ARDUINO-ASSISTED ROBOTIC AND CODING APPLICATIONS IN SCIENCE TEACHING: BULB BRIGHTNESS ACTIVITY[1]

Nevin Kozcu Çakır[2], Sıla Yurdakul[3], Gürcan Çetin[4]

ABSTRACT

This research aims to design a sample Arduino-assisted robotics and coding activity in accordance with the 5E instructional model. Also, it aims to set an example for how technology is integrated into science courses, especially in the structuring of abstract and hard-to-understand concepts in science teaching. The activity provides guidance to science teachers. The study was carried out with the participation of 6th graders in a public school in the academic year 2021-2022. The designed activity was carried out in the science laboratory with the participation of 15 secondary school students in the science course. The related activity was prepared for the concept of bulb brightness in the chapter on electricity in the secondary school 6th-grade science curriculum. This activity also aims at teaching students how to code, improving their attitudes and motivation towards the course, and helping them relate the factors that influence bulb brightness with real life.

Keywords: science teaching, robotics and coding, Arduino, bulb brightness.

FEN ÖĞRETİMİNDE ARDUINO DESTEKLİ ROBOTİK VE KODLAMA UYGULAMALARİ: AMPUL PARLAKLIĞI ETKİNLİĞİ

ÖZ

Bu araştırmanın amacı, 5E öğrenme modeline uygun örnek bir Arduino destekli robotik ve kodlama etkinliği tasarlamak ve fen derslerine teknolojinin entegresyonuna örnek bir uygulama sağlamaktır. Yapılan etkinliğin fen eğitimini gerçekleştiren öğretmenlere rehberlik etmesi amaçlanmaktadır. Çalışma, Muğla ili Menteşe ilçesinde yer alan bir devlet okulunda ortaokul 6. sınıf öğrencileri ile 2021-2022 eğitim-öğretim yılı 1. döneminde gerçekleştirilmiştir. Tasarlanan etkinliğin uygulaması fen bilimleri dersinde 15 ortaokul öğrencisi ile fen laboratuvarında yürütülmüştür. İlgili etkinlik ortaokul 6. sınıf fen bilimleri öğretim programı doğrultusunda elektrik konusunda yer alan ampul parlaklığı kavramının öğretilmesine yönelik olarak 5E öğrenme modeline göre tasarlanmıştır. Etkinlik ile öğrencilerin kodlamayı öğrenmeleri, teknolojiye yönelik tutumlarının ve derse karşı motivasyonlarının artması, ampul parlaklığını etkileyen faktörleri gündelik hayatla ilişkilendirme yapmaları hedeflenmektedir.

Anahtar Kelimeler: fen öğretimi, robotik ve kodlama, Arduino, ampul parlaklığı.

Article Information:
Submitted: 02.21.2022
Accepted: 09.17.2022
Online Published: 10.31.2022

---

[1] Ethics committee approval was obtained from Mugla Sitki Kocman University Ethics Committee with the document dated 24 May 2021 and numbered 210250. This paper was written using the project data of 2209 TUBITAK University Students Research Projects Support Program titled "The Effect of Robotic and Coding Supported Activities for Science Course on Motivation, Attitude, and Success".

[2] Assoc. Prof. Dr., Mugla Sitki Kocman University, Faculty of Education, Department of Science Education, nkozcu@mu.edu.tr, ORCID: https://orcid.org/0000-0002-7538-7882.
[3] Science Teacher, Bayır School, sila_yurdakul99@hotmail.com, ORCID: https://orcid.org/0000-0001-9192-5460
[4] Asst. Prof. Dr., Mugla Sitki Kocman University, Faculty of Technology, Department of Information Systems Engineering, gcetin@mu.edu.tr, ORCID: https://orcid.org/0000-0003-3186-2781

INTRODUCTION

The rapid change in scientific knowledge has affected all aspects of life and has led to the rapid development of technology. The development of technology has changed the needs and expectations of individuals in society. Therefore, individuals need to have good scientific literacy skills in order to meet their changing expectations and understand changing situations. This requirement has led to restructuring in education. The structuring of curriculums has required the use of approaches, methods, techniques, and strategies that will enable individuals to construct information rather than memorize information in classes. The 5E learning model, which is the subject of the current research, has emerged as a result of these interactions and has been used especially in science courses. The 5E learning model is based on the constructivist approach and cognitive psychology and is used to enhance the quality of applications in science classes and design lessons (Bybee, 1997). Bybee (1997) states that the use of this approach helps students redefine, organize, examine, and change their existing ideas by interacting with their peers and environments. The structures introduced in the science curriculum have necessitated the use of technology in education, together with the 5E learning model based on the constructivist approach and have led to the development of educational technologies. (Korucu & Bicer, 2020). In science courses, students actively learn by doing/experiencing, as well as through the trial-and-error method. Also, the courses attract attention in terms of their topics and content that contribute to the development of 21st -century skills (problem-solving, creative thinking, critical thinking, communication, etc.) and reveal curiosity and the desire to learn. Because of these features, it is easy to integrate technology into the science learning outcomes (Gündoğan, 2020). Robotics and coding are one of the technologies used in the science course (Benitti, 2012; Beran et al., 2011; Johnson et al., 2015; Mubin et al., 2013). Coding can be defined as the whole or a part of a set of commands written to make a computer, electronic circuit, or mechanical system execute an operation or achieve a specific purpose. Students carry out coding in two ways: text-based coding, and block-based coding. Text-based coding is carried out by the students using the keyboard. On the other hand, block-based coding is carried out by combining existing codes using drag-and-drop and jigsaw puzzle techniques. The studies in the literature reported that using block-based coding in this way in teaching is effective in developing students' problem-solving, creativity, inquiry, algorithmic thinking, and cognitive skills (Czerkawski & Lyman, 2015; Lau & Yuen, 2011; Psycharis & Kallia, 2017; Strawhacker & Bers, 2015; Wanget al., 2012). Robotics is one of the new technology areas popular in the world; and it facilitates the combination of functional robotic components, which gain mobility through various commands, with technology (Erdoğan et al., 2020). Robots are electronic devices that sense the environment using their sensors, interpret the obtained data by their microcontrollers or processors as they are programmed, and generate various reactions accordingly. Thus, such educational robotic practices attract the attention of students by offering opportunities for them to learn by doing/experiencing (Prensky, 2010), increase their motivation (Ortiz, 2015), develop creative, critical, and computational thinking skills (Kazımoğlu et al., 2012), and contribute to the development of engineering skills and improve motivation to use technology (Güven, et. al, 2020). Moreover, it contributes positively to their cognitive, affective, social, and moral development (Shimada et al., 2012; Wei et al., 2011). In particular, since such practices support constructivist learning theory (Alimisis & Kynigos, 2009) and improve student performance (Mubin et al., 2013), the use of Arduino sets, which are examples of robotic coding applications in science courses, have been increasingly used in recent years. Arduino set is preferred more than other robotic sets because it is simple, economical, and understandable, and it allows for conducting various experiments easily (Koparan et al., 2021).

