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Employing an underwater vehicle in education as a learning tool for Python programming

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Abstract
Getting students motivated and interested in their education can be challenging in any classroom setting, even more so in an online learning environment. In this spectrum, educational robotics (ER) has demonstrated numerous advantages in the educational environment, not only by facilitating teaching, but also enabling the cultivation of manyfold skills, including creativity, problem-solving, and teamwork. Meanwhile, many methods have been developed with the aid of technology to improve the teaching process and boost students' ability to learn. Blended learning is one approach that integrates conventional classroom methods with digital resources in an effort to foster students' creativity. But how can blended learning be combined with robotics? The objective of this paper is to evaluate the impact of employing an underwater vehicle, called educational underwater vehicle (EDUV), in conjunction with a dedicated programming learning platform within the context of a programming course that is offered at the high school level. In this work, this platform is utilized by students in secondary education, and a survey was conducted prior and after using the underwater vehicle's platform based on two questionnaires. The survey included 112 Greek participants, 64 males and 48 females in the age range of 14–18 years old. The experimental results show an increase in their motivation and creativity. In other words, they are more engaged in the classroom and the lesson becomes more enjoyable. More specifically, the survey revealed that most participants are familiar with computers but have limited knowledge of robotics and programming. After training on the EDUV platform, participants showed a significant increase in correct responses for Python and Blockly environments, with an average of 50.7% in four programming-related questions. The platform also reduced "do not know" replies, which means that the student's self-esteem increased. The paired sample *T*-test showed that the EDUV

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platform positively influenced participants' perceptions of robotics and motivated them to further their education. In this paper, the related work is discussed, and the architecture of the vehicle is analyzed, along with the integration with the online platform. In addition, the methodology performed is explained and divided into steps. Finally, the experimental results are discussed. Instructions, 3D models, and code can be found in the github repository https://github.com/MariosVasileiou/EDUV.

KEYWORDS

blended learning, educational robots, marine robotics, secondary education, underwater vehicles

1 | INTRODUCTION

Information and Communication Technologies (ICT) have become an integral component of education, and instructors employ them to improve student learning. The advancement of the Internet and its associated technologies has resulted in the incorporation of e-learning into educational institution procedures, and this drift was amplified by the COVID-19 pandemic [12]. Online education has a variety of potential advantages, such as the ability to circumvent the time and place constraints of conventional educational environments. Following that, it provides students with the option of deciding where, when, and how to educate [20]. Another advantage of online learning is its increased accessibility. Individuals who were formerly precluded from education owing to geography, financial restraints, disability, or the absence of accessibility can now join. Despite the flexibility and equality of access offered by online learning, numerous criteria have been highlighted as essential for the success of online learners. Principal among these concerns is the motivation of online students and their ability to engage in the e-learning environment effectively [20, 29].

The physical interaction with the scholars is a fundamental element of the learning process and cannot be replaced [7, 15]. For instance, physical interaction conveys several facial expressions, vocal tones, eye contact, and body language. In light of this, blending learning can enhance traditional teaching models and boost student engagement and retention in the classroom [34]. Blended learning combines the two most effective learning approaches: face-to-face teaching and online interaction utilizing digital educational material [39]. In other words, in a blended learning course, when face-to-face interaction is combined with online platforms, tutors and apprentices use digital tools for active learning [13].

Correspondingly, educational robotics (ER) has been shown to have several benefits in the classroom by facilitating teaching and developing a wide range of abilities, such as innovation, problem-solving, and collaboration [33]. In all grade levels, ER can be used as a resource for teaching Science, Technology, Engineering, and Mathematics (STEM) subjects, as well as Computer Science [21]. Furthermore, students are more engaged and motivated when they use robotic tools for education because they can see the tangible results of their efforts. Alongside, 3D-printing technology is constantly evolving, enabling researchers to manufacture their conceptual designs quickly, affordably, and with moderate knowledge. 3D-printing is used in a multitude of fields, including robotics and education, enabling students to construct their designs quickly and affordably.

1.1 | Online and blended learning

Rapid technological advancements have facilitated distance learning. Most terminology (such as online, web-based, computer-based, or blended learning) shares the ability to utilize a network-connected computer, which allows students to access course materials from any location at their own pace using a variety of electronic devices [8]. When used effectively, online learning has the potential to improve the quality of education by making classes more interactive, stimulating, and adaptable for each individual learner [32]. In other words, the teaching becomes more student-centered. Informatizing education requires creating online courses to meet the needs of newer forms of instruction like network distance learning and mobile online learning, while overcoming the space-time constraints of offline instruction [23]. According to a research [6], there is no discernible difference in learning outcomes between a traditional and online classroom. Nevertheless, the motivation of students is the most important factor that contributes to success in online education. Correspondingly, another study identifies the variables that affect student achievement in online education [24]. In particular, only motivation and environment affect student behavior. According to the findings of this study, the teacher characteristics, motivation, and organizational structures improve student performance. Likewise, according to the findings of a study [26], each of the categories of service quality has a positive association with the students' levels of motivation and overall satisfaction.

