Scientific journal
PHYSICAL AND MATHEMATICAL EDUCATION
Has been issued since 2013.
Науковий журнал
ФІЗИКО-МАТЕМАТИЧНА ОСВІТА
Видається з 2013.

p-ISSN 2413-1571
e-ISSN 2413-158X
DOI: 10.31110/2413-1571
https://fmo-journal.org/

DOI 10.31110/2413-1571-2023-038-4-003 UDC 37.09:378:621.3:004.94

ПРОЄКТНИЙ МЕТОД У STEM-ОСВІТІ ІЗ ЗАСТОСУВАННЯМ ПРОГРАМНО-АПАРАТНОЇ ПЛАТФОРМИ ARDUINO

Олексій ВОРОНКІН ✉
Український вільний університет, Німеччина
oleksii.voronkin@ufu-muenchen.de
https://orcid.org/0000-0003-4088-7147
Сергій ЛУЩИН
Національний університет «Запорізька політехніка», Україна
luschin@zntu.edu.ua
https://orcid.org/0000-0003-2135-0520

АНОТАЦІЯ

Формулювання проблеми. *Одним із перспективних методів навчання у STEM-освіті є метод проєктів. Проєктний метод у STEM-освіті обумовлює актуальність і дослідницький характер теми проєкту, забезпечення взаємозв'язку теоретичних знань із практикою, практичне втілення результатів проєкту. Проєкт, як засіб реалізації STEM-освіти, дозволяє інтегрувати знання з різних предметних галузей під час розв'язання реальних задач, створення діючих макетів, що обумовлює їх практичне використання.*

Матеріали і методи. *Використано методи аналізу та систематизації науково-педагогічної літератури; узагальнення результатів вітчизняного і зарубіжного досвіду щодо використання проєктного методу у STEM-освіті із застосуванням програмно-апаратної платформи Arduino. Наведено експериментальну методику створення діючого фізіотерапевтичного лазерного пристрою для лікування нежитю. Застосовано програмне комп'ютерне моделювання для імітації роботи пристрою з розробкою коду для плати Arduino UNO.*

Результати. *На прикладі виконання STEM-проєкту «Розробка фізіотерапевтичного лазерного пристрою для лікування нежитю» показано як можна інтегрувати низку різнорівневих, дидактичних і дослідницьких завдань. Наведено узагальнений опис основних структурних елементів плати Arduino Uno. Сформульовано типовий алгоритм ознайомлення з роботою плати Arduino. Вказано основні розділи курсу фізики, знання яких є базовими для реалізації проєкту. Показано як використання бітової матриці станів лазера дозволяє створювати циклічні режими опромінення, що періодично змінюють один одного. Наведено приклад коду з обробкою бітової матриці станів лазера. Скетч керує режимами напівпровідникового лазера, відображає час опромінення на рідкокристалічному дисплеї та подає звуковий сигнал по закінченню часу опромінювання, що задається потенціометром. Подано фрагмент симуляційного моделювання фізіотерапевтичного пристрою в середовищі Tinkercad Circuits.*

Висновки. *Практичний досвід використання проєктного методу в STEM-освіті показав, що він дозволяє студентам активно досліджувати реальну проблему, застосовувати отримані знання на практиці, розвивати навички співпраці, комунікації та критичного мислення. Виконання проєкту сприяє поєднанню різних видів діяльності, таких як пізнавальна, творча, практична, дослідницька, а також розвитку навичок мислення, мотивації та відповідальності за свою діяльність. Впровадження проєктного методу дає можливість забезпечити якісну підготовку фахівців з природничих наук, здатних ефективно застосовувати свої знання та навички у практичних ситуаціях та сприяти подальшому розвитку STEM-галузей в Україні.*

КЛЮЧОВІ СЛОВА: *проєктний метод; STEM-освіта; платформа Arduino; програмування; інженерне мистецтво.*

PROJECT METHOD IN STEM EDUCATION USING ARDUINO SOFTWARE AND HARDWARE PLATFORM

Oleksii VORONKIN ✉
Ukrainian Free University, Germany
oleksii.voronkin@ufu-muenchen.de
https://orcid.org/0000-0003-4088-7147
Sergiy LUSHCHIN
National University «Zaporizhzhia Polytechnic», Ukraine
luschin@zntu.edu.ua
https://orcid.org/0000-0003-2135-0520

ABSTRACT

Formulation of the problem*. One of the promising methods of training in STEM education is the method of projects. The projected method in STEM education determines the relevance and research nature of the topic of the project, ensuring the interconnection of theoretical knowledge with practice, practical implementation of the results of the project. The project, as a means of implementing STEM education, allows you to integrate knowledge from different subject industries when solving real tasks, the creation of existing layouts, which causes their practical use.*