Arduino-assisted robotic coding applications seem to come to the fore more than other applications particularly in education due to the following reasons: it facilitates the understanding of the topics of science courses, which include abstract concepts that are conceptually difficult to understand, offers more experimental content, and data; it allows students to control the reactions of a model that they are able to touch and see with their eyes; it involves multiple senses in the learning process; it offers equal opportunity in learning, and it can be configured according to the learning speed of each individual. Arduino-assisted robotic coding applications facilitate the concretization of concepts that are difficult to understand and eliminate the difficulties experienced by students in structuring these concepts visually in the mind. Thus, it is reported that such applications should be involved in the teaching of science topics (Grubbs, 2013; Kılınç, 2014; Koç Şenol, 2012; Kozcu Çakır & Güven, 2019; Okkesim, 2014). Given that the students study abstract operations in this term, they should be provided with teaching experiences based on Arduino-assisted robotic coding applications to allow them to realize meaningful learning in science topics where abstract and complicated concepts are covered, to increase their willingness to learn scientific knowledge, to allow them to generate new ideas by adapting the knowledge they have learned to different fields and daily life.

The current research aims to design and develop an example Arduino-assisted robotics and coding activity in accordance with the 5E instructional model so that students can learn by structuring knowledge. The research was developed for the following learning outcomes in the sixth-grade science curriculum: "Predicts the variables on which the brightness of a light bulb in an electrical circuit depends." and "Tests their predictions.". In this context, the activity is performed while teaching the concepts of light bulb brightness, conductor, and insulator, which are covered by the secondary school sixth-grade science course curriculum. Therefore, the present study aimed to achieve the following objectives by performing this activity:

1. Introducing Arduino-assisted robotics and coding applications to students.
2. Teaching block-based coding to students.
3. Creating a model by which data about bulb brightness can be obtained concretely.
4. Teaching the factors affecting the brightness of the bulb using the created model.
5. Ensuring that the knowledge about the brightness of the bulb is associated with daily life.
6. Improving the attitudes of the students towards technology.
7. Improving the motivation of students toward science courses.
8. Integrating Arduino-assisted robotics and coding applications into daily life.

ACTIVITY IMPLEMENTATION

The activity was carried out with sixth-grade students in a public school in the Menteşe district of Muğla province in the first semester of the 2021-2022 academic year. The activity was carried out in the science laboratory with the participation of 15 secondary school students. The performed activity was designed in accordance with the 5E instructional model in line with the secondary school science curriculum. The 5E instructional model encompasses the steps of engagement, exploration, explanation, elaboration, and evaluation. In line with these steps, Arduino-assisted robotic coding applications were used for the subject of "Electrical Resistance and Factors Affecting It" in the "Electric Transmission" unit.

Materials

The following materials were used in the activity:

- laptop computer,
- Arduino UNO,
- Arduino USB cable,
- battery,
- jumper cable,
- alligator clips cable,
- ACS712 30 A current sensor,
- a long steel nail,
- a short steel nail,
- a thick steel nail, and
- graphite.

Engagement

In order to review the existing knowledge of the students and to determine whether they have misconceptions about the topic, the following questions were asked to the students: "What can be done to increase or decrease the brightness of a light bulb in a simple electrical circuit?" and "How can you define the dependent and independent variables and constants before designing or performing an experiment?" It was observed that the students had difficulty answering the question about the brightness of the bulb, and it was determined that they had the wrong ideas about how a change in the circuit elements in a simple electrical circuit could change the brightness of the bulb. Based on the students' answers, it was observed that they had misconceptions such as "The battery in the circuit is the same, so the changes made in the conductive wire will not change the brightness of the bulb." In addition, while determining the dependent, independent, and control variables, which are among the scientific process skills in creating an experimental setup, they were observed to confuse the dependent and independent variables. The teacher enabled them to define the explanations of dependent and independent and control variables by asking questions.

The students were requested to form groups after answering the introductory questions. Arduino circuit elements, which were taught in the previous lessons, and small sheets of paper with the names of the circuit elements were distributed to each group. The attention of the students was drawn to the subject by asking them to match the circuit elements and their names.

The students were asked which Arduino elements correspond to the elements in the circuit drawn on the board (Figure 1), thereby helping them question their own ideas and try to establish the association between the concepts. After this relationship is established, the teacher wrote which circuit element matches with the circuit element in the Arduino setup after noting the students' answers on the board. As in the dialogue below, pairings were made in the classroom environment.

> Student: Yes sir, we always draw circuits or create circuits with small light bulbs. The circuit elements here are confusing.
> Teacher: Let's define them one by one, without confusion, and write them on the board. For example, what is in the circuit I drew on the board?
> Student A: There is a light bulb, conductive wire, battery, and ammeter.
> Teacher: Look at the Arduino elements in front of you, is there anything like a light bulb?
> Students: Yes, there is.
> Teacher: Well, there are small cables, what do you think?
> Students: It can be a conductor wire!
> Teacher: Yes, conductive wire. So, what does the conductive wire do? We talked about this in our previous lesson.
> Student B: It conducts the current.
> Teacher: The color wires you see in the same way are the conductor wires. Well, there is an ammeter. What is its function?
> Student C: It measures voltage.
> Teacher: Are you sure?
> Student A: No, the ammeter is used to measure the current flowing through the circuit.
> Teacher: Yes, it allows measuring the current passing through the circuit. Well, we have already explained Arduino and its circuit elements. What was in here?
> Student B: There were sensors that allowed us to perceive our work and the environment.
> Teacher: Yes, with sensors, we were perceiving things in the environment that we could not perceive with our sense organs. What do you think the sensor I got in my hand corresponds to in the circuit drawn on the board?
> Students: The ammeter.