In comparison, blended learning integrates traditional classroom instruction with digital coursework. In this regard, a postcourse survey of the lesson "Data structures and algorithms" revealed that not only were students pleased with the pedagogical approach used, but that they also performed above and beyond in the classroom [11]. Another paradigm is that of Zeng et al. [40], in which a blended classroom model was utilized in the course "Principles of Chemical Engineering." This study showed that based on the students' independent study using microvideos and mixed online and offline learning, the learning effectiveness was significantly increased. Blended learning not only involves the use of cutting-edge educational technology and digital tools, but it also reimagines the learning beliefs of students and the teaching practices of educators.

1.2 | Tools to facilitate programming learning

There are manifold studies that investigate the impact of digital tools on programming learning. A study presented in Omeh et al. [25] investigated the effects of infusing a computer programming class with a new pedagogy, namely a mix of problem-based learning and context-based learning that was alternated with online tools. A quasi-experimental research approach was employed in the study. The findings demonstrated that students worked together on Google classroom and Google Meet platforms. This effectively enhanced collaboration learning among rookie programmers, allowing them to choose when to study, which ultimately made both learning and teaching of programming easier and increased their motivation.

When it comes to introducing students to programming and computer science, block-based programming is quickly becoming the method of choice [38]. It has become a standard feature of the computer science curriculum thanks to the popularity of tools like Scratch and events like the Hour of Code hosted by Code.org. There are many major aspects of block-based programming that set it apart from both traditional text-based programming and visual programming strategies. Block-based programming utilizes puzzle-styled blocks connected to each other, forming a list of blocks. Each block has a distinct functionality and corresponding color.

Blockly is a client-side open-source JavaScript library for developing block-based visual programming and can be found on a variety of different platforms that teach computer programming. A script language like Python may be represented in a more intelligible manner using Blockly. In a research, Blockly was used as a teaching tool to facilitate programming learning of a microcontroller called "M5Stack" [1]. By working with M5Stack devices, students may quickly get experience with Blockly Programming and then apply their newfound skills to the Internet by utilizing the MQTT Protocol offered by the M5Stack graphical user interface. Students reported more comfort and enjoyment with programming after taking this approach. Correspondingly, a popular Block-programming web-based platform is BlockPy [4] which focuses on Python and provides a variety of intriguing features. Learners receive helpful feedback as they work through challenges, and the environment facilitates their progression to higher-level programming environments by permitting them to move freely and naturally between block and text-based programming. This work was followed by research over the course of four semesters called "computational thinking," and BlockPy was used by students with no programming background and a superficial familiarity with this subject.

1.3 | Robotics in education

In the most recent decade, an increasing number of researchers have been working to develop robotic systems that are capable of improving the procedures that are currently utilized in education. Several studies investigate different aspects of education, analyzing teaching methods, contrasting various forms of technology, and assessing the usefulness of various educational kits. LEGO Robotics has demonstrated satisfactory results among many robotics kits when several factors are taken into account [33]. This robotic tool has been used in various research projects and has beenintegrated into both classrooms and online platforms [30].

Another study [41] revealed five key points about the effects of ER:

- The use of educational robots has more of a positive impact on the students' creative abilities than it does on their ability to solve problems.
- Kindergarten pupils were the ones that benefited from ER the most; middle school students saw a slightly lesser impact.

- Girls learned far more from ER than did boys.
- Learning improved across all educational robotic teaching course lengths; however, the effect would noticeably diminish as the course term lengthened.
- The total impact of robots in education was 0.821.

Furthermore, underwater vehicles both autonomous and remotely operated, play a role in education [36]. In a study [18], a fully operational underwater glider was created to serve as a platform for oceanographic research and education. Bumblebee, a glider, can be handled by a small crew without heavy equipment. Bumblebees have self-contained emergency systems and communication packages. The underwater vehicle might be used for AI experimentation and navigation algorithm development without hardware expertise. Similarly, a practical and affordable autonomous underwater vehicle (AUV) is ideal for instructional use [37]. The system includes two types of AUV testbeds, a precise ultrasonic range system, an LBLF coordinate detection system, and a 2FSK ultrasound communication system. Participating in the construction of this experimental system gave undergraduate students personal gratification and academic improvement. Likewise, an AUV platform, Lucky fin, was constructed by students by applying classroom concepts to their projects [31]. Students can build and implement various control algorithms and conduct experiments to determine and analyze underwater vehicle hydrodynamic parameters. The platform has two testing tanks and one underwater vehicle. The control card, user control program interface, and manipulator's arm are designed for depth, direction, target tracking, and capture.

Therefore, teachers and researchers should use all of its benefits to help students improve their creativity and problem-solving skills and to give ideas for how to make and use educational robots.

1.4 | Summary

During the COVID-19 pandemic, institutions worldwide were requested to adopt online learning modalities. However, this drift resulted in a reduction in student motivation and engagement [12]. In light of this, the present project was launched with the aim of enhancing students' motivation, engagement, and creativity. Our method of teaching programming was inspired by the literature and has parallels to Reeborg's World and related initiatives [27, 28] that used virtual robots, but the key distinction is that the educational underwater vehicle (EDUV) platform allows users to remotely manage a real robot, which can make learning more creative, engaging, and pleasurable.