Materials and methods. *Methods of analysis and systematization of scientific and pedagogical literature were used; generalization of the results of domestic and foreign experience in the use of a prose method in the STEM education using the ARDUino software and hardware platform. The experimental method of creating an active physiotherapy laser device for treatment of the runny nose is presented. A software modeling is used to simulate a device with the design of the Arduino Uno board.*

Results*. The example of the implementation of the STEM project "Development of a physiotherapeutic laser device for the treatment of runny nose" demonstrates how it is possible to integrate many different-level, didactic, and research tasks. A generalized description of the main structural elements of the Arduino Uno board is given. A typical algorithm for familiarizing yourself with the operation of the Arduino board is formulated. The main sections of the physics course are indicated, the knowledge of which is fundamental for implementing the project. It is shown how using a bit matrix of laser states allows the creation of cyclic irradiation modes that periodically change each other. An example of a code processing a bit matrix of laser states is provided. The sketch controls the modes of the semiconductor laser, displays the exposure time on the liquid crystal display, and emits a sound signal at the end of the exposure time set by the potentiometer. A fragment of the simulation modeling of a physiotherapy device in the Tinkercad Circuits environment is presented.*

Conclusions*. The practical experience of using the project method in STEM education has shown that it allows students to investigate a real problem actively, apply the acquired knowledge in practice, and develop cooperation, communication, and critical thinking skills. Implementation of the project contributes to the combination of various activities, such as cognitive, creative, practical, and research, as well as the development of thinking skills, motivation, and responsibility for one's actions. Implementing the project method makes it possible to provide high-quality training for specialists in natural sciences who can effectively apply their knowledge and skills in practical situations and contribute to the further development of STEM fields in Ukraine.*

KEYWORDS: *project method; STEM education; Arduino platform; programming; engineering art.*

Для цитування:
Voronkin O., Lushchin S. Project method in STEM education using arduino software and hardware platform. *Фізико-математична освіта*, 2023. Том 38. № 4. С. 24-30. DOI: 10.31110/2413-1571-2023-038-4-003
Voronkin, O., & Lushchin, S. (2023). Project method in STEM education using arduino software and hardware platform. *Фізико-математична освіта*, 38(4), 24-30. https://doi.org/10.31110/2413-1571-2023-038-4-003

For citation:
Voronkin, O., & Lushchin, S. (2023). Project method in STEM education using arduino software and hardware platform. *Physical and Mathematical Education*, 38(4), 24-30. https://doi.org/10.31110/2413-1571-2023-038-4-003
Voronkin, O., & Lushchin, S. (2023). Project method in STEM education using arduino software and hardware platform. *Fizyko-matematychna osvita – Physical and Mathematical Education*, 38(4), 24-30. https://doi.org/10.31110/2413-1571-2023-038-4-003

✉ Corresponding author

INTRODUCTION

Formulation of the problem. STEM education involves the integration of natural sciences, technology, engineering creativity, and mathematics. One of the promising methods is the project method, which determines the relevance and research nature of the project topic, ensures the relationship of theoretical knowledge with practice, and directs the result of the creative search to practical implementation. The project as a means of implementing STEM education allows for the integration of knowledge from various subject areas while solving real problems, and creating working models, which determine their practical use.

An actual problem of training qualified pedagogical specialists in the field of natural sciences, in particular physics, in modern conditions is the implementation of research training with the use of innovative practices, and the ability to combine face-to-face and distance learning methods. The use of digital tools, modern software, and hardware platforms allows an increase in the effectiveness of the educational process, to make it more visible due to the practical implementation of the results of experimental work and the creation of a simulation model of the operating device.

Analysis of actual research. The project method is one of the learning approaches proposed by the American philosopher and educator John Dewey at the end of the 19th and the beginning of the 20th century. The goal of project-based learning is to stimulate students' interest in certain problems, the solution of which is implemented through planning, research, and aimed at practical results (Morgan, 1983). William Heard Kilpatrick emphasized the importance of the "project" as a central element of learning that stimulates active participation and self-activity of students in the learning process. Edward Collins emphasized the connection between learning and real life, supporting the idea that project tasks should have real meaning for students, and their results can be used in real situations. Howard Parkhurst has shown that projects should provide students with opportunities to develop valuable skills and abilities that are important in real-life contexts. It was also established that project-based learning contributes to the development of skills of "critical thinking, cooperation, communication, reasoning, synthesis and stability in conditions of limited time and a defined goal" (Barron, 2003) and involves various types of activities.