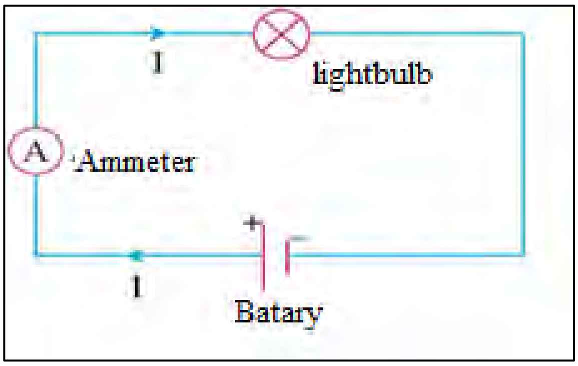


Figure 1. Circuit Drawn on the Board

The question "Do you want to observe the robotic circuit elements and the factors that affect the electrical resistance?" was asked to students to inform them about the next phase of the lesson Then, they were given Arduino circuit elements.

Exploration

As the first step before setting up the circuit using the Arduino circuit elements, Appendix 1 (Appendix 1: Graph drawing, reading, and interpreting skills) was given to the students to ensure that they answer the questions there. This appendix is used to describe the basic components of a graph, what to consider when drawing a graph, and how to create a graph; also, graph reading, and interpretation exercises were performed. Thus, the graph reading skill, which is one of the scientific process skills, was reminded to the students. The teacher first asked the students about the graph in Appendix 1: "How many liters of milk has the milkman sold for a week?" Considering the graphics created by the students, their reading skills were evaluated, and necessary corrections were made. Secondly, they were asked to determine the difference between the day the milkman sells the most and the day he sells the least. The teacher observed that the students generally had difficulty determining the minimum and maximum values in a graph. The teacher then solved the second question in a similar way by discussing it with the students and asking the students to review the second question. Finally, they were allowed to draw a graph with the values given to them. Thus, graph reading skills were repeated so that the students can better read the graph that will be created in the next step.

In the second step, each group was asked questions about the Arduino elements given to them and their functions to remind the students about the Arduino Uno information given in previous lessons. Then, the instructions in Appendix 2 (Appendix 2: Arduino Circuit Setup Instructions) were given to each group, and the students were asked to set up the Arduino circuit required for the activity.

In the third step, reminder questions were asked about the codes in the mBlock software studied in the previous lessons. The ready-to-use codes shown in Figure 2 were given to the students, and their associations with the circuit elements were discussed. (For example, "Which element is the analog pin associated with?" and "Which data does it provide?") Then, the connection of the created circuit with the ready-to-use code was transferred to the Arduino microprocessor via a USB cable.

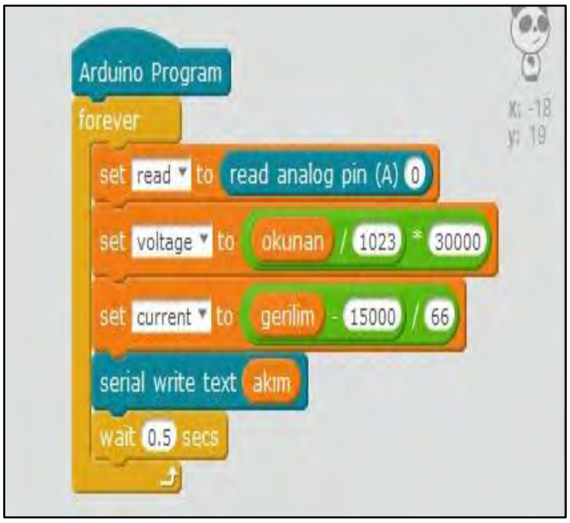


Figure 2. Ready-to-use Code Prepared Using mBlock

It was checked whether the Arduino-assisted robotics and coding application were running or not. The students were asked to open the Serial Plotter tab in the tools menu in the Arduino software (Figure 3). The graph is drawn using the serial plotter by measuring the variables in the setup.

Figure 3. Serial Plotter in Arduino Software

Then, the observation form was distributed to the students. They were asked to record the peaks of the graphic data of each variable changed in the Arduino mechanism in the observation form provided (Appendix 3: Observation Form). It was observed that the students carefully processed the data into the observation form due to their previous experiences, had a lot of fun, and corrected each other through in-group discussions.

At the end of the observation, they were asked to fill in the variables section at the end of the worksheet for each experiment. A whole class discussion was held by asking the students why they observed the peak values and the reasons for the changes in the graph.

Explanation

Before performing the graph observation using the Arduino software, students' knowledge about the graphs was activated by distributing Appendix 1 to the students. The students were asked to perform the following three experiments by using the robotic setup, which is prepared using Arduino UNO, current sensor, battery, jumper cable, and alligator clips cable (Figure 4. Robotic setup prepared) and opening the Serial Plotter tab from the Arduino software.

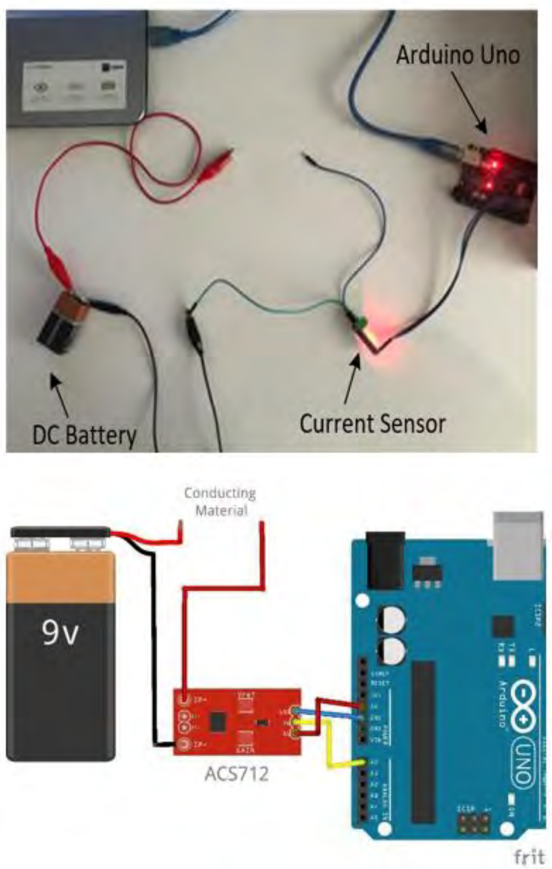


Figure 4. Robotic Setup Prepared and Its Diagram

The experimental setup was arranged for each stage by changing the variables in each experiment (Figure 5, Figure 6, and Figure 7), and the graphs obtained from the serial plotter were examined. The students were informed that the value determined on the serial plotter indicated the brightness of the bulb in each setup. In experiment 1, the students examined the relationship between the brightness of the bulb and the length of the conductor.