Despite the existence of numerous vehicles (e.g., ground, aerial, and marine), the existing EDUVs are limited to physical interaction and are used to teach mainly mechanics, control, and hydrodynamics [2, 14, 42]. The proposed platform is designed to utilize an underwater vehicle [35] through an online platform for programming education using both text-based and block-based programming. In light of this, some research questions that this paper is investigating are raised:

> **RQ1:** *How is the EDUV platform used in education?*
>
> **RQ2:** *What level of computer, programming, and robotics knowledge does the target audience possess?*
>
> **RQ3:** *To what extent were they able to utilize the site's resources to advance their education?*
>
> **RQ4:** *How does the EDUV platform stimulate the student's creativity and motivation?*

This paper presents an underwater vehicle, called EDUV, operated through a dedicated programming learning platform to enhance the learning process at the high school level (Figure 1). Students are introduced to the computer course to acquire the fundamentals and subsequently interact with the robot and platform. The purpose of this study is to promote students' creativity, and comprehension of the lecture with a novel, nontraditional robotic system. To this purpose, a study involving 112 K-12 Greek students was carried out to assess the effects of the aforementioned system imposition. The contribution of this study lies in the application of a novel pragmatic underwater vehicle within an online educational platform

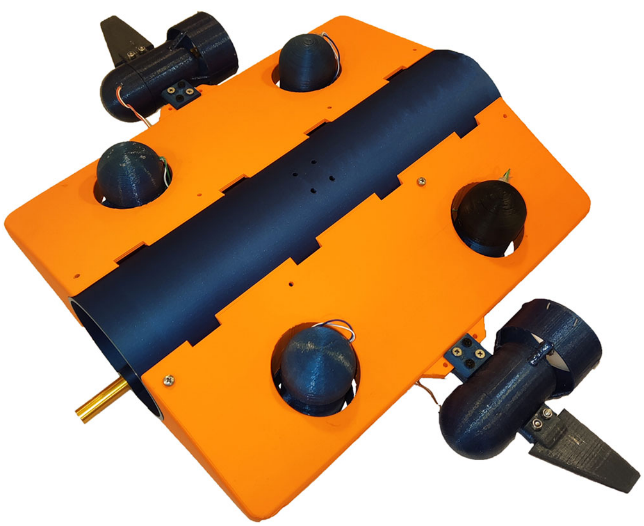

FIGURE 1 Photograph of the educational underwater vehicle.

to stimulate creativity and motivation. The employment of both Blockly and Python provides students with the opportunity to develop coding skills in two separate coding environments, thereby facilitating their familiarity and proficiency in coding. In addition, instructions, 3D models, and code can be found in github repository https://github.com/MariosVasileiou/EDUV.

The remainder of this paper is organized as follows: Section 2 describes the design and development of the underwater vehicle, along with its electronics, mobility, and control. Section 3 presents an overview of the EDUV programming platform and its integration with the vehicle. Section 4 quotes the methodology, including the steps followed, while in Section 5, the results obtained are discussed. Section 6 concludes the paper.

2 | EDUV

In this section, the architecture of the vehicle is analyzed along with the components. Furthermore, the mobility and control of the vehicle are quoted.

2.1 | Design

The majority of the underwater vehicles are too expensive and lack customizability. When compared to conventional underwater vehicles, our design stands out for being adaptable, portable, and inexpensive. The EDUV's primary goal is to be low-priced and adaptable. Based on this viewpoint, the robot is made of easily replaceable materials. For this reason, 3D printing using PLA filament—a substance resistant to water and humidity—is the best option we have for dealing with our limitations.

The Autodesk Fusion360 CAD software was used to create the sketch. The designed pieces are easily interchangeable, and the 3D-printed body may be quickly constructed, replaced, and modified. Different course scenarios call for different approaches; therefore, modularity is essential. Due to its compact size, this vehicle may be easily transported and adjusted by a single individual. Figure 2 depicts its dimensions as 376 × 300 × 87 mm (W × L × H), and with empty ballast tanks, it weighs 1.5 kg. In addition, as shown in Figure 2a, its frame is comprised of three main parts: part "P2" is the center cylinder, and parts "P1" and "P3" are the ballast tanks. In addition, it is equipped with six thrusters, four of which are arranged in a vertical fashion (Motors M1–M4) in the form of a square, and two of which are responsible for the horizontal movement (Motors M5–B6). To enhance the stability of the horizontal axis and inhibit roll movement, two fins are attached to the horizontal motors facing the front (Figure 2a, F1–F2).