The project method in the field of STEM education is quite common in many countries, including Ukraine. Government programs in Australia, China, Great Britain, Israel, Korea, Singapore, and the United States aim to ensure high-quality education and often include project methods in their curricula and programs, which encourages teachers to use interactive methods, robotics, and programming to engage students in STEM education. (Kushnir et al., 2017). On August 5, 2020, the Decree of the Cabinet of Ministers of Ukraine No. 960 approved the Concept of the Development of Science and Mathematics Education (STEM) in Ukraine. According to this concept, educational methods and educational programs of STEM education should be aimed at the formation of competencies that are important and relevant in the labor market. Among them, critical, engineering, and algorithmic thinking, information processing and data analysis skills, digital literacy, creativity, and innovation, as well as communication skills, are distinguished.

Various aspects of the introduction of STEM education in Ukraine were highlighted in the works of Ukrainian scientists. Thus, the authors of the article (Stryzhak et al., 2017) conducted an analysis of the content of key concepts of STEM, which are fundamental in understanding the essence of the new educational direction, Natallia Honcharova compiled a glossary of terms defining the essence of the concept of STEM (Honcharova, 2015), in the article (Salnyk et al., 2023) considered the possibilities of introducing STEM technologies integrated with information and communication technologies into the education system.

In general secondary education institutions of Ukraine, STEM education is mainly implemented in the form of electives and clubs (Kryvonos, 2017), where such platforms as LEGO, RoboRobo, Mindstorms, Iskra.JS, BrainPad, MicroBIT, Arduino, ESP32, Micro:bit, Raspberry are used Pi and others. In the regions, work was launched on the creation of STEM centers (laboratories), holding various events to popularize scientific and technical education - STEM weeks, scientific picnics, festivals of making, etc. (Patrykeeva et al., 2017). The university course in physics involves conducting experimental work with the measurement of physical quantities and subsequent data processing and analysis. To improve this course, in the article (Honda et al., 2021) it is proposed to hold a workshop on the physical foundations of measurements and technical means of automation based on the Arduino platform and a Raspberry Pi single-board computer for students of physics majors.

Thus, the method of projects in the field of STEM can be applied at different educational levels and in different learning contexts. It is a universal approach that can be successfully used in secondary (Zorenko & Shcherbyna, 2010), vocational and technical education (Herliand, 2017), in higher education (Ognianyk & Nichyshyna, 2018), as well as postgraduate education (Salnyk et al., 2023). At the same time, despite the available pedagogical research, questions remain regarding the specifics of using the project method in educational institutions in the context of STEM education.

The purpose of the article. In view of this, the purpose of the article is to reveal the features of the use of the project method in STEM education when teaching physics using the example of the project "Development of a physiotherapeutic laser device for the treatment of runny nose", which provides the opportunity to combine theoretical knowledge with the ability to perform an experiment, practical implementation of project results in the creation of simulation models of the operating device, stimulation of various types of student activities.

METHODS OF THE RESEARCH

Scientific and methodological research was performed using theoretical and empirical research methods: analysis and systematization of scientific pedagogical and methodical literature related to project-based learning and STEM education, generalization of the results of domestic and foreign experience regarding the use of the project method in STEM education with the application of the Arduino hardware and software platform, publicly available data relevant to the research topic, as well as simulating the operation of the device with the development of code for the Arduino UNO board. The combination of these research methods provided a scientific approach to the implementation of the project.

This scientific research was carried out using the TinkerCad Circuits software environment and the Arduino hardware and software platform. This platform allows you to use programming in the process of learning natural sciences, which makes it interesting for the implementation of educational and research STEM projects. Arduino coding is based on a simplified version of the C/C++ programming language (Baran et al., 2019). We used the most popular version of the basic platform – the Uno board, built on the ATmega328 microcontroller. The board has 14 digital input/output pins, 6 analog inputs, a USB connector, an additional connector for connecting external power, an ICSP interface, and a reset button.