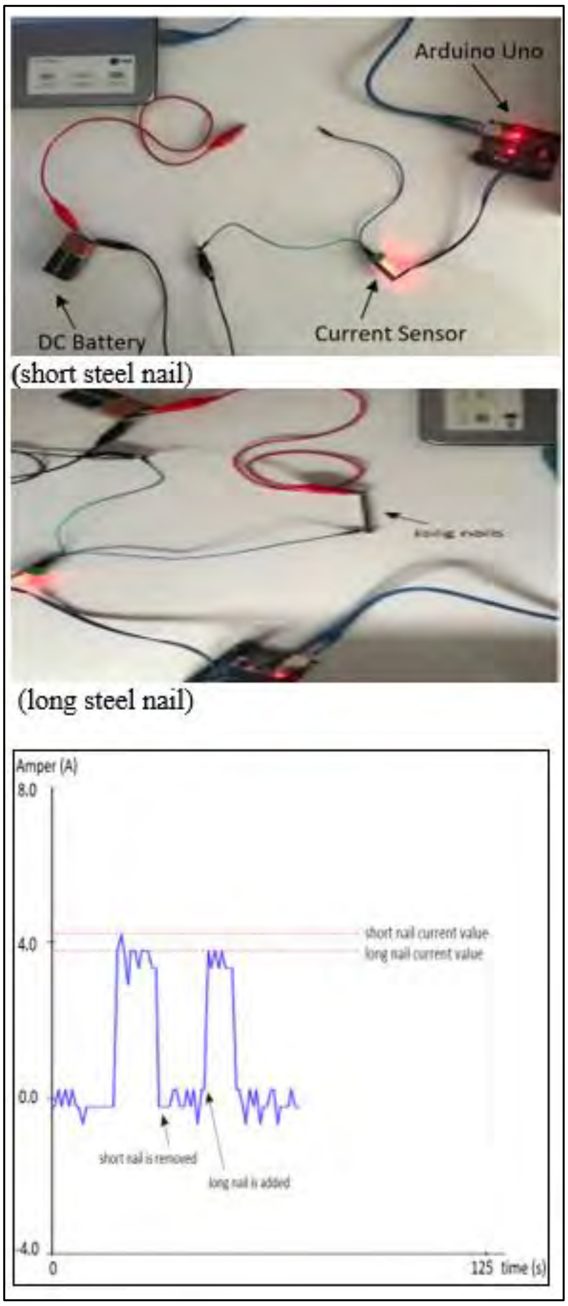


Figure 5. Experiment Setup for the Length of the Conductor and the Observation Made on the Serial Plotter

In experiment 2, the students investigated the relationship between the brightness of the bulb and the cross-sectional area of the conductor. In experiment 3, they examined the relationship between the brightness of the bulb and the type of conductor.

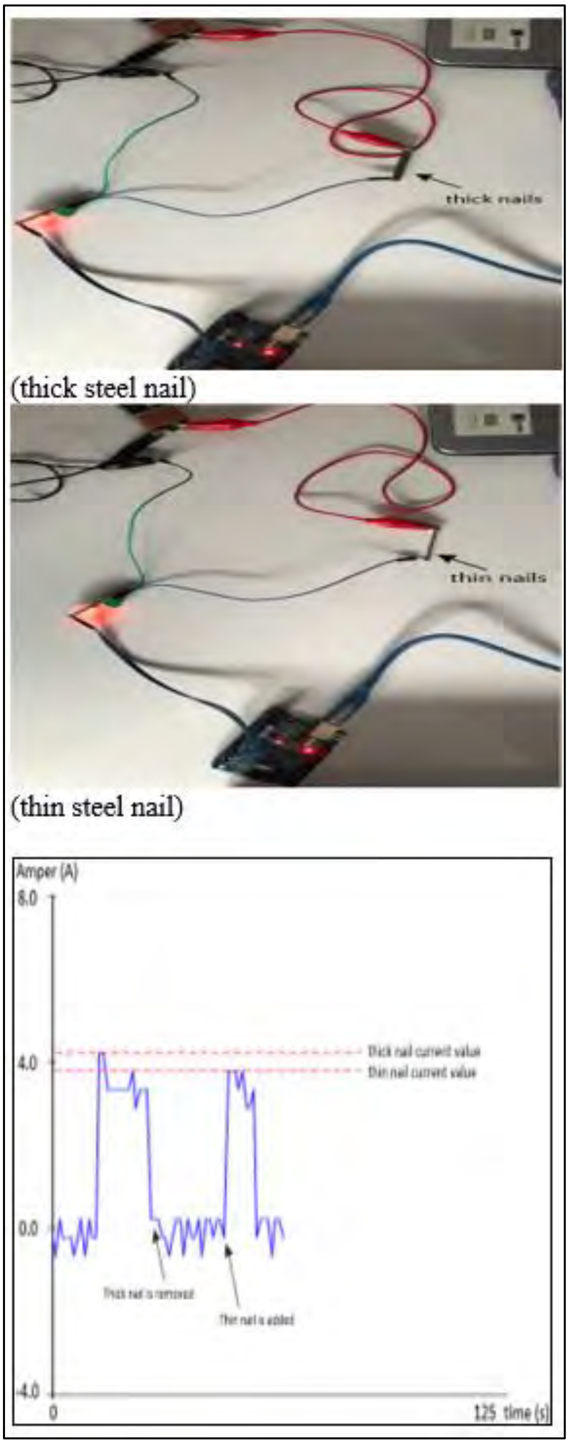


Figure 6. Experiment Setup for the Cross-sectional Area of the Conductor and the Observation Made on the Serial Plotter