2.2 | Components and electronics

The robot's movement relies on six DC motors controlled by 12 mini relays. The motors feature 800 RPM/V with a

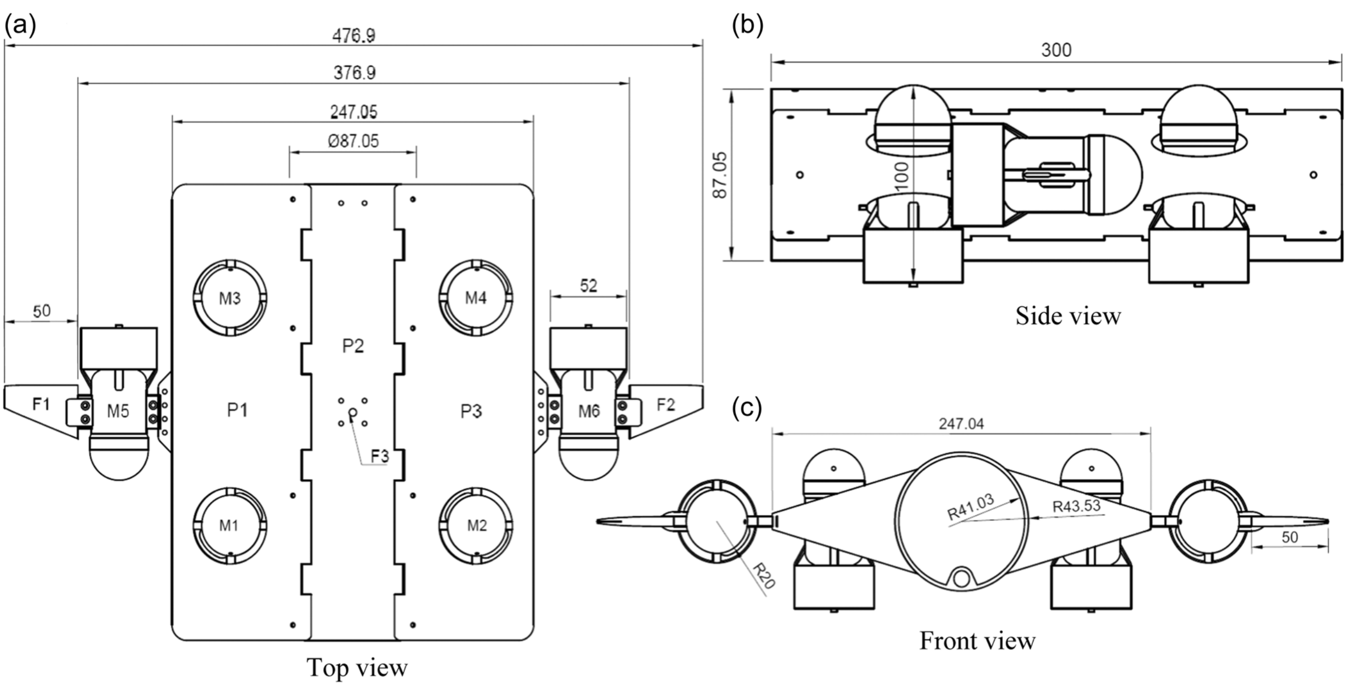

FIGURE 2 Schematics and dimensions of educational underwater vehicle: (a) Top view, (b) Side view, (c) Front view.

max efficiency current of 0.74 A in three cells Li–Poly battery cells at 11.1 v, 2700 mAh rated capacity. The battery provides power to the motors through the relays at 9.6–12.6 V (rated 11.1 v), while single board computer and camera are powered by a DC step-down converter with five-volt output which is connected to the battery. The commands for controlling the vehicle originate from an affordable single board computer that was necessary to manage the motors' motion. Namely, a Raspberry Pi 4 Model B with 2GB Ram. A submersible camera is connected to the Raspberry Pi single board computer to provide visual feedback to the surface device.

A key element of the proposed underwater vehicle is its low cost. The total cost of the robot fluctuates around 160 euros. The components of the robot and their prices are included in Table 1.

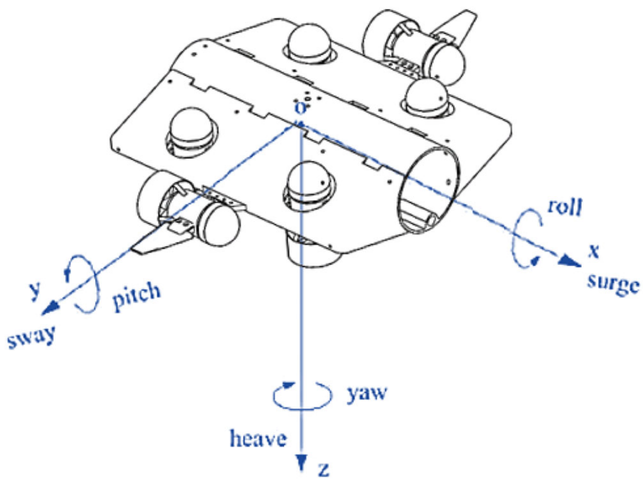

FIGURE 3 Translational and rotational motions.