RESULTS OF RESEARCH

As one of the possible options, we considered an example of a project on the development of a physiotherapeutic laser device for the treatment of rhinitis. The connection between the development of this project and the teaching methodology is established by a number of the following provisions. The principles of engineering art and information technologies are used in the development of a physiotherapeutic laser device. Engineers, apply scientific principles, develop models, conduct experiments, and solve practical problems. It is these principles that are the basis for STEM education, which stimulates students to actively research, make and apply the acquired knowledge. The development of a physiotherapy laser device also requires knowledge of mathematics and natural sciences, which are components of STEM education. The basis of the project method, which is used during the development of a physiotherapeutic laser device, is the use of an integrated approach and consideration of the philosophy of various fields of knowledge, combining scientific and research, natural, technological, and medical aspects. This project was implemented using the TinkerCad Circuits software environment and the Arduino hardware and software platform. This provided a convenient way to simulate and test the software sketch without having to have a physical Arduino UNO board. The combination of TinkerCad Circuits and Arduino gave us a high level of flexibility and speed in developing and testing the software sketch. This approach made it possible to eliminate possible errors in the physical implementation of the device on the Arduino platform.

Getting to know the Arduino platform usually involves the following steps:

1. Overview of a specific board, for example, UNO.
2. Installing on a personal computer Arduino IDE, which is the main software for developing and programming Arduino.
3. Registration in simulation services such as TinkerCAD, Wokwi. Such environments provide the ability to simulate and test Arduino applications without access to the physical board.
4. Definition of the structure of the program code.
5. Understanding the task, and its algorithmization with sketch writing.
6. Simulation modeling, debugging, and uploading the sketch to the controller.

The first sketch is traditionally devoted to flashing an LED. Already at this initial stage, we propose to combine informatics and natural sciences into a single project "Development of a physiotherapeutic laser device for the treatment of rhinitis." The project can be implemented in institutions of secondary education, professional pre-higher education, and higher education.

The project involves several types of activities, namely: cognitive, creative, research, and practical, because students have:

– repeat and generalize the main physical properties of light;
– reveal the differences in light generation by LEDs and semiconductor lasers;
– to determine the mechanisms of biological action of light;
– to analyze the principles of construction of industrial LED and laser physiotherapy devices;
– develop a model of a simple low-intensity laser therapeutic device for the treatment of rhinitis based on the Arduino UNO board, write a sketch;
– evaluate the advantages and disadvantages of the proposed model, and identify issues that need to be refined;
– present the results of the project and draw conclusions.

At first, students should focus on studying the "Optics" section of the physics course - the scale of electromagnetic waves, and the spectrum of light radiation; on the basis of literary sources, determine photophysical and photochemical reactions that occur as a result of the interaction of light with biological structures. Thus, a treatment method combining optical radiation and a photosensitizer, i.e. a photosensitive drug, is widely used in various fields of medicine (Zavadska et al., 2021). Next, students should establish that there is a certain selectivity of biological processes to the wavelength of radiation and a certain limiting value of the radiation power density for triggering physicochemical reactions (Wieneke & Gerhard, 2018; Yakovenko & Samoilenko, 2018). The nature of photophysical and photochemical reactions depends on the physical parameters of light, its penetrating ability, the properties of the tissues themselves, and the phenomena of resonant absorption of energy. For example, the depth of penetration of optical radiation into biological tissues decreases as the wavelength decreases (Sokrut & Kazakov, 2008). Therefore, studying the literature will allow us to determine the effectiveness of the therapeutic effect by groups of diseases depending on the wavelength.

Laser radiation plays a special role in phototherapy because of several properties, such as monochromaticity, coherence, and greater depth of penetration into biological tissues (Baxter, 1994). As a result of this influence, changes occur in the irradiated tissues at various levels:

1. Subcellular level. Laser radiation can cause excited states of molecules in tissues, promote the formation of free radicals, coagulation of protein structures, and acceleration of protein synthesis.

2. Cellular level. The influence of laser radiation can change the membrane potential of cells and the permeability of membranes.

3. Fabric level. Laser therapy can change intercellular fluid pressure, and improve tissue microcirculation and oxygen balance.

4. System level. Exposure to laser radiation can cause adaptive neuro-reflex and humoral reactions in the body.

The next stage of the project is the analysis of the principles of operation of industrial phototherapy devices, for example, K-Laser (K-Laser USA), Photizo Vetcare (Medlight SA), BioPhotas Celluma (BioPhotas Inc.), Handy Cure (Handy Cure LTD), which should be done according to the main physical and technical characteristics: wavelengths of radiation; radiation modes (continuous, pulsed, modulated); radiation power; frequency range for pulsed and modulated radiation; exposure time; therapeutic effect, etc.

