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## Arduino-Assisted robotic and coding applications in science teaching: Pulsimeter activity in compliance with the 5E learning model

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### ABSTRACT

The purpose of the current study is to design and develop an Arduino-assisted robotic and coding activity in compliance with the 5E learning model for middle school students to construct knowledge and realize learning in science teaching. The study was conducted on 6<sup>th</sup> grade students attending a private middle school in Turkey in the second term of the 2018 and 2019 school year. Application of the designed activity was carried out in the science laboratory with the participation of 10 students who were the members of the STEM club. The activity was designed to teach the concept of pulse addressed within the subject of circulatory system in the science curriculum in line with the 5E learning model. With this activity developed, systematic contraction and relaxation movements of the heart while working were modeled through robotics and coding. In addition, through this activity, it was intended to introduce the students to coding, to improve their attitudes towards technology, to develop their information processing skills and to help them to relate the concept of pulse to daily life. In this way, the students were provided with opportunities to experience Arduino-assisted robotic and coding applications and to integrate such applications into their daily life.




### KEYWORDS

Science teaching; robotics and coding; Arduino; pulse concept

### Introduction

In the 21st century, with the rapid developments in technology, the use of technology in education and the integration of these technologies into the lessons have come to the fore. The importance of these applications has been increasing with each day as a result of the possibilities brought by them not only to our daily life but also to educational environments. Today, many educational technologies with different features are used. Examples of these applications include augmented reality, mobile learning, wearable technology, hologram, digital storytelling and digital games (Günüç 2017; Johnson et al. 2015). In addition to these technologies, robotic and coding applications are among the most important emerging technologies. In robotic and coding applications, students first get engaged in coding in a block-based program that works with the drag-and-drop system, and these codes are put into the robotic tools to make them functional.

In the literature, it is stated that with such robotic applications, many cognitive, affective and psycho-motor characteristics of students such as creativity, multidimensional thinking, critical and analytical thinking, product creation and problem solving can be developed (Benitti 2012; Gura 2012). When we look at robotic and coding applications in science education, it is seen that Lego Mindstorms RCX, NXT and EV3 sets are generally used (Koç-Şenol and Büyük 2015; Okkesim 2014). With the use of these robotic sets, students are allowed to learn by experimenting, designing and doing. However, in some studies, it is stated that such sets do not contribute significantly to the formation of enhanced learning environments, development of creativity, increase in academic achievement and development of coding skills (Lindh and Holgersson 2007; Varnado 2005; Williams et al. 2007). In this respect, microcontroller arduino, which is easy to use and easy to understand,

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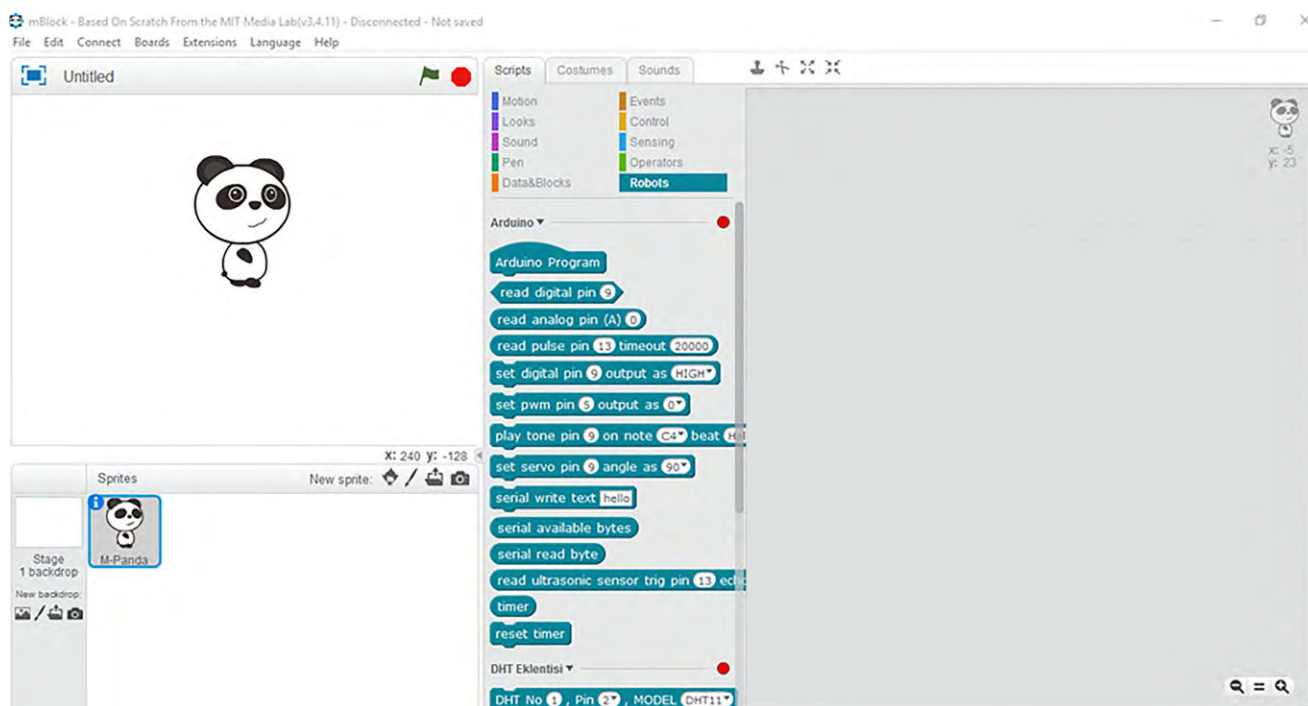


