Applying the Python Programming Language and Arduino Robotics Kits in the Process of Training Future Teachers of Computer Science

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Abstract. **The article explores the possibilities and advantages of applying the Python programming language for using Arduino robotics kits in the process of training future computer science teachers in pedagogical institutions of education. Considerable emphasis is placed on analyzing the principles of operation of simple programs and devices. This analysis visualizes the possibilities of using the Arduino platform and Python libraries to create robots that can be implemented in education and everyday life. The authors have presented a working model of a robot built and programmed on the basis of Arduino components to measure humidity in computer laboratories and develop automatic plant irrigation systems to maintain appropriate conditions in classrooms. They also provide an example of integrating the learning of the Python programming language with the use of Arduino robotics kits. This method aims to enhance the quality of training for future computer science teachers, broaden their methodological toolkit, and equip them with the ability to teach students using innovative methods. The study's results and the developed teaching materials aim to increase students' interest in STEM education and prepare a new generation of computer science teachers for the challenges of the modern technological world. This will expand their methodological arsenal and develop their ability to use integrated technical, engineering, and mathematical solutions to solve theoretical and practical problems. This study can serve as a guide for popularizing the use of Arduino and Python in educational institutions. It may encourage future computer science teachers to introduce STEM and practical teaching methods, which can contribute to better student learning and improve the quality of professional education in the field of information technology. The study presents opportunities for utilizing modern digital technologies in vocational education and encourages interest in STEM education among computer science teachers and students. This contributes to the development of a new generation of engineers and technology leaders. Further research could focus on developing targeted training courses and methods for integrating the Python programming language and Arduino robotics kits into STEM education. It is crucial to create interdisciplinary STEM courses with the involvement of computer science, physics, mathematics, and vocational education teachers in the IT industry.**

Keywords: Arduino; Python; STEM education; Arduino programming; computer science teacher.

I. INTRODUCTION

Problem statement. Nowadays, robotics and programming are becoming increasingly popular and integrated into education. Robots are becoming ubiquitous in our daily lives and education. For example, we use them to process Bigdata or to observe phenomena that require round-the-clock monitoring.

This also applies to education, as the inclusion of robotics in educational programs guides us to understand the principles of using robots and programming to train computer science teachers. This study also takes into account the importance of integrating STEM (Science, Technology, Engineering, Mathematics) technologies into the educational process.

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After all, STEM is an approach to education that combines different sciences, technologies, engineering creativity and mathematical thinking. Interdisciplinarity is an important concept in STEM education and is considered a pedagogical innovation. The main challenge in developing STEM curricula is integrating related yet independent disciplines. This requires careful consideration of established ontologies. Science as a way of knowing that helps to understand the world around us:

- "Technology as a way to improve the world, which is sensitive to social changes;
- Engineering as a way to create and improve devices for to solve real-world problems;
- Mathematics as a way of describing the world (analyzing the world and real problems with the help of numbers)" [1].

STEM is a suitable field for learning scientific knowledge and engineering skills, promoting the development of critical thinking and innovative solutions in technology and science. Integrating STEM technologies creates a practical learning environment that supports the development of creativity and technical abilities for both students and teachers. STEM is an educational paradigm that emphasises scientific, technological, engineering, and mathematical aspects of learning. The approach aims to develop critical thinking, problem-solving, creativity, and practical skills among students, creating the basis for future scientific and technological innovation. STEM education not only trains a new generation of science and technology professionals but also enhances the intellectual level of society and promotes the development of engineering solutions to various global challenges. This approach is widely used in modern educational programs and fosters creative and innovative approaches to solving complex problems in all spheres of life. The level of development of educational systems achieved today in the developed countries of the world is a significant factor in their intellectual, economic, social, scientific, technical, innovative, technological and cultural development, which largely ensures the stability and evolutionary nature of development in these countries, allows to improve the life structure, deepen democratic processes, gradually increase the spiritual and material level of peaceful, creative life of the population - the main goal of the progressive development of man and society [2].

According to scientists Bykov V., Boichuk V., Morse N., Umanets V., teachers of the State Vocational School Vinnytsia Interregional Higher Vocational School, Higher Vocational School No. 11, and the State Vocational School Vinnytsia Higher Vocational School of Services, teachers are not fully capable of implementing this type of program in the educational process. However, STEM education is gradually spreading in the Ukrainian educational space, which to some extent compensates for this issue. Because STEM technology is an important part of modern education, as it helps to develop the relevant competencies of teachers and students in science, technology, engineering and mathematics [3].

One of the areas of application of STEM education is robotics. This is an applied science that deals with the development of automated technical systems. Robotics in the educational process takes the form of variable modules that, with the help of ICT and educational tools, give students the skills to design robots and write programs to control them. Research and publications show that using Python to control Arduino robots has great potential. This was considered by such scientists as: Dayal Vanambathina V. Krushynskyi, Y. Lebedieva, Lee E, V. Loshak, Sikora O. V., D. Montefusco, Morze V., E. Chornyi, E. Myronenko, O. Lysenko.