2.3 | Mobility and control

Mobility refers to the robot's capacity to move freely in its surroundings, whereas mobility analysis describes how that movement is broken down into its axes. To accomplish the goal of the mission, it is essential to have a thorough understanding of the capabilities of the vehicle, which include its advantages as well as its limitations. This section analyzes the motions that the vehicle is capable of performing. The thruster configuration of the vehicle allows it to have five degrees of freedom (DoF) and can perform the below movements (as shown in Figure 3):

- *Translational–Surge*: Two horizontally aligned thrusters provide the linear longitudinal movement (forward/backward).
- *Translational–Heave*: Four vertically oriented thrusters are capable of performing a linear vertical (up/down) motion.
- *Translational–Sway*: This movement, which is a linear transverse motion on the *Y*-axis, cannot be performed by the vehicle but can be substituted by a composite of a translational and a rotational movement (e.g., a movement in roll axis and vertical motion).
- *Rotational–Roll*: To perform a roll, the vehicle tilts to the side along its longitudinal (*X*) axis, utilizing its four vertical thrusters.
- *Rotational–Pitch*: In a similar fashion, the robot rotates up and down along its *Y*-axis by employing its four vertical thrusters.
- *Rotational–Yaw*: The vehicle rotates around its vertical (*Z*) axis using its two horizontal motors.

TABLE 1 Vehicle's components and price.

Part	Qty	Total cost (€)
DC motors	6	36.00
Mini relays	6	6.00
Raspberry Pi 4 Model B 2 GB	1	50.00
LiPo battery 2700 mAh 11.1 V	1	21.0
DC Step down to 5 v 3 A	1	2.00
Camera	1	11.00
Propellers	6	4.00
PLA 3D filament (in kg)	1	19.00
Cables etc. (approximately)	-	10.00
Total		**159.00**

In addition, it was noted that fins play an active role in the robot's stability and movement. In this way, two fins are attached to the horizontal motors facing forward. In essence, horizontal fins that are facing forward decrease the ease of roll and increase stability. Stability is critical for our application scenario, in which students are expected to program it.

The vehicle underwent testing at sea in the 0–5 m depth range. It was crucial to assess the vehicle's stability as well as its three rotational and two translational motions. EDUV was tested for this reason in all rotational motions and horizontal motion at a depth of about 0.5 m, while vertical motion was tested at 0–1 m depth. For these measurements, the IMU MPU-6050 was placed on the vehicle. The outcomes were as expected since the robot responded to the roll, pitch, yaw, horizontal, and vertical motion commands with great precision and within a reasonable amount of time. More specifically, the vehicle has a speed of 0.6 m/s during horizontal translational movement and 0.35 m/s during vertical translational movement. The vehicle can also rotate at speeds of 59 degrees per second for roll, 53.7 degrees per second for pitch, and 68.6 degrees per second for yaw.

The vehicle can be controlled remotely from the platform. More specifically, it can execute a series of commands to achieve the desired outcome. EDUV supports the following moving commands from the platform:

- *Forward for n seconds*: The vehicle performs horizontal translational motion and moves forward for *n* seconds.
- *Backward for n seconds*: The vehicle performs horizontal translational motion and moves backward for *n* seconds.
- *Emerge for n seconds*: The vehicle performs a vertical translation motion and moves upwards for *n* seconds.
- *Dive for n seconds*: The vehicle performs vertical translational motion and moves downwards for *n* seconds.
- *Turn Right for n seconds*: The vehicle performs yaw rotational motion and turns to the right for *n* seconds.
- *Turn Left for n seconds*: The vehicle performs yaw rotational motion and turns to the left for *n* seconds.
- *Turn Up for n seconds*: The vehicle performs pitch rotational motion and turns upwards for *n* seconds.
- *Turn Down for n seconds*: The vehicle performs pitch rotational motion and turns downwards for *n* seconds.
- *Roll Right for n seconds*: The vehicle performs a roll rotational motion and rolls right for *n* seconds.
- *Roll Left for n seconds*: The vehicle performs a roll rotational motion and rolls left for *n* seconds.

These commands are written in the Python programming language, and each of them represents a function of the underwater vehicle. These functions are executed by the Raspberry Pi microcomputer, located on the surface, which is connected to the motors with a waterproof tether for transferring power. In addition, the operator is responsible for resetting the vehicle to its initial location after each test.

3 | EDUV PROGRAMMING PLATFORM

In this section, the programming platform is described, its technical details are quoted, and the integration with the underwater vehicle is explained.

3.1 | Platform overview

Students can learn programming through the use of the EDUV Platform by remotely controlling an underwater vehicle, with the assistance of the Blockly library, or by directly entering Python code into a coding environment. In this manner, the process of learning is made to be more engaging and entertaining.

The EDUV Platform is a website that is divided into three primary sections (Figure 4):

- The Blockly section, where users may utilize Blocks to create the program (Figure 4 left window).
- The coding area, where the students may enter Python code either by typing it in or by clicking a button that automatically interprets the code into Python from the Blockly blocks (Figure 4 right window).
- The third section contains live video from the underwater vehicle. This area is directly beneath the coding and Blockly window.

In addition, the user is able to perform various actions on the website through the use of the buttons located at the top of the page. More specifically, step-to-step code execution can be enabled, which provides the user increased visibility of his actions. When enabled, the user can pause, play, or even switch between the steps of his code. Furthermore, there are buttons that allow the user to inspect the code and run the program.