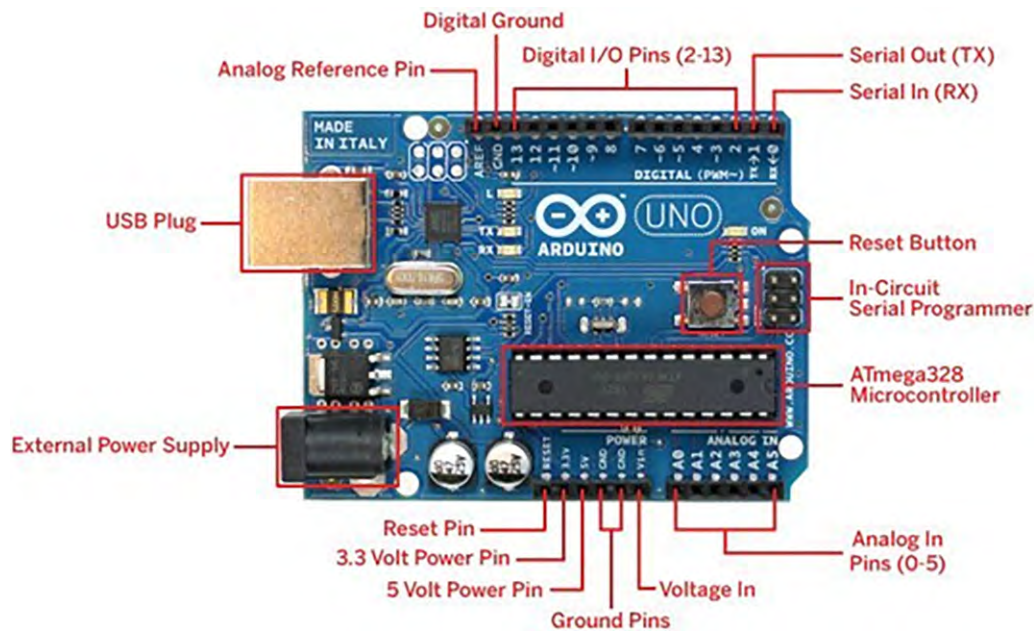
Figure 1. mBlock block-based coding platform.