Python is a widely used programming language that simplifies project development. It has a large user base and numerous libraries that can be used to program Arduino robots. Many publications provide code examples and explain how Python and Arduino interact, which can extend robot functionality and create new programs.

Additionally, using Python to control Arduino robots has great potential in STEM education. Python is a programming language that is accessible to beginners, making it easy to learn how to code and program robots. Python is widely used in educational projects and programs to program robots, demonstrating its popularity in this field.

Arduino is a popular platform for developing electronic projects, and using Python in conjunction with it simplifies and improves the development of these projects. The Python programming language is known for its simplicity and accessibility, making it an ideal choice for both beginners and experienced developers. Additionally, the large community of Python users and feature-rich libraries make it easy to interact with Arduino, expand the capabilities of robots, and create new programs. A plethora of publications and code examples are available, making the process of learning and developing for Arduino using Python accessible and informative.

II. MATERIALS AND METHODS

The aim of this study is to investigate the potential advantages of using Python programming language with the Arduino platform in STEM education. The study will explore how this combination of tools can benefit computer science teachers and create interactive and practical learning environments for students.

The study of using Python and Arduino in STEM education is an urgent task. Today, the level of digital competence among teachers does not fully meet the demands of the modern technological era. Introducing programming and robotics in schools creates the preconditions for training qualified engineering and technical personnel in the future. STEM education enables the organic integration of natural science, technology, engineering, and mathematical knowledge to solve practical problems. This contributes to the development of skills in applying the acquired competence in practice, stimulates interest in natural sciences and develops logical thinking. In particular, in the training of future skilled workers in such specialties as: 4113.7241 Information and Software Processing Operator and Electromechanic for the Repair and Maintenance of Computing Machines (based on 9th grade), 7241 Electromechanic for the Repair and Maintenance of Computing Machines (based on 11th grade), 7242 Installer of information and communication equipment, which are provided by such vocational schools as the State Vocational School "Vinnytsia Interregional

Vocational School", Higher Vocational School No. 11 and Vinnytsia Higher Vocational School of Services. The higher education institution where the authors work has existing cooperation agreements with the above-mentioned vocational education institutions (https://vspu.edu.ua/?p=first). In particular, the authors cooperate with the STEM Laboratory of the State Vocational Educational Institution "Vinnytsia Interregional Higher Vocational School".

The Arduino platform is an ideal tool for STEM education due to its accessibility, simplicity, and versatility. Arduino boards can interact with a variety of sensors and devices to collect environmental data and control motors,

lights, pumps, and more. Programming these devices using Python provides ample opportunities for interactive and project-based learning. Students can create weather stations, smart home systems, robots, and more.

The study aims to analyze the application of Arduino and Python in educational projects, specifically in creating a system for measuring humidity and an automated irrigation system. The study will focus on the principles of collecting sensor data, processing them in Python, and controlling actuators to enhance the understanding of software and hardware interactions. This text demonstrates the potential of using Arduino and Python to create solutions for real-life tasks.

The study's results will serve as methodological guidelines for teachers on the use of programming and robotics in STEM education. The proposed projects can be modified and adapted to different age categories and used to teach computer science, physics, mathematics, engineering, and technology. Involving schoolchildren in the creation of such solutions can increase motivation and develop logical and computational thinking, as well as skills in the exact sciences and engineering. Therefore, studying the use of Python and Arduino has significant practical significance for improving the quality of STEM education, developing effective teaching methods, and training IT teachers.

III. RESULTS AND DISCUSSION

The Research Laboratory on the use of information technologies in education at Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University (VSPU), which includes, one of the authors, who is the responsible person for occupational health and safety at the Educational and Research Institute of Pedagogy, Psychology, and Training of Higher Education, members of the laboratory work closely with the departments of biophysics at Vinnytsia Pirogov National Medical University and the Institute of Digitalization of Education at the National Academy of Sciences of Ukraine. During our research, we concluded that the Arduino platform is suitable for developing control systems for switches and sensors. These systems can control a range of indicators, motors, and other devices. Arduino-based modules are autonomous and can interact with computer software. Python is a suitable software for implementing various projects that benefit society. To work with Arduino, you can use the Python libraries that are designed to program robots, which are listed below:

- PySerial is a library that enables communication between Python and Arduino via the Serial port. It provides functions to open, close, and configure the Serial port, as well as transfer data between Python and Arduino.
- Firmata is a library that enables communication between Python and Arduino using the standard Firmata protocol. It provides functions to control pin outputs and read data from sensors using common Firmata commands.
- PyMata is a Python wrapper for the Firmata library. PyMata is a library that provides a simpler and more convenient interface for interacting with Arduino. It enables control of pins, sensor data reading, servo control, and more.
- The Arduino library allows for direct code writing in the Python environment and the ability to rewrite Arduino sketches in Python for robot control.
- Johnny-Five is a JavaScript library that facilitates interaction with Arduino and other boards. It is capable of supporting a wide range of sensors and devices, and features a user-friendly and straightforward interface for interacting with them.