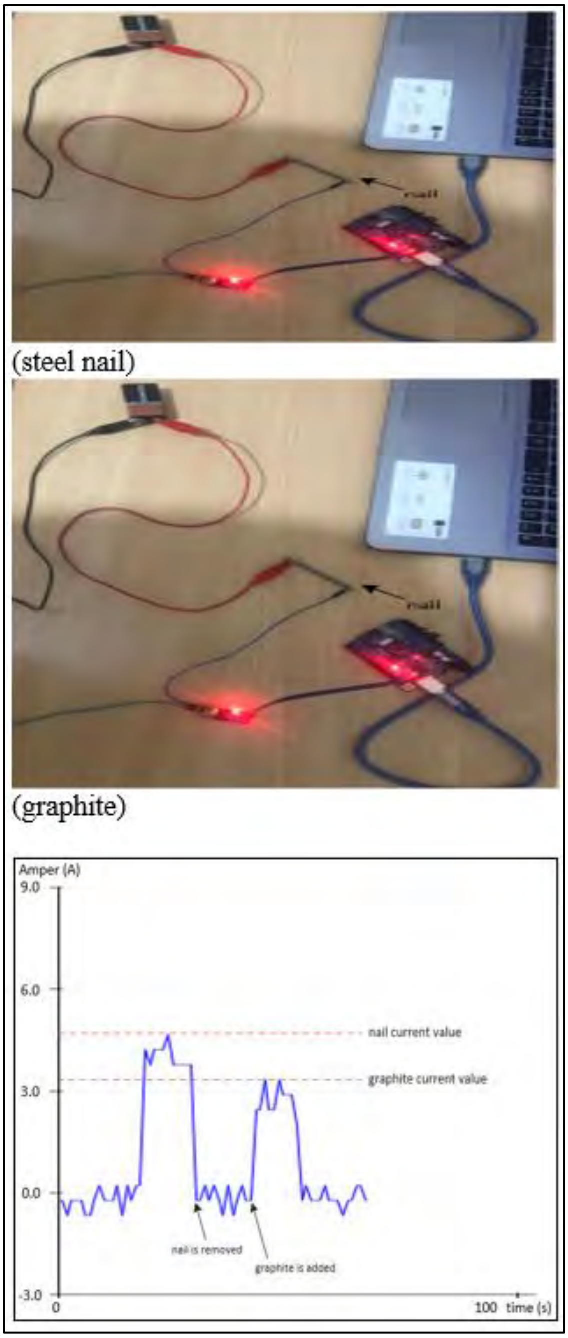


Figure 7. Experiment Setup for the Type of Conductor and the Observation Made on the Serial Plotter

The students, who had been reminded about the graph knowledge, were asked to fill in the observation form in Appendix 3, taking into account the peak values of the graphs created in the serial plotter tab of the Arduino software.

The teacher facilitated a class discussion on the relationships between the brightness of the bulb and the variables affecting the brightness, which helped clarify the concepts. The observation results of each experiment were discussed. Part of the discussion on experiment 1 is given below as an example.

> Teacher: Let's look at the graph in the first experiment together. Considering the graph here, is the peak value of the long nail or the short nail higher?
>
> Students (Laughing all together): Of course, the short nail's peak is higher.
>
> Teacher: What do you think is the reason for this?
>
> Students: We don't know.
>
> Teacher: We talked about the rheostat before, and we mentioned that it serves to increase or decrease the resistance in the circuit. If we consider the length of the nails we use here as a rheostat, why did extending the length decrease the brightness of the bulb?
>
> Students (together): Residual resistance.

Elaboration

The following 'Luminous House' activity worksheet was distributed to the students. They were asked to answer the questions about the given activity and discuss it in their group. Then, the concept is associated with daily life by creating a discussion environment about the answers to these questions in the class.

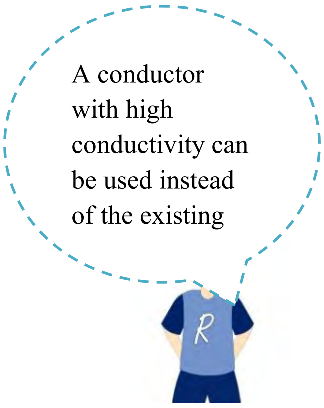
Activity: Luminous House

Defne and her family decide to go to their village after the schools are closed. They want to experience the natural life in the village this year as they do every year. However, Defne's father thinks of building a house in a corner of the garden in their village, and he begins the preparations for the house. The construction of the house is completed after a period. Defne enters the house excitedly. However, something catches her attention. Although the lamps of the house are on, the interior of the house is not sufficiently illuminated. Defne begins to think about this case and remembers the topic of "factors affecting the electrical resistance" that she learned last year. However, she cannot remember what they are.

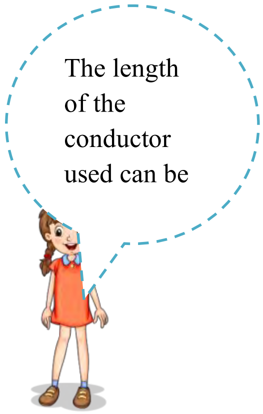
- Would you like to help Defne? Which factors affect electrical resistance?

....
....

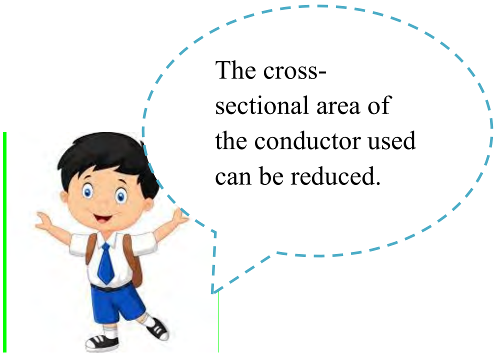
- So, what can be done to improve the illumination of the house?



Cihangir



Duru



Nezih

Whose ideas are correct, Cihangir, Duru, or Nezih? Please mark.

○ Cihangir ○ Duru ○ Nezih

In your opinion, is there a wrong idea? If yes, please explain the correct one.

....
....
....
....

Evaluation

The puzzle given in Appendix 4 was distributed to the students, and they were asked to solve the puzzle. Then, the answers to the questions in the puzzle were evaluated, and the reasons were discussed in the classroom. In the second and third questions in the puzzle, the teacher asked the students to answer the questions about the length and thickness of the conductor, taking into account the dependent, independent, and control variables while setting up an experiment. Below are examples of the answers of the students while doing the puzzle in the classroom:

> Teacher: Let's do the puzzle in the worksheet I gave you according to what we learned.
> Students: Yes (excitedly).
> Teacher: Looking at the second and third questions, we see that we are given conductors with different lengths and thicknesses.
> (Students examined pictures and read the descriptions.)
> Teacher: Please read the second question, which variable is different?
> Students: Their length.
> Teacher: Considering the experiment we did and discussed in our lesson, which one here conducts electricity better?
> Students: First
> Teacher: Why?
> Students: Of course, the resistance is high.