supported by programs that are working with the drag-and-drop system and which allows the production of different projects with various sensors and interaction and communication with the environment, is recommended. Arduino's having a structure that has connections with many branches of science makes it possible to easily integrate it into educational environments. In particular, that fact that the software and hardware of such microcontroller cards are open source, that they are supported by programs with block-based coding, that they can have access to many applications from its library without needing any knowledge of coding, and that advanced technologies can be added to these cards plays an important role in the widespread use and dissemination of arduino-assisted robotic coding applications in educational environments (Dökmetaş 2016). In addition, the use of arduino-style microprocessors in education allows students to control the reactions of a model they can touch and see and makes it possible for learners to investigate the situations they encounter in daily life with arduino-assisted robotic applications. Moreover, in the literature, it is pointed out that arduino-assisted robotic and coding applications are defined as a new way leading to the constructivist learning because with the activities

students conduct by using arduino materials and sensors, they can both develop different perspectives to better understand the life in their environment and add a new dimension to their understanding of productivity. Thus, arduino-assisted robotic and coding applications teach students knowledge construction, algorithmic thinking, collaborative work, creativity and problem solving, as well as scientific method, programming logic and engineering design processes (Alimisis and Kynigos 2009). In addition, it is stated that such applications facilitate the teaching of abstract and difficult-to-understand concepts in science subjects. In this connection, the purpose of the current study is to design and develop an arduino-assisted robotic and coding activity in compliance with the 5E learning model for middle school students to construct knowledge and realize learning in science teaching.

#### **mBlock platform and Arduino uno microprocessor**

mBlock platform is a program allowing 8-16 year-old children to easily code. mBlock has a compiler and converter that can convert code blocks into C++ language. Here, the codes are in the form of ready-to-use blocks, and the codes are produced by using the drag-and-drop system



**Figure 2.** Microprocessor of Arduino uno (<https://robu.in/product/arduino-uno-r3-without-cable/>).

without needing to write any codes. The prepared code blocks can be uploaded to the Arduino microprocessor and can be operated independently from the computer. Thus, the operation of robotic activities can be managed (Şahin 2018). In addition, this program can be easily downloaded for free and unrestricted (<http://www.mblock.cc/mblock-software/>). The ready-to-use blocks in the Robots tab of the mBlock platform and the interface of the platform are given in Figure 1.

Arduino uno is a microprocessor (development) card. There are 14 digital pins and 6 analog pins on it and through these pins, the codes written for the circuits prepared can be loaded to the processor, values can be read from the sensors and motor and similar devices can be operated. In this way, the design of many electronic projects and smart systems can be made. The structure of the microprocessor of Arduino uno is given in Figure 2.

After a general introduction to the basic features of robotics and coding, information about how the pulse activity was designed and developed in line with the 5E learning model in accordance with the objectives stated in the middle school science course curriculum is presented below. In this connection, the following objectives are intended to be accomplished through this activity;

1. Introduction of the arduino-assisted robotic and coding applications to students,
2. To create a robotic model for contraction and relaxation movements of human heart,
3. To teach the concept of pulse on the model,
4. To relate the concept of pulse to daily life,
5. To teach block-based coding to students,
6. To improve students' attitudes towards technology,
7. To develop students' information processing skills,
8. To enable the integration of the Arduino-assisted robotic and coding applications into daily life.

## Methods

The study was conducted on 6<sup>th</sup> grade middle school students attending a private middle school in Marmaris province of the city of Muğla in the second term of the 2018 and 2019 school year. Application of the designed activity was carried out in the science laboratory of the school with the participation of 10 students who were the members of the STEM club. The activity was developed in compliance with the 6<sup>th</sup> grade middle school curriculum and the 5E learning model. The 5E learning model consists of five phases of learning which are Engage, Explore, Explain, Elaborate and Evaluate. Through these five phases of learning, the arduino-assisted robotic



**Figure 3.** Ali's speech bubble.

and coding applications addressing the concept of pulse within the subject of circulatory system were conducted.

### Materials

- Tablet or laptop computer
- Arduino uno
- Arduino usb cable
- Pulse sensor
- Breadboard
- Led lamp
- Jumper cables

### Procedure

#### Engagement

- By asking the following questions “Which organs constitute the circulatory system?” and “How is the structure of the heart?”, the students’ previous knowledge was reviewed.
- By asking the following questions “Have you ever listened to the beat of your heart with stethoscope?”, “How many times do you think the human heart beats a minute?” and “Have you ever seen the EKG results of your own or one of your relatives?”, the students’ attention was drawn to the subject. Then the related worksheets were handed out to the students.
- The students were asked to read the thoughts seen in the speech bubble of Ali (Figure 3).