Blockly environment allows the user to choose between a manifold of block-commands: Logic (if, not, equal etc.), Loops (for, while, count etc.), Math (add, sq root, sin etc.), Text (find in text etc.), Lists (create, append etc.), Variables, custom Functions, and EDUV Functions. Additionally, the website offers error and infinite loop detection, and a relevant warning is sent to the user to debug the code.

3.2 | Technical details

The server's primary setup consists of two components: XAMPP Apache, which acts as the website's primary server, and OBS Studio, which is in charge of recording, encoding, and streaming the live-stream content used by the platform in SLDP format, a streaming protocol built on web sockets. Additionally, Phpseclib is a component of the platform that is in charge of establishing Secure Shell (SSH) connections between the website and the vehicle. Also, an ethernet connection is used to transmit data between EDUV and the server.

The website was developed with the help of Hypertext Markup Language (HTML), Hypertext Preprocessor

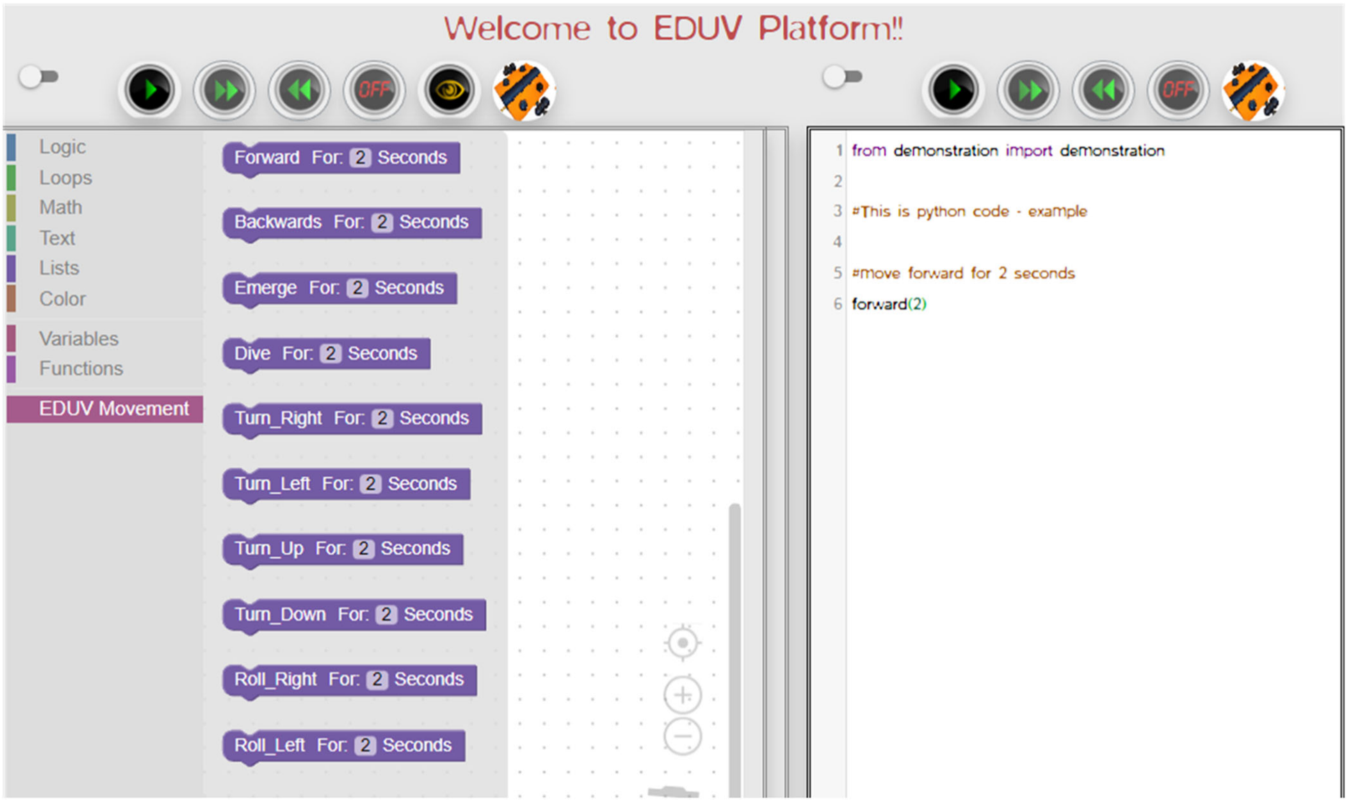

FIGURE 4 Educational underwater vehicle platform's Blockly and code area.

(PHP), Cascading Style Sheets (CSS), JavaScript, Python, and a JavaScript-based text editor called Codemirror. In addition, the Blockly [17] Javascript library from Google was utilized, as was the Brython Python-to-Javascript compiler, which was developed to supplant Javascript with Python. The website will run programs that have been created with Blockly as well as those that have been written in Python.