As a result of the answers and discussions of the students, it was seen that the misconceptions about the variables affecting the brightness of the bulb were eliminated.

After the evaluations, the students were asked to write a reflective diary at their homes about the activity including "the purpose of the activity", "scientific knowledge about the learned scientific concept", "affective experiences for the activity" and "integration of the activity into daily life". In the next class, some of these reflective diaries were read so that the students were informed about their progress.

CONCLUSION and SUGGESTIONS

Modern education replaced traditional education, and it required the integration of technology into the education system. Furthermore, it is expected to raise individuals who question, reach knowledge, and research themselves instead of an education understanding where students passively memorize and accept the knowledge without questioning it (Bağra & Kılınç, 2021). The integration of robotics and coding into the 5E model highlights such applications as the students become active at all stages, learning by doing becomes at the forefront, technology is actively used in the learning process, and its association with science teaching has been increasing each passing day. Also, the topics of the science course are quite suitable for robotics and coding (Okkesim, 2014), and they can be used to concretize abstract topics. Therefore, this study was conducted to allow the students better understand the factors affecting the brightness of the bulb. Also, it aimed to conduct an exemplary application of the related literature.

In the study, an Arduino-assisted robotic coding activity was developed in accordance with the 5E instructional model for teaching the concept of factors affecting the brightness of the bulb, which is an abstract concept in the sixth-grade science course curriculum. With this activity, an example model was created using Arduino-assisted robotics and coding in teaching the factors affecting the brightness of the bulb. In this model, the independent variables in each experimental setup were changed gradually and the factors affecting the brightness of the bulb were examined. Thus, thanks to this model, the factors affecting the brightness of the bulb were observed concretely, and conceptual learning has been achieved by helping students structure the new knowledge in their mind. 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 the brightness of a light bulb, explain the concept in detail, and use scientifically correct expressions for the purpose of the activity. In this regard, one student wrote in his diary as follows:

> In our previous experiment by setting up a simple electrical circuit related to the brightness of the bulb, we could not observe very well how the brightness of the bulb changed. But here we looked at the change in the graph and saw how much of a difference there actually was.

> Technology has made our work easier, and I understand better, I will not forget anymore. (SA).

Moreover, it was found that the students stated in their science diaries that they enjoyed the activity, had great fun doing the activity, and wanted science classes to be delivered by using more technological devices. In this context, one student wrote in her diary as follows:

> … it was enjoyable because I saw how the brightness of the light bulb can benefit us in our daily life. I realized how important it is to use technology. It turns out that science class is our life, now I will love this lesson. It wasn't difficult. (SD).

Thus, she indicated her interest in the robotic coding activity and that learning science with technological tools is enjoyable.

The studies on robotic coding applications in the literature report that these activities improved the academic performance of the students (Chou, 2018; Felicia & Sharif, 2014), and improved their attitudes and motivations toward the course (Fokides et al., 2017). Also, several studies report that such activities improved their problem-solving skills (Chou, 2018) and algorithmic-thinking skills (Czerkawski & Lyman, 2015; Cakir & Guven, 2019). According to the results of the activity, the following suggestions can be made:

- It is recommended to add learning outcomes related to robotics and coding to the curriculum of the science course.
- It is recommended to open robotics and coding laboratories in schools.
- Teachers should be supported with professional development to be able to teach these types of activities.
- Since robotics and coding are interdisciplinary fields, they should be applied to interdisciplinary studies where the courses are integrated.

REFERENCES

Alimisis, D., & Kynigos, C. (2009). Constructionism and robotics in education. In D. Alimisis (Ed.), *Teacher education on robotics-enhanced constructivist pedagogical methods* (pp. 11-26). ASPETE.

Bagra, A., & Kilinc, H. H. (2021). Secondary school students' views on coding education. *International Journal of Social and Humanistic Sciences*, *4*(1), 36-51. https://doi.org/10.47155/mamusbbd.946241

Benitti, F. B. V. (2012). Exploring the educational potential of robotics in schools: A systematic review. *Computers & Education*, *58*(3), 978-988. https://doi.org/10.1016/j.compedu.2011.10.006

Beran, T., Ramirez Serrano, A., Kuzyk, R., Fior M., & Nugent S. (2011). Understanding how children understand robots: Perceived animism in child-robot interaction. *International Journal of Human-Computer Studies, 69,* 539-550. https://doi.org/10.1016/j.ijhcs.2011.04.003

Bybee, R. W. (1997). *Achieving scientific literacy: From purposes to practices. Portsmouth*. Heineman Publication.

Cakir, N. K., & Guven, G. (2019). Arduino-Assisted robotic and coding applications in science teaching: Pulsimeter activity in compliance with the 5E learning model. *Science Activities, 56*(2), 42-51. https://doi.org/10.1080/00368121.2019.1675574

Chou, P.N. (2018). Skill development and knowledge acquisition cultivated by maker education: Evidence from Arduino-based educational robotics. *EURASIA Journal of Mathematics, Science and Technology Education*, *14(10)*, 1-15.

Czerkawski, B. C., & Lyman, E. W. (2015). Exploring issues about computational thinking in higher education. *TechTrends, 59*(2), 57-65.

Erdogan, O., Toy, M., & Kurt, M. (2020). Investigation of the effect of robotic applications on some 21th century skills of science teacher candidates. *Avrasya Sosyal ve Ekonomi Araştırmaları Dergisi (ASEAD), 7*(4), 117-137.

Fokides, E., Papadakis, D., & Kourtis-Kazoullis, V. (2017). To drone or not to drone? Results of a pilot study in primary school settings. *Journal of Computers in Education, 4*(3), 339-353. https://doi.org/10.1007/s40692-017-0087-4

Grubbs, M. (2013). Robotics intrigue middle school students and build STEM skills. *Technology and Engineering Teacher, 72*(6), 12-16.

Guven, G., & Cakir, N. K. (2020). Investigation of the opinions of teachers who received in-service training for Arduino-assisted robotic coding applications. *Educational Policy Analysis and Strategic Research, 15*(1), 253-274. https://doi.org/10.29329/epasr.2020.236.14

Guven, G., Cakir, N. K, Guven, E., Sulun, Y., & Cetin, G. (2022). Arduino-assisted robotics coding applications integrated into the 5E learning model in science teaching. *Journal of Research on Technology in Education, 54*, 1, 108-126. https://doi.org/10.1080/15391523.2020.1812136.