- Students were encouraged to question their own ideas and to establish connections between the concepts.
- The students were asked the question “Do you want to examine your heart’s beating graph by using the materials available?” and then they were asked to establish the Arduino-assisted robotic mechanism.

#### Exploration

- This section was carried out according to the instructions given to the students (Appendix Pulsimeter Instructions).
- The pulse sensor was connected to the Arduino microprocessor by the students by following the instructions in the worksheet.
- After each student had completed the above procedure, the Arduino microprocessor was connected to the computer (Figure 4).
- The ready-to-use codes in the arduino program were transferred to the arduino microprocessor by the students via the usb cable (Figure 5).
- Whether the arduino-assisted robotic and coding application is working was checked.
- Students were asked to open the serial plotter tab in the tools menu in the arduino program.
- Each student placed his/her finger on the pulse sensor in the robotics and coding assembly that they had created and measurements were performed (Figure 6).
- Each student recorded the peak and bottom values in the pulse graph.



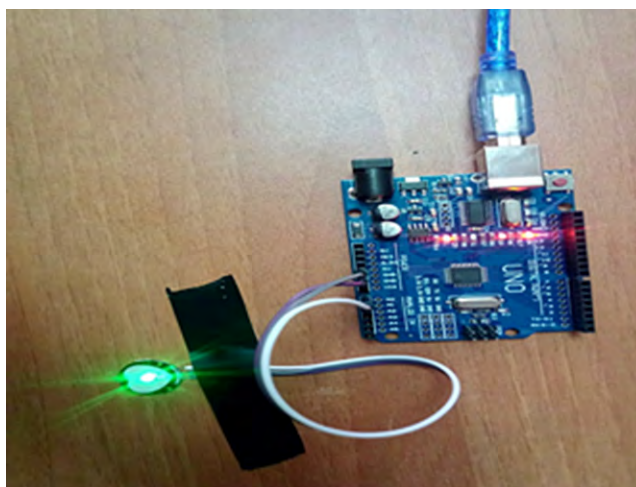


Figure 4. Arduino-assisted robotic mechanism.

```

Pulse | Arduino 1.8.9
File Edit Sketch Tools Help
Pulse
#include <SoftwareSerial.h>
void setup() {
  Serial.begin (9600);
}

void loop() {
  Serial.println (analogRead (0) );
  delay (20);
}

```

Figure 5. Ready-to-use codes in arduino program.

- The relationship between the pulse graph formed in the arduino program and the contraction and relaxation movements of the heart was discussed with the students. In addition, a discussion environment was created by asking students what the peak and pit values in the pulse graph in the arduino program are.