On the one hand, Blockly is used to execute the program with the help of Neil Fraser's Js interpreter [16]. Also, Blocky automatically prevents errors when writing code. These errors cause the website to fail since the Js Interpreter throws unhandled exceptions when they occur. These exceptions are identified by the Platform and utilized to generate guided feedback for the user to correct coding errors. A Blockly trap was developed for infinite loops to prevent an endless program. A relevant warning is sent to the user, and execution is stopped if a line of code runs more than 1000 times.

On the other hand, the manual insertion of the code is performed using Brython, which is a Python-to-Javascript compiler that enables Python code to be executed within a browser without the need for additional plugins or server-side support. This strategy was chosen since it offers many benefits. The most notable advantage is the rapid processing of the code, which significantly reduces the total execution time. In addition, Brython inspects the code for mistakes and identifies them. Simultaneously, these mistakes are gathered and converted into appropriate messages that are presented to the user to fix the code. Regarding infinite loops, when Brython is utilized for execution, a straightforward trap is employed. If code output exceeds a certain threshold, execution is halted, preventing the website's unavoidable crash, which would happen if the endless loops were run.

3.3 | Integration of EDUV and platform

The website and the underwater vehicle communicate via an SSH connection. In particular, when the “execute command” button is pressed, it causes the code to be compiled and a.py file to be produced. This file, which contains the commands that need to be run in the vehicle, is transferred to the EDUV using SFTP, and the SSH protocol is used to execute the commands. The commands are compiled on the Raspberry Pi, which controls the motion of the underwater vehicle.

Regarding the hardware used to utilize the Platform, the Raspberry Pi and the laptop are connected through Wi-Fi to the access point. The access point, which is a mobile phone,

FIGURE 5 Hardware diagram of the platform. EDUV, educational underwater vehicle.

is connected to the internet through cellular data. On the other hand, an internet-connected client computer is used for the website to be accessible to the students. Figure 5 shows the hardware employed in a diagram.

RQ1: How is the EDUV platform used in education?

This section describes the utilization of the platform as a tool for the teachers to stimulate students' motivation and creativity while increasing their engagement in the course. The students can create text or block-based code to operate an underwater vehicle remotely. This way, the lesson becomes more entertaining because the students are required to program a real robot through the online website. They can compile their code online, and the commands are sent via SSH and SFTP to the vehicle. Even though they cannot access the real robot physically, they can program it virtually (within constraints) and correct their code online using the aforementioned online compiler.

4 | METHODOLOGY

In this section, the methodology followed is described. The design of the study is explained, along with the related steps.

The EDUV Platform is utilized with a view to stimulating the creativity and motivation of the students in a blended environment. In other words, students can use this platform regardless of where they are located—either at the school or at home—to send a combination of movement commands to an underwater vehicle that is deployed at sea. However, before using the robot, students must first learn about its capabilities as well as some fundamental programming concepts. Specifically, the teacher should go over some fundamental programming concepts with the class, like loops, if statements, variables, operations, and functions, before demonstrating the motions of the vehicle. The platform isn't meant to be a replacement for the instructor but rather a tool to help him teach programming more effectively by boosting the students' engagement, creativity, and motivation.

Regarding vehicle programming, the learners work in pairs at the platform since studies have shown that working in pairs is more beneficial for computational thinking and programming skill development than working alone [5, 9, 10, 19]. In particular, pair programming is an approach that originated in industry but has shown positive results in improving both performance and retention in academic and professional settings where computer programming is taught [19]; is a method where two people collaborate on creating software while using the same computer. The results demonstrate that students' prior experiences with computers and willingness to work together served as important factors influencing their partners, and working in pairs proved more beneficial for developing computational thinking and programming skills than working alone, especially for students with less expertise [5, 9, 10].

The EDUV Platform is utilized by students in pairs to remotely control an underwater vehicle with a view to increasing motivation and stimulating creativity. But how is the scholar's willingness to learn and engage in lessons measured? To address this, questionnaires were used both before and after the utilization of the platform. The questionnaire used before experimentation is divided into four main sections. The first Section is based on the University of North Texas' Computer Attitude Questionnaire (CAQ) V5.22 [43] with the following subscales:

- CAQ-F1: Evaluates the participants' importance of computers.
- CAQ-F2: Determines the sample's computer-related satisfaction.
- CAQ-F7: Assesses the level of computer-related anxiety.

The questionnaires in the second section are based on the SCAPA questionnaire [22], which examines the participant's attitudes and opinions concerning the programming. The third section is about the viewpoints of the participants about robotics and is based on the 4-H Nebraska's Robotics and GPS/GIS Interest Questionnaire [3]. Lastly, the fourth section evaluates the participant's understanding of Python and Blockly using four questions about the output of programs written in Blockly or Python.