Johnson, L., Adams Becker, S., Estrada, V., & Freeman, A. (2015). *NMC horizon report: 2015 higher education edition*. The New Media Consortium.

Kazimoglu, C., Kiernan, M., Bacon, L., & Mackinnon, L. (2012). A serious game for developing computational thinking and learning introductory computer programming. *Procedia-Social and Behavioral Sciences, 47*, 1991-1999. https://doi.org/10.1016/j.sbspro.2012.06.938

Kılınc, A. (2014). *The using of robotic technology in teaching of light unit 7th grade (*Unpublished master thesis). Erciyes University Institute of Educational Sciences.

Koc Senol, A. (2012). *Science and technology laboratory applications supported by robotic: ROBOLAB* (Unpublished master thesis). Erciyes University Institute of Educational Sciences.

Koparan, E. T., Yüksel, B., & Koparan, T. (2021). Arduino ile programlamanın öğrencilerin fen bilimlerine yönelik başarı [The effects of programming with arduino students' achievements, attitudes and self-sufficiency intented for science]. *Yükseköğretim ve Bilim Dergisi, 11*(1), 118-127. https://doi.org/10.5961/jhes.2021.434

Korucu, A. T., & Bicer, H. (2020). Investigation of middle school students' attitudes towards robotic coding according to different variables. *International Technology and Education Journal, 4*(1), 30-35.

Lau, W. W., & Yuen, A. H. (2011). Modelling programming performance: Beyond the influence of learner characteristics. *Computers & Education, 57*(1), 1202-1213. https://doi.org/10.1016/j.compedu.2011.01.002

Mubin, O., Stevens, C. J., Shahid, S., Al Mahmud, A., & Dong, J. J. (2013). A review of the applicability of robots in education. *Journal of Technology in Education and Learning*, *1*, 13. https://doi.org/10.2316/Journal.209.2013.1.209-0015

Okkesim, B. (2014). *Robotics applications in science and technology education* (Unpublished master thesis). Erciyes University Institute of Educational Sciences.

Ortiz, A. (2015). Examining students' proportional reasoning strategy levels as evidence of the impact of an integrated LEGO robotics and mathematics learning experience. *Journal of Technology Education, 26*(2), 46-69.

Prensky, M. (2010). *Teaching digital natives: Partnering for real learning.* Thousand Oaks.

Psycharis, S. & Kallia, M. (2017). The effects of computer programming on high school students' reasoning skills and mathematical self-efficacy and problem solving. *Instructional Science, 45*(5), 583-602. https://doi.org/10.1007/s11251-017-9421-5

Shimada, M., Kanda, T., & Koizumi, S. (2012). How can a social robot facilitate children's collaboration? In S. S. Ge, O. Khatib, J. J. Cabibihan, R. Simmons, &

M. A. Williams (Eds.), *Social robotics* (pp. 98-107). Springer.

Strawhacker, A., & Bers, M. (2015). "I want my robot to look for food": Comparing kindergartner's programming comprehension using tangible, graphic, and hybrid user interfaces. *International Journal of Technology and Design Education, 25*(3), 293-319. https://doi.org/10.1007/s10798-014-9287-7

Wang, Y., Li, H., Feng, Y., Jiang, Y., & Liu, Y. (2012). Assessment of programming language learning based on peer code review model: Implementation and experience report. *Computers and Education*, *59*(2), 412–422. https://doi.org/10.1016/j.compedu.2012.01.007

Wei, C. W., Hung, I. C., Lee, L., & Chen, N. S. (2011). A Joyful classroom learning system with robot learning companion for children to learn mathematics multiplication. *Turkish Online Journal of Educational Technology, 10*(2), 11-23.

Yıldız, T., & Seferoğlu, S. S. (2021). The effect of robotic programming on coding attitude and computational thinking skills toward self-efficacy perception. *Journal of Learning and Teaching in Digital Age, 6*(2), 101-116.

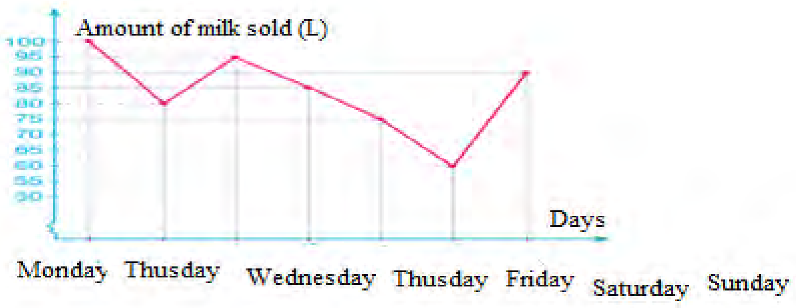
Citation Information

Kozcu Çakır, N., Yurdakul, S., & Çetin, G. (2022). Arduino-assisted robotic and coding applications in science teaching: Bulb brightness activity. *Journal of Inquiry Based Activities, 12*(2), 90-107. https://www.ated.info.tr/ojs-3.2.1-3/index.php/ated/issue/view/24

Appendix 1

Graph Drawing, Reading, and Interpreting Skills

Example 1: The graph below shows the amount of milk sold by a milkman by day of the week.



Answer the following questions considering the graph above.

1. How many liters of milk did the milkman sell in total during the week?
2. How many liters more milk did the milkman sell on the day he sold the most milk compared to the day he sold the least?
3. How many liters more milk did the milkman sell on Sunday than on Saturday?

Example 2: The weekly temperature of a province is 12°C, 14°C, 13°, 10°C, 9°C, 11° C, and 15°C for the days between Monday and Sunday, respectively. Let's show these data by drawing a line graph.

Appendix 2

Arduino Circuit Setup Instructions

1. Arduino UNO, battery, jumper cable, USB connection cable, alligator clips cable, and current sensor are taken.
2. The VCC pin on the current sensor and the 5V pin on the UNO are connected using a female-male jumper cable.
3. The OUT pin on the current sensor and the A0 pin on the UNO are connected using a female-male jumper cable.
4. The GND pin on the current sensor and the GND pin on the UNO are connected using a female-male jumper cable.
5. Alligator clips cable is attached to the + pole of the power supply. A male-male jumper cable is attached to the input pin on the other end of the current sensor. The alligator clips cable and jumper cable are connected. Thus, the current sensor is connected to the power supply.
6. Alligator clips cable is attached to the - pole of the power supply. A male-male jumper cable is attached to the output pin on the current sensor.
7. Observation is made by connecting the free end of the alligator clips cable and the free end of the jumper cable using the test materials.