### Explanation

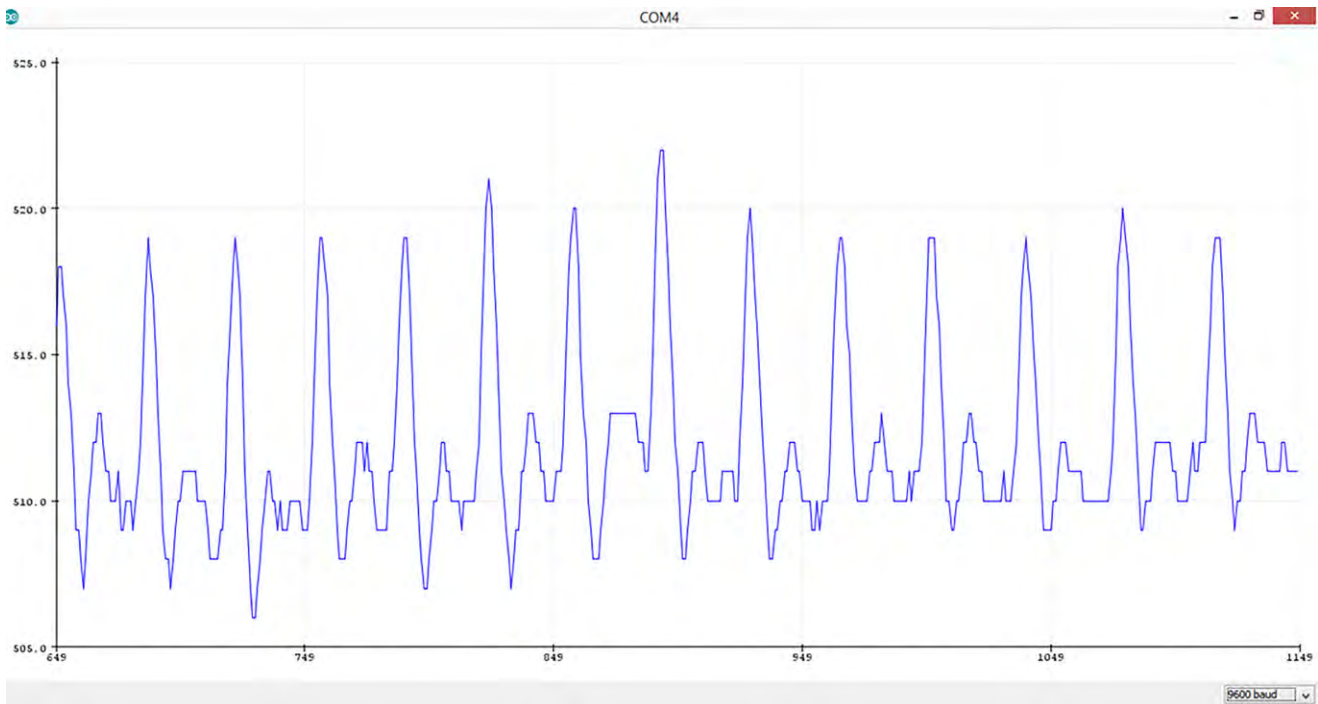
- In this phase, the students were asked to use the mBlock program to visualize the contraction and relaxation movements of the heart through an analogy of the flashing of the LED lamp in accordance with the instructions in the worksheets.
- By using the arduino microprocessor, breadboard, led lamp, pulse sensor and jumper cables,

the robotic mechanism for this analogy was established (Figure 7).

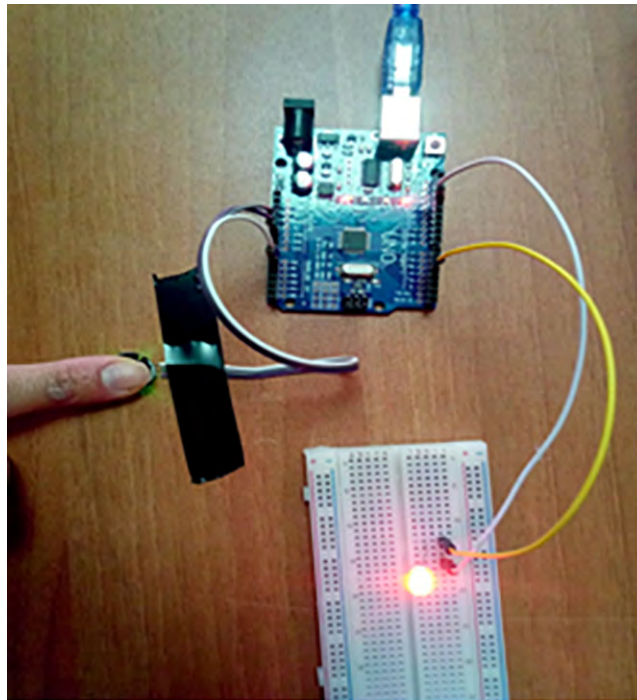
- In line with the instructions, codings were executed in the mBlock program by means of the drag-and-drop technique. However, in this section, students were asked to encode with the ready-to-use block codes by considering their own peak and pit values (Figure 8).
- The codes generated with the ready-to-use code blocks in mBlock program were transferred to the Arduino microprocessor via the usb cable.
- Each student placed his/her finger on the pulse sensor in the generated robotic and coding mechanism and observed and examined the flashing of the led lamp.
- The students were asked to explain the relationship between the pulse graph drawn in arduino and the flashing of the led lamp.
- In the light of established relations, the concept of pulse was clarified with robotic and coding applications in science laboratory (Figure 9).