Particular attention should be paid to devices designed for the treatment of nasal congestion, allergic, acute, chronic, neuro vegetative rhinitis Rhinolight (Newtone Technologies), MLS Laser Therapy (ASA Laser), LaserStim (LiteCure Medical), BioFlex Laser Therapy Systems (Meditech International Inc.), Healthy Nose (Bionase), "Lika-therapist M", "ATMOS-AntiNasmork". A careful study of the instructions for these devices will allow you to understand that the treatment is quite typical - the light is directed to the lower nasal conchas with the help of a nozzle. The power of the laser emitter in them varies from 5 mW to 50 mW, and the irradiation time is from 2 to 15 minutes on both sides, depending on the specific treatment protocol. The therapeutic effect is manifested in reducing inflammation, removing swelling of the mucous membrane, narrowing blood vessels, improving microcirculation and blood circulation, improving detoxification ability, reducing pain, accelerating tissue regeneration, increasing the anti-allergic ability of the mucous membrane, etc.

Some devices work only in the continuous mode of radiation, however, in numerous literary sources, for example (Baxter, 1994; Tuner & Hode, 2002; Pantyo, 2009), the perspective of exposure to laser radiation in the pulsed mode is noted. The pulse significantly reduces the thermal effect on biological tissues, and the correctly set spacing of the pulses allows you to approach resonance effects. However, there are no recommendations for frequency selection during pulsed irradiation of the lower nasal concha in the literature, which allows students to creatively approach the development of a model of a laser device. Therefore, the proposed solutions can be the most diverse both in terms of hardware and software. For example, you can use laser heads, laser modules with wavelength λ = 650 nm, power <5 mW, <10 mW, or use a combination of two wavelengths (among other parameters) to ensure optimal effect.

Students have to propose the parameters of the impulse operation of the device, write a sketch, evaluate the advantages and disadvantages of the software code, identify issues that need to be refined, and present the project. The first ideas are usually implemented using the digitalWrite and delay functions. Deeper knowledge of the programming language allows you to use the millis function, loop operators, the if-else construction, and interrupts.

A solution with a variable frequency of pulses during irradiation, which reduces the adaptation processes of biological tissues to a constant stimulus, deserves attention. The use of a bit matrix of laser states allows you to create cyclic irradiation modes that periodically change each other. Table 1 shows an example of 12 cyclic laser modes. Here, 1 byte encodes 8 bits of states that change sequentially in 1 second, that is, the minimum time for one state of the laser is 1/8 of a second. If the period of change of each mode is set to, for example, 10 seconds, then the complete irradiation cycle will be 2 minutes.

Table 1

Bit matrix of laser states

Regime	A sequence of 8 bits	Login "1" (s)	Logical "0" (s)	Logical "1" (s)	Logical "0" (s)
		(based on 1 second)			
1	11111111	1	–	–	–
2	00001111	0,5	0,5	–	–
3	01110111	0,375	0,125	0,375	0,125
4	00110011	0,25	0,25	0,25	0,25
5	00010001	0,125	0,375	0,125	0,375
6	00000101	0,125	0,125	0,125	0,625
7	00011101	0,125	0,125	0,375	0,375
8	00000001	0,125	0,875	–	–
9	11000011	0,25	0,5	0,25	–
10	11100111	0,375	0,25	0,375	–
11	11101111	0,5	0,125	0,375	–
12	01111111	0,875	0,125	–	–

An example of a possible version of the code for the Arduino UNO board with processing of the bit matrix of the laser states according to table 1 is given below.

```
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
byte modes[] = {
  0B00000000,
  0B11111111,
  0B00001111,
  0B01110111,
  0B00110011,
  0B00010001,
  0B00000101,
  0B00011101,
  0B00000001,
  0B11000011,
  0B11100111,
  0B11101111,
  0B01111111
};
uint32_t ms, ms1 = 0, ms2 = 0;
```

```
uint8_t  blink_loop = 0;
uint8_t  blink_mode = 0;
uint8_t  modes_count = 0;
LiquidCrystal_I2C lcd(0x27, 16, 2);
const int potPin = A0;
int laserDuration = 0;
unsigned long startTime = 0;
const int buzzerPin = 9;
void setup() {
 pinMode(13, OUTPUT);
 digitalWrite(13, LOW);
 modes_count = 1;
 blink_mode = modes[modes_count];
 lcd.init();
 lcd.backlight();
 lcd.clear();
 lcd.print("Laser Therapy");
 pinMode(buzzerPin, OUTPUT);
}
void loop() {
  ms = millis();
  if( ( ms - ms1 ) > 125 || ms < ms1 ){
     ms1 = ms;
     if( blink_mode & 1 << (blink_loop & 0x07) ) digitalWrite(13, HIGH);
     else  digitalWrite(13, LOW);
     blink_loop++;
   }
  if( ( ms - ms2 ) > 10000 || ms < ms2 ){
     ms2 = ms;
     blink_mode = modes[modes_count++];
     if( modes_count >= 12 ) modes_count = 1;
  }
  int potValue = analogRead(potPin);
  laserDuration = map(potValue, 0, 1023, 120, 600);
  if (digitalRead(13) == HIGH) {
    if (startTime == 0) {
      startTime = millis();
    }
    unsigned long elapsedTime = (millis() - startTime) / 1000;
    lcd.setCursor(0, 1);
    lcd.print("Time: ");
    lcd.print(elapsedTime / 60);
    lcd.print(" min ");
    if (elapsedTime % 60 < 10) {
    lcd.print("0");
    }
    lcd.print(elapsedTime % 60);
    if (elapsedTime >= laserDuration) {
      digitalWrite(13, LOW);
      startTime = 0;
      lcd.clear();
      lcd.print("Laser Therapy");
      tone(buzzerPin, 1000, 700);
    }
  }
  delay(125);
}
```