Appendix 3

Observation Form

OBSERVATION FORM

For Experiments 1, 2, and 3, connect the free ends in the circuit using the desired item. Record the result of the observation. (Note: The peak value here indicates the brightness of the bulb.)

*Experiment 1***:** Length of the Conductor

Which one has the highest peak value according to the observation results?
a) Long steel nail b) Short steel nail

Experiment 2: Cross-sectional Area of the Conductor

Which one has the highest peak value according to the observation results?
a) Thick steel nail b) Thin steel nail

Experiment 3: Type of the Conductor
Which one has the highest peak value according to the observation results?
a) Steel nail b) Pencil lead (graphite)

	Experiment 1	Experiment 2	Experiment 3
Dependent variable			
Independent variable			
Constant variable			

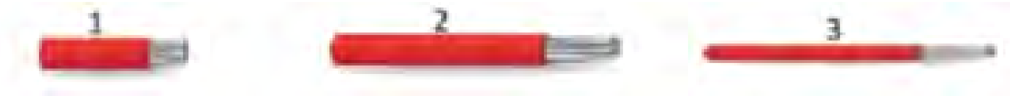
Appendix 4

Evaluation Puzzle

- **The answers to the questions in the puzzle:** copper wire, decreases, thick, aluminum wire, increases, cross-sectional area, conductor type, decreases, bulb brightness, short, number of batteries, type (Note for teachers).

1. Pelin wondered if the type of conductor had an effect on the brightness of the bulb, and she set up the electric circuit as shown in the figure. She first used copper wire, then she used aluminum wire. She observed the brightness of the bulb in both circuits she set up. In which circuit is the brightness of the bulb higher?

- **Answer questions 2 and 3 according to the figure below**.

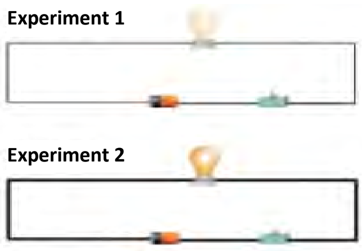


	1	2	3
Length:	1m	2 m	2 m
Vertical Cross-Sectional Area:	10 mm^2	10 mm	5 mm^2
	Nickel Chrome Wire	Nickel Chrome Wire	Nickel Chrome Wire

2. Which of the nickel-chromium wires 1 and 2 conduct electricity better?

3. Which of the nickel-chromium wires 2 and 3 conduct electricity better?

- **Considering the experiment setups given below, it is observed that the brightness of the bulb in Setup 1 is less than that of the bulb in Setup 2. Answer questions 4 and 5 based on this information.**



4. What is the dependent variable in the controlled experiment whose setup is given above?

5. What is the independent variable in the controlled experiment whose setup is given above?

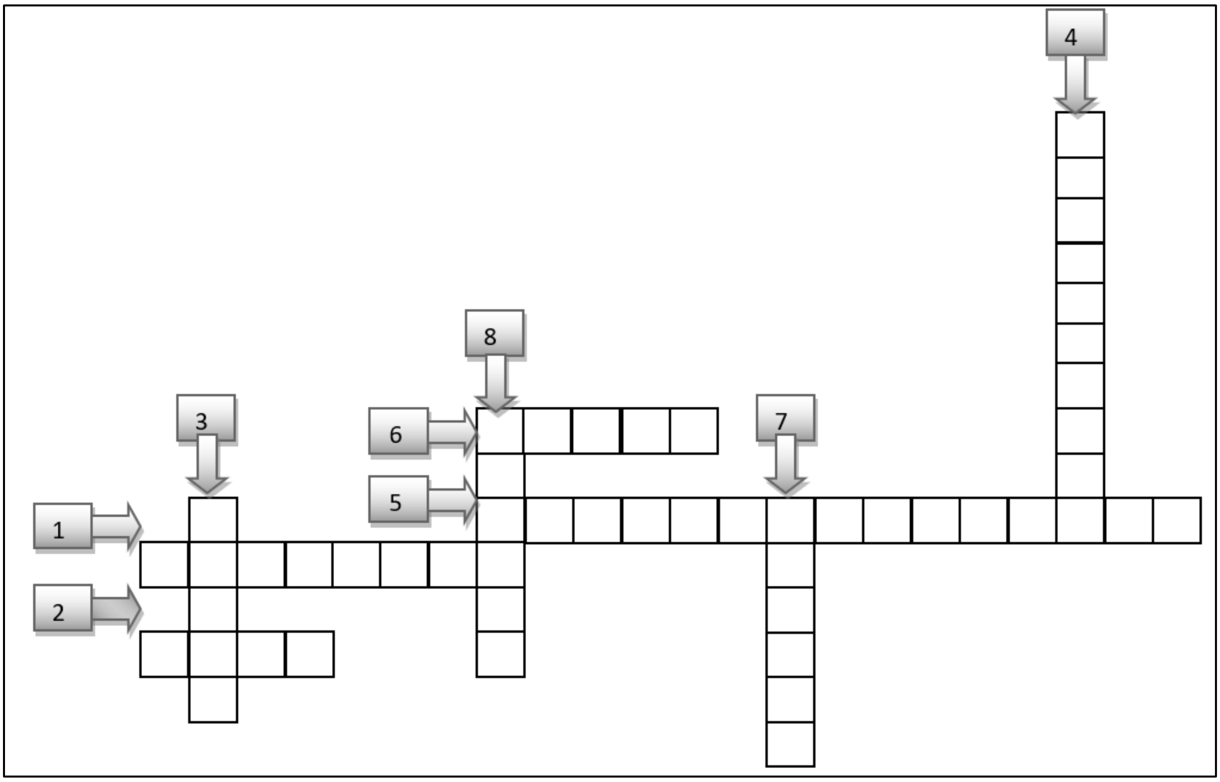
- **The copper wire used in the circuit will be replaced with a thick, thin, and long copper wire in the test setup below following the steps and the brightness of the bulb will be observed. Questions 7 and 8 will be answered based on the results of these observations.**

6. What is observed in the brightness of the bulb if a thick copper wire is connected?

7. What is observed in the brightness of the bulb if a long copper wire is connected?

8. What is observed in the brightness of the bulb if a thin copper wire is connected?

Note: The answers to the questions above include the answers to the puzzle below. Complete the puzzle below after answering the questions.


4
8
3
6
7
1
5
2