An example of using Python libraries and Arduino sensors is to collect data on indoor humidity and save it in a text file.

The main component for collecting indoor humidity data is a humidity sensor, such as the DHT11. By connecting this sensor to an Arduino and using PySerial, we can collect and write data to a text file.

This requires only a minimum set of components. For this project, we utilized either an Arduino UNO, Arduino Nano, or Arduino Mega, along with a DHT11 or DHT22 temperature sensor module. In our specific case, we opted for the DHT11 temperature sensor module, a breadboard, and connecting wires.

The DHT11 is a digital sensor that measures both temperature and humidity, and allows for calibration of the digital output signal. It is composed of a capacitive humidity sensor and a thermistor. The sensor includes an ADC for converting analog humidity and temperature values. These are the characteristics of the ADC:

- Power supply and I/O 3.5-5.5 V
- Determination of humidity 20-95% with 5% accuracy
- Temperature detection 0-50 deg. with an accuracy of 2 deg.
- Polling frequency no more than 1 Hz (no more than once every 1 sec.)
- Dimensions 15.5mm x 12mm x 5.5mm
- 4 pins with a leg spacing of 2.54mm

Conclusions:

- Vcc (3-5V power supply)
- Data out - Data output
- Not used
- General.

After selecting the components, the next step is to connect to the Arduino (Fig. 1.). Let's describe the main

points. The module is equipped with a three-pin connector of the 2.54mm standard, to G - connect to GND, V - connect to the +5V pin, S - connect to the digital pin (in the example D4).

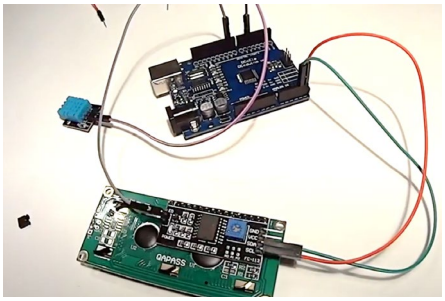

Fig. 1. Mounting the Arduino unit with the DHT11 sensor

After connecting the appropriate sensor (in our case, DHT11), you need to "fill" (download) the sketch for operation. For the DHT11 module to work, you need to download the library (Fig. 2.) and add it to the "libraries" folder in the Arduino IDE folder.

Fig. 2. Contents of the library for the DHT11 module

We recommend restarting the environment if it was running when you added the library.

Below is a sample sketch in which we will measure and send temperature and humidity data to the PC serial port(Listing.1.).

```
      //Tested on Arduino IDE 1.0.5
      #include // Add the DHT11 library
      dht11 DHT; // declare a variable of
class dht11
      #define DHT11_PIN 4 // The DHT11 sensor
is connected to digital pin number 4

      void setup(){
      Serial.begin(9600); // port speed
      Serial.println("DHT TEST PROGRAM ");
// Print the text
      Serial.print("LIBRARY VERSION: "); //
Print the text
      Serial.println(DHT11LIB_VERSION);
      Serial.println(); // Empty string
      }

      void loop(){
      int chk;
      ;
      // error monitoring
      chk = DHT.read(DHT11_PIN); // reading
data
      switch (chk){
      case DHTLIB_OK:
      break;
      case DHTLIB_ERROR_CHECKSUM:
      Serial.println("Checksum error, \t");
      break;
      case DHTLIB_ERROR_TIMEOUT:
      Serial.println("Time out error, \t");
      break;
      default:
      Serial.println("Unknown error, \t");
      break;
      }
      // display the humidity and
temperature values
      Serial.print("Humidity = ");
      Serial.print(DHT.humidity, 1);
      Serial.print(", Temp = ");
      Serial.println(DHT.temperature,1);
      delay(1000);
      }
```

Listing.1. An example sketch in which temperature and humidity data are measured and sent to a PC serial port.

Below is the code to collect humidity data with the DHT11 sensor and save the data to a text file. (Listing.2)

```
      import serial
      import time
      ser=serial.Serial('COM3',9600)       #
підключення Arduino
      while True:
            try:

       data=ser.readline().decode().strip()
            if data:
                  humidity, temperature =
data.split(',')
                  # збереження данпх у
текстовий файл
                  with
open('humidity_data.txt','a') as file:

       file.write('f'{time.time()},
{humidity}, {temperature}\n')
             except KeyboardInterrupt:
            ser.close()
            break
```

Listing.2. Code for collecting indoor humidity data

Thus, when you start the program and our robot, the process of data processing takes place. Our library connects to the Arduino board and starts a loop to process the data received from the DHT11 sensor and the end result is a file in which we will have data on time, humidity and temperature. The principle of Arduino operation using the DHT11 module under the control of the PySerial library is shown schematically on (Fig. 3.)