This sketch controls the modes of the semiconductor laser, displays the exposure time on the liquid crystal display, and emits a sound signal when the exposure time set by the potentiometer has expired. In general, the code consists of 9 main elements:

1. Connection of libraries: Wire.h - for working with the I^2C communication protocol, LiquidCrystal_I2C.h - for controlling a character liquid crystal display via I^2C.
2. Declaration of the modes[] array describing the bit matrix of laser states.
3. Initialize the Arduino board pins and objects, including the pins for the laser, display, and piezo emitter.
4. Implementation of the main loop() cycle.
5. Control of laser operation modes in a cycle according to the bit matrix of states defined by the modes[] array.
6. Reading the value of the potentiometer to determine the duration of exposure.
7. Display exposure time in minutes and seconds.
8. Checking the condition of reaching the duration of irradiation and turning off the laser, resetting the time, and updating the relevant information on the display.
9. Delay stabilizing display.

The electrical circuit uses a semiconductor laser connected to pin 13 of the Arduino UNO board, a character liquid crystal display 1602 connected via I²C to pins A4 and A5 of the Arduino UNO board, a potentiometer connected to analog input A0 of the Arduino UNO board, a piezoelectric emitter, connected to pin 9 of the Arduino board. Fig. 1 shows a fragment of a simulation model of a physiotherapy device, its operation can be checked in the Tinkercad Circuits environment using the web call: https://www.tinkercad.com/things/lFGmWB0Meyv?sharecode=3JdwxSJU-rgyzuxGwGCG0Gn8MShV6Ya72Tz-QdpqVRc.

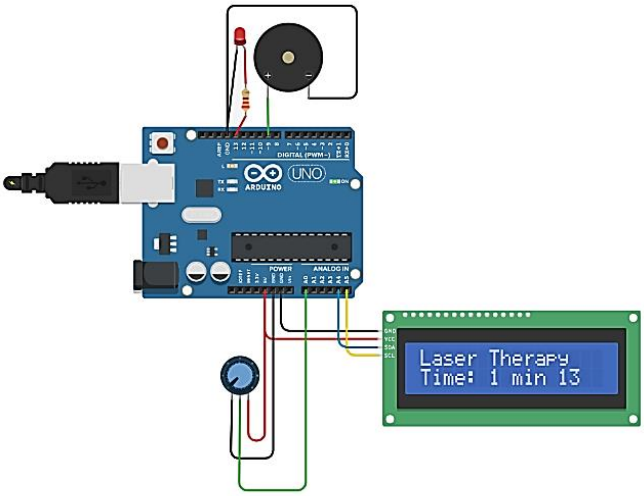

Fig. 1. Simulation modeling of the created physiotherapeutic device in the Tinkercad Circuits environment (for the simulation, a red LED was used instead of a semiconductor laser with λ = 650 nm)

The considered project was implemented as part of the integrated course "Natural Sciences" at the Serhii Prokofiev Severodonetsk professional art College, which is taught according to the program recommended by the Ministry of Education and Science of Ukraine for general secondary education institutions (author team led by V.R. Ilchenko). The specified educational program allows the implementation of projects in accordance with the material base of the educational institution.

CONCLUSIONS AND PERSPECTIVES FOR A FURTHER RESEARCH

The practical experience of using the project method in STEM education has shown that it allows students to actively investigate a real problem, apply the acquired knowledge in practice, and develop cooperation, communication, and critical thinking skills.

Implementation of the project contributes to the combination of various types of activities, such as cognitive, creative, practical, and research, as well as the development of thinking skills, motivation, and responsibility for one's activities.