### Elaboration

- The students were asked the questions “Why is learning our pulse rate important for our health?”, “Why do you think doctors want EKG in hospitals?” and “Is there a similarity between an EKG taken at hospital and the pulse graph generated in the classroom?”
- The students were asked to give examples of where and why to use the pulsimeter mechanism created with the arduino-assisted robotic and coding in daily life.



**Figure 6.** Arduino pulse graph.



**Figure 7.** The robotic mechanism for the led lamp flashing analogy of the contraction and relaxation movements of the heart.

### **Evaluation**

- The students were asked to write a science diary about the activity.
- The science diary included the following contents; “the purpose of the activity”, “the learned science concept and the scientific information about it”, “affective experiences related to the activity” and “integration of the activity into daily life”.
- The science diaries were evaluated by the researchers by means of the rubrics prepared.

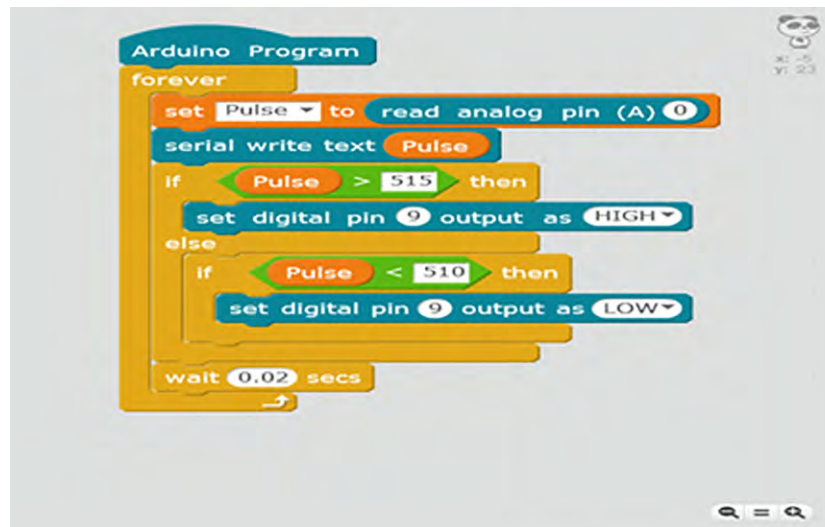


Figure 8. Coding formed with ready-to-use codes in mBlock program.



Figure 9. Robotic and coding applications in science laboratory.

### Findings and conclusion

As a result of the current study, an instructional activity as an example to the integration of the robotic and coding applications developed to make students understand the concept of pulse, which is an abstract concept addressed in the subject of the circulatory system within the unit of the systems in our body in the 6<sup>th</sup> grade middle school science curriculum, into the 5E learning model was developed. With this activity, an exemplary application model was created to visualize the systematic contraction and relaxation movements of the heart by using the arduino-

assisted robotic and coding applications. Here, the students were allowed to see the concept of pulse on a model and to construct more easily in their minds. This activity conducted according to the Next Generation Science Standards (NGSS) can be said to include Practices, Core ideas and Crosscutting dimensions (NGSS Lead States 2013). When the developed activity is examined, it can be said that the students' active participation in robotic coding activity and establishing mechanisms are related to the science and engineering practices dimension, teaching the concept of pulse in life science discipline is related to the