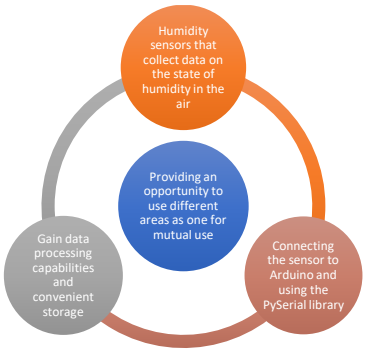

Fig. 3. Arduino and Python interaction diagram for robot control

Another example is an automatic garden irrigation system using Arduino, soil moisture sensors, and pumps. (Listing. 3.)

```
      import serial
      import time
      ser=serial.Serial('COM3',9600)       #
підключення Arduino
      def pump_on():
            ser.write(b'H')
            print('Pump ON')

      def pump_off():
            ser.write(b'L')
            print('Pump OFF')
      while True:

moisture_data=ser.readline().decode().stri
p()
            moisture=int(moisture_data)
            if moisture < 400:
              pump_on()
            else:
              pump_off()
            time.sleep(1)
```

Listing. 3. Code for an automatic irrigation system

An automatic garden irrigation system uses a variety of elements and components. The main components for this are:

- Arduino - a microcontroller that is responsible for controlling the system and collecting data from the sensors.
- Soil moisture sensors - they measure the moisture level in the soil and transmit the data to the Arduino.

Soil moisture sensors are used to measure soil moisture, which are capable of determining moisture based on measuring the resistance between two electrodes installed in the soil. Soil moisture sensors can have different moisture measurement ranges, accuracy, and response speeds.

The most popular soil moisture sensors are:

Capacitive Soil Moisture Sensor

Resistance Soil Moisture Sensor

Frequency Domain Reflectometry Soil Moisture Sensor

Any of these soil moisture sensors can be used for an automatic garden irrigation system, depending on specific needs and requirements. The system includes pumps, which are controlled by the Arduino, and relays that turn thepumps on and off based on soil moisture levels.

Additionally, power supplies are used for the Arduino, sensors, and pumps.

Communication: To provide communication between the Arduino and a computer, USB cables and Bluetooth modules can be used, as well as to program the microcontroller.

Materials:

A variety of materials such as plastic, metal, and wood can be used to create an irrigation system, as well as tools and small parts to assemble and configure the system.

To develop professional competencies, numerous resources are available on the internet for creating various projects based on the Arduino platform.

https://www.arduino.cc/en/software - official website with software

https://all3dp.com/2/most-useful-arduino-projects/ - Arduino projects

https://projecthub.arduino.cc/ - Arduino projects on official website

The use of these innovative and informational [5-6] technologies in order to provide future skilled workers with constant access to educational materials makes it possible to work independently at a convenient time and in a convenient mode, allows you to free up time in the classroom for the educational process of high-quality professional training of future skilled workers in the service sector [4].

IV. CONCLUSIONS

This study examines the possibilities and benefits of using the Python programming language in combination with the Arduino platform to train computer science teachers and create interactive learning environments in the context of STEM education. The study analyzes the principles of Python libraries, such as PySerial, Firmata, and PyMata, which facilitate communication between Python and Arduino, control of outputs, and reading of data from sensors. The text provides specific examples of projects that use Arduino and Python, such as a humidity measurement system that uses a DHT11 sensor and stores data in a text file, and an automatic garden irrigation system that uses soil moisture sensors. The study emphasizes the importance of integrating STEM technologies into the educational process, as it contributes to the development of critical thinking, creative and practical skills, and the creation of innovative approaches to problem solving. The study concludes that the combination of the Python programming language and the Arduino platform meets the principles of STEM education.

It is promising both for the educational process and for creating useful inventions and projects for the benefit of society. These technolo

gies are simple and accessible, which allows for the development of innovative approaches in education and encourages interest in STEM among teachers and students.

The study's results indicate that educational materials created with Arduino and Python can enhance the skills of vocational teachers, broaden their methodological toolkit, and cultivate their capacity to teach with innovative technologies [7-9].

Future research could concentrate on designing specialized training courses and techniques for incorporating Python, Arduino, and STEM into educational programs for both teachers and students. The development of interdisciplinary STEM courses that involve teachers

from computer science, physics, mathematics, and other related disciplines is essential. These courses can aid in the preparation of well-rounded professionals for the future.

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