The project method in STEM education is an effective tool for developing and improving students' professional competencies and preparing them for modern challenges in the field of science, technology, engineering, and mathematics. Implementing the project method makes it possible to provide high-quality training for specialists in natural sciences who can effectively apply their knowledge and skills in practical situations and contribute to the further development of STEM fields in Ukraine.

We considered an example of a project involving the development of a physiotherapeutic laser device for the treatment of rhinitis. The connection between the development of this project and the teaching methodology is based on several provisions. When creating a physiotherapeutic device, students use the principles of engineering art, and information technology. They create models, conduct simulations and solve practical problems based on scientific principles. It is these principles that are the basis of STEM education, which encourages students to actively research, make, and use the acquired knowledge. The successful development of a physiotherapeutic laser device also requires knowledge of natural sciences and mathematics, which are components of STEM education. The project method involves the application of a complex approach and taking into account the philosophy of various fields of knowledge, which allows for the integration of research, natural, technological, and medical aspects to achieve the set goal.

We believe that the project method creates powerful prerequisites for improving the teaching methods of STEM disciplines. At the same time, the large-scale development of STEM education in Ukraine requires specialists with scientific and pedagogical training who have deep multidisciplinary knowledge. A possible direction of research is the study and analysis of foreign methods of teaching STEM disciplines and the development of a model for the formation of the readiness of Ukrainian pedagogical staff to apply the project method in STEM education. This may include such aspects as the preparation of teachers to use the project method, the development of integrated educational materials and practical tasks, and the creation of a favorable educational environment.

REFERENCES (TRANSLATED AND TRANSLITERATED)

1. Baran, V. S., Vlasiuk, H. H., Onykiienko, Yu.O., & Smolenska, O.I. (2019) Osnovy mikroprotsesornoi tekhniky: laboratornyi praktykum [Fundamentals of microprocessor technology: laboratory practice]. *Natsionalnyi tekhnichnyi universytet Ukrainy «Kyivskyi politekhnichnyi instytut imeni Ihoria Sikorskoho» – National Technical University of Ukraine «Igor Sikorsky Kyiv Polytechnic Institute»*. https://ela.kpi.ua/bitstream/123456789/27992/1/OMPT_laboratorni.pdf. (in Ukrainian).

