1 Content 2 Content 6 Content 8 Content 10
Activity 4. Assembly engineer [eNGINEER] 27 mins	<i>Students practice in groups</i> assembling circuits for traffic signal lights on alumni plates following the steps as in section 3.1.2. Assembly and operation process (each group should have 06 students, practice assembling green, red, yellow lights in parallel, each light needs 02 students to assemble)	Practice
	Teacher summarizes the first period	
Period 2 – Power circuit and Arduino for traffic lights		
Activity 1. Forming design thinking [Explore] 15 mins	<i>Students formed the mindset</i> of designing traffic light control circuit products under the guidance of teachers. Thereby, students determine the contents to learn to build traffic lights.	Content 3 Content 5 Content 12 Content 13
Activity 2. Assembly Engineer [eNGINEER] 30 mins	<i>Students practice in</i> the steps as in section 3.1.2. Assembling and operation process	Practice

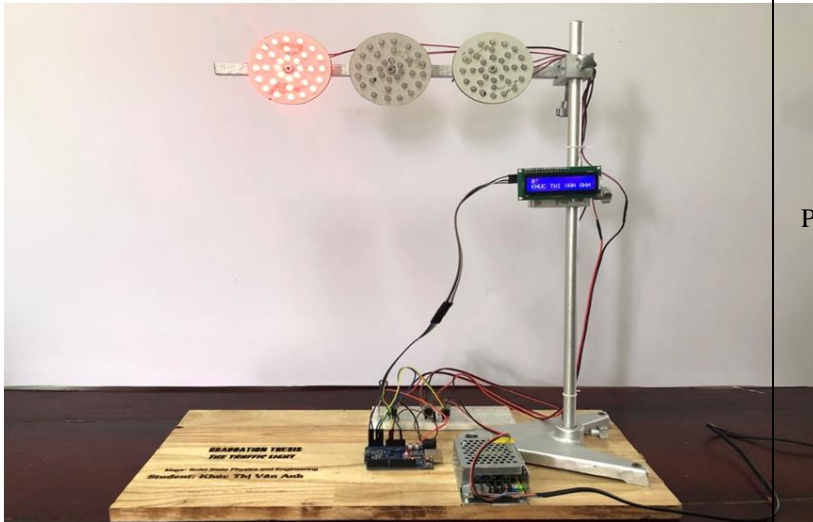
Period 3 - Programming traffic light control code		
<p>Activity 1. Learn about command blocks on kidcodes <i>[Explore] software for 5 minutes</i></p>	<p>Students learn about command blocks on kidcodes software, especially loop command blocks, arduino output settings at high or low levels, control and display information on LCD, time settings.</p>	<p>Content 14 Content 15</p>
<p>Activity 2. 20-minute <i>[eNGINEER] programming engineer</i></p>	<p><i>Students practice</i> programming to control traffic lights, set time for green, red, yellow lights, and display information on LCD.</p>	<p>Practice</p>
<p>Activity 3. Operation <i>[eNGINEER] [Evaluate] 20 mins</i></p>	<p><i>Students design, assemble</i> the power parts, Arduino circuits on the base, and LCD, blue, red, yellow signal lights on the signal lamp stand. <i>Students operate</i> traffic light control circuits and observe blue, red, yellow signal transfer time, and information is displayed on LCD. <i>Students review and evaluate</i> products and learning process (see Fig. 15).</p> 	<p>Practice</p>
<p>Teachers sum up the third period and the entire topic</p>		

Fig. 15. Traffic signal lights.

In this work, we proposed a new STEM topic, traffic signal lights. Based on the content of section 3.2, this topic is proposed and built to be completely consistent with the current general education curriculum, issued in 2006. In the subjects of physics and technology, students have learned about single electronic components and practice investigating and assembling some simple electronic circuits. In the subject of informatics, students have learned about branching and looping structure, so that

students can completely use scratch drag and drop language or C++ to program for arduino microcontroller. However, the arduino microcontroller is new to students, so it can surprise upper-secondary school students about the identification of input and output ports, computer pairing, installation and programming (the third period in the teaching process). This can be overcome if teachers pre-assign tasks for students to learn at home through virtual labs, such as tinkercad. Thanks to this software,

students can completely design, assemble, program for the arduino, and especially pre-simulate the working principle of the topic completely online. Therefore, the teaching process according to the proposed 6E process has a good basis for teaching implementation. In the process of teaching, it is a little bit difficult for teachers to master a lot of interdisciplinary knowledge such as basic electronics, programming, arduino, etc. To be able to integrate this topic when teaching, besides background knowledge required in both teachers and students, schools need to equip arduino kits and computers for students to manipulate and program. In the process of designing the teaching process, it is very important to balance the time between tasks, the task of making led matrix lights is time consuming, so we may assign the task to students to cut and drill the round aluminum plate at home first. Methods that can be used to teach this STEM topic are hands-on or project teaching.

#### 4. Conclusion

In this paper, we have proposed and built a new STEM topic “Traffic signal lights”. This topic is suitable with one of the perspectives on building an overall general education program (the third perspective), which refers to focusing on practice, applying knowledge and skills learned to solve problems in learning and life. Furthermore, we continue to apply the 6E teaching process (a student-centered teaching model that helps students practice essential 21st century skills) to design a teaching process for this STEM topic. Based on the analysis of the knowledge content of the topic corresponding

to the current general education curriculum in the subjects of physics, informatics and technology of grades 11 and 12, the proposed topic can be completely incorporated into the organization of STEM teaching for upper-secondary school students. This research will be further developed through pedagogical experiments.

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