core ideas dimension and the students' producing engineering designs with pulse concept and relating this to life science is related to the crosscutting concepts dimension. In this context, teaching in accordance with these three dimensions is important for students to learn scientific concepts easily, to develop creativity and critical thinking skills and to acquire the 21<sup>st</sup> century skills. When its NGSS basis is examined, it is seen that the common point of these three dimensions is to encourage students to STEM fields. The fact that the developed robotic coding activity is an example for STEM education makes this study important. Furthermore, it is thought that students' experiencing with such technological applications and their being directed to designing something with these experiences will help them to improve their problem solving skills. When the students' science diaries were examined, it was determined that they could associate the robotics and coding mechanism they created with the concept of pulse, explain the concept in detail and use scientifically correct expressions for the purpose of the activity. In this regard, one student writes his/her diary (Ö<sub>3</sub>) "To visually see the contraction and relaxation of the heart, we connected the led lamp to the pulsimeter robotic coding assembly and saw that the heart contracted as the lamp lit, and the heart relaxed when the lamp went out. We related this to pulse.". Moreover, it was seen that the students stated in their science diaries that they had enjoyed the activity, had had great fun doing the activity and they wanted science classes to be delivered by using more technological devices. In this connection, one student writes his/her diary (Ö<sub>7</sub>) "... it was enjoyable because you wonder how the heart is working and you design something to see this and then you set up a mechanism and see it." Thus he/she indicated his/her interest in the robotic coding activity and that learning science with technological tools is enjoyable. In addition, the students stated that they had done each stage in order to establish the robotic and coding mechanism and they mentioned the importance of the algorithmic processing sequence by stating that the mechanism would not be working even when one of the stages was mistaken. In this context, in light of the data elicited through the science diaries, it can be said that with the use of this activity in the teaching of

the pulse concept, the students' cognitive thinking skills developed, their attitudes towards technology improved and the concepts of everyday life and science were related to each other. When the relevant literature is examined, it is seen that there are some studies reporting that these applications positively affect students' academic achievement (Chou 2018; Felicia and Sharif 2014), attitudes and motivation towards the course (Fokides, Papadakis and Kourtis-Kazoullis 2017; You and Kapila 2017), problem solving skills (Chou 2018). Middle school students can gain experience in coding with ready-to-use code blocks with arduino-assisted robotics and coding applications, and have the opportunity to integrate technological applications into daily life. In line with all these results, the integration of robotic and coding applications into a 5E learning model by employing technology in structuring an abstract concept in a science course may enable students to participate actively in all stages of the course, increase their attitudes towards technology, and develop their coding and information processing skills. Thus an inquiry-based learning is realized. This allows students to develop their higher order thinking skills.

While using the developed pulsimeter activity in the teaching of the related concept, it is suggested that students should be informed about arduino and its basic components and that simple activities should be conducted following this introduction. In addition, the introduction of the mBlock program should be made to show how coding is performed with ready-to-use block codes. It is also suggested that each part in the activity of the pulsimeter should be performed step by step with the students and the necessary feedback should be given and the relationship between the activity and the concept should be discussed.

## ORCID

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## Appendix APP

### *Pulsimeter instructions*

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Every man's heart rate is different. Many factors such as body movements (running, walking), emotional state (sadness, anxiety, happiness), being hungry or full or the temperature affect our heart rate. A heart rate in the range 60-100 is considered to be normal. In people doing sports for many years, the normal heart rate can be reduced to 50 or even 40. The reason for this is that the heart muscles are strengthened and can pump more blood each time as a result of doing sports. It has been reported that the heart of the famous bike racer Lance Armstrong beats 32 times a minute while resting. If you are doing sports and your heart beats at a low rate without resulting in any complaints, then do not worry about it. If you have complaints such as fatigue, dizziness, fainting accompanying low heart rate, you should definitely see a doctor. So let's do our pulsimeter and find out if our hearts beat fast or slowly ...

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### Stages of making a pulsimeter

1. Arduino uno's connection to the pulse sensor
  - Connect the (+) output on the pulse sensor to the 5V on the Arduino with the jumper cable.
  - Connect the (-) output on the pulse sensor to the GND on the Arduino with the jumper cable.
  - Connect the (S) output on the pulse sensor to the A (0) analog pin input on the Arduino with a jumper cable.
  - Connect the Arduino microprocessor to the computer with the usb cable.
  - Run the Arduino program and load the ready code.
  - Open the Tools-Serial Plotter tab in the Arduino program.
  - Place your finger on the pulse sensor and let it plot the pulse graph.

2. Arduino uno's connection to the led lamp
  - In addition to the above-described setup, connect the LED lamp.
  - Place the led lamp on the breadboard.
  - Connect the long leg (+) of the led lamp to the digital pin (9) input on the Arduino.
  - Connect the short leg (-) of the LED lamp to the GND input on the Arduino.
- Open the mBlock program and do the following codings.
- Load the related codes to arduino uno with the usb cable.
- Observe the status of the LED lamp flashing by placing your finger on the pulse sensor.