2. Barron, B. (2003). When smart groups fail. *The Journal of the learning sciences*, 12(3), 307–359.
3. Baxter, G. D. (1994). *Therapeutic Lasers: Theory and Practice.* Churchill Livingstone.
4. Herliand, T. M. (2017) Stratehiia vykorystannia proektnykh tekhnolohii u profesiinii pidhotovtsi maibutnikh kvalifikovanykh robitnykiv [The strategy of using design technologies in the professional training of future skilled workers]. *Proektni tekhnolohii navchannia u profesiinii pidhotovtsi maibutnikh kvalifikovanykh robitnykiv – Project learning technologies in professional training of future skilled workers*. (Kyiv, 25 zhovt. 2017). 23–25. IPTO NAPN Ukrainy. (in Ukrainian).
5. Honcharova, N. O. (2015). Hlosarii terminiv, shcho vyznachaiut sutnist poniattia STEM [Glossary of terms that define the essence of the concept of STEM]. *Informatsiinyi zbirnyk dlia dyrektora shkoly ta zaviduiuchoho dytiachym sadochkom – An information collection for school principals and kindergarten managers*, 17–18 (41), 90–92. (in Ukrainian).
6. Honda, A. R., Nikolenko, Ya. V., & Lyashenko, Yu. O. (2021). Metodychni rekomendatsii do praktykumu z fizychnykh osnov vymiriuvan ta tekhnichnykh zasobiv avtomatyzatsii na bazi ARDUINO ta RASPBERRY [Methodic Guidelines of Physical Measurement and Technical Tools Automation Based on ARDUINO and RASPBERRY PI]. *Visnyk Cherkaskoho universytetu. Seriia «Fizyko-matematychni nauky» – Bulletin of the Cherkasy Bohdan Khmelnytsky National University. Seriia «Fizyko-matematychni nauky»,* 1, 126–141. http://eprints.cdu.edu.ua/5203. (in Ukrainian).
7. Iakovenko, N. P., & Samoilenko, V. B. (2018). *Fizioterapiia [Physiotherapy]*. VSV «Medytsyna». (in Ukrainian).
8. Kryvonos, O. M. (2017). Robototekhnika v shkoli [Robotics in School]. *Teoriia i praktyka vykorystannia informatsiinykh tekhnolohii v navchalnomu protsesi – Theory and practice of using information technologies in the educational process*, (90–91). National Pedagogical Dragomanov University. https://core.ac.uk/download/pdf/85129061.pdf. (in Ukrainian).
9. Kushnir, N. O., Valko, N. V., Osipova, N. V., & Kuzmych, L. V. (2017). Vidkryti osvitni resursy dlia orhanizatsii navchannia u konteksti STEM-osvity [Open Educational Resources to Organize Training in the Context of STEM-Education]. *Vidkryte osvitnie e-seredovyshche suchasnoho universytetu – Open Educational e-Environment of Modern University,* 3, 247–255. http://nbuv.gov.ua/UJRN/oeeemu_2017_3_41. (in Ukrainian).
10. Morgan, A. (1983). Theoretical aspects of project-based learning in higher education. *British Journal of Educational Technology*, 14(1), 66–78.
11. Ognianyk, V., & Nichyshyna, V. (2018). Metodyka orhanizatsii proektnoi diialnosti maibutnikh uchyteliv matematyky u protsesi vyvchennia temy «Kratni intehraly ta yikh zastosuvannia» [The Methodology of Organizati on Project Work for Training Teachers In Mathematics in the Process of Learning the Topic «Multiple Integrals and the Use of It»]. *Naukovi zapysky molodykh uchenykh – Scientific Notes of Young Scientists*, (2). https://phm.cuspu.edu.ua/ojs/index.php/SNYS/article/view/1532/1551. (in Ukrainian).
12. Pantyo, V. V., Nikolaychuk, V. I., & Pantyo, V. I. (2009). Vplyv nyzkointensyvnoho lazernoho vyprominiuvannia na biolohichni obiekty (ohliad literatury) [Influence of Low-Intensive Laser Radiation on Biological Objects (Examination of Literature)]. *Naukovyi visnyk Uzhhorodskoho universytetu. Seriia Biolohiia – Sci. Bull. Uzhgorod Univ. Series*: Biology, (26), 99–106. (in Ukrainian).
13. Patrykeeva, O., Vasylashko, I., Lozova, O., & Gorbenko, S. (2017). Uprovadzhennia STEM-osvity u zahalnoosvitnikh ta pozashkilnykh navchalnykh zakladakh: metodychnyi aspekt [Implementation of STEM-education in general and extramural educational institutions: methodical aspect]. *Ridna shkola – Native school*, 9–10, 90–95. http://nbuv.gov.ua/UJRN/rsh_2017_9-10_18. (in Ukrainian).
14. Salnyk, I. V., Somenko, D. V., & Siryk, E. P. (2023). Vykorystannia platformy Arduino u pidhotovtsi vchyteliv fizyky do STEM oriientovanoho navchannia [Using the Arduino Platform in the Preparation of Physics Teachers for STEM-oriented Education]. *Informatsiini tekhnolohii i zasoby navchannia – Information Technologies and Learning Tools*, 95(3), 124–142. (in Ukrainian).
15. Sokrut, V. M., & Kazakov, V. M. (Eds.). (2008). *Fizychni chynnyky v medychnii reabilitatsii [Physical factors in medical rehabilitation]*. Donetsk National Medical University. (in Ukrainian).
16. Stryzhak, O. Ye., Slipukhina, I. A., Polikhun, N. I., & Chernetckiy, I. S. (2017). STEM-osvita: osnovni definitsii [STEM-Education: Main Definitions]. *Informatsiini tekhnolohii i zasoby navchannia – Information Technologies and Learning Tools*, 62(6), 16–33. (in Ukrainian).
17. Tuner, J., & Hode, L. (2002). Laser Therapy Clinical Practice & Scientific Background. Prima Books.
18. Wieneke, S., & Gerhard, Ch. (2018) *Lasers in Medical Diagnosis and Therapy: Basics, applications and future prospects.* Institute of Physics Publishing. https://iopscience.iop.org/book/mono/978-0-7503-1275-2.pdf.
19. Zavadska, T. S., Boiko, I. I., & Boiko, A. G. (2021). Fotodynamichna terapiia v onkolohii [Photodynamic Therapy in Oncology]. *Onkolohiia – Oncology*, 23(1–2), 53–56. (in Ukrainian).
20. Zorenko, I. S., & Shcherbyna, I. Yu. (2010). Vykorystannia proektnoho metodu pid chas vyvchennia uchniamy anhliiskoi movy [The use of the project method during students' learning of the English language]. *Aktualni problemy navchannia ta vykhovannia liudei z osoblyvymy potrebamy – Actual problems of education and upbringing of people with special needs*, 7(9), 289–299. (in Ukrainian).