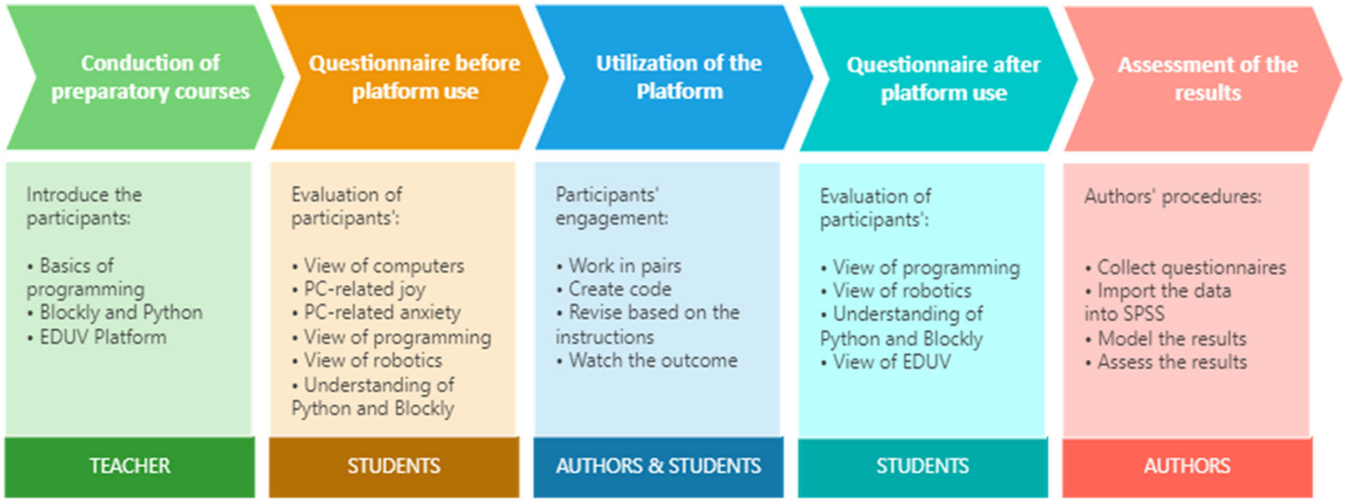

FIGURE 6 Steps of the methodology followed.

The second questionnaire is completed after the platform has been used to evaluate the impact that the EDUV website has on the participants' perspectives on programming and robotics. This questionnaire incorporates some of the questions from the first questionnaire and a section on the website's content. The Result Section includes quotes from the participants' questions and their appropriate responses.

Each participant receives a unique ID from the teacher, which they use to complete the online questionnaire to track and compare the questions asked before and after the use of the platform. This way, the participants remain anonymous to the authors, and the results for each one are not given to the instructor. Therefore, the teacher supervises the proper insertion of their ID but does not know the outcome, and so the students have the absolute freedom to express their opinions without worrying about their identity or their semester marks.

To facilitate a clearer comprehension of the procedures that were carried out, a chart illustrating their primary steps is provided in Figure 6. The five steps are exhibited in the arrows, while the subprocesses are given in the box below each arrow.

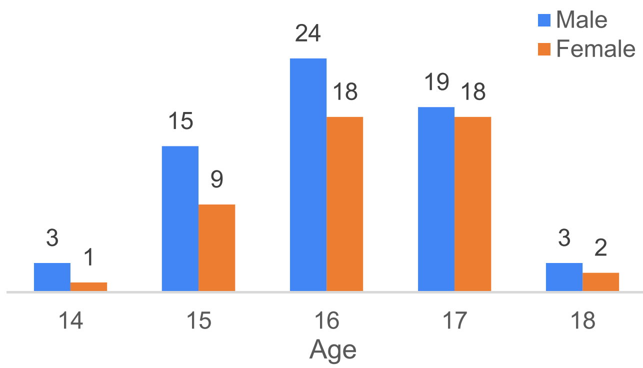

FIGURE 7 Participants' age and gender distribution.

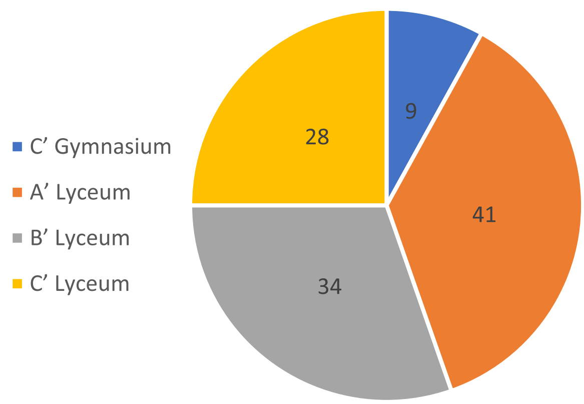

FIGURE 8 Participants' grade distribution.

5 | RESULTS OBTAINED AND DISCUSSION

5.1 | Result analysis of the first survey

The survey included 112 Greek participants, 64 males and 48 females, in the age range of 14–18 years old. The student's age and gender distribution are shown in Figure 7.

The participants are secondary school students, and 9 go to C′ gymnasium, 41 to A′ lyceum, 34 to B′ lyceum, and 28 to C′ lyceum, as illustrated in Figure 8.

RQ2: What level of computer, programming, and robotics knowledge does the target audience possess?

The participants indicated that they had been using a computer for a minimum of 1 year and up to 10 years, with 4.43 being the mean value. Also, their weekly average usage of computers of any kind is 13.56, and the analytical distribution is given in Figure 9. As can be seen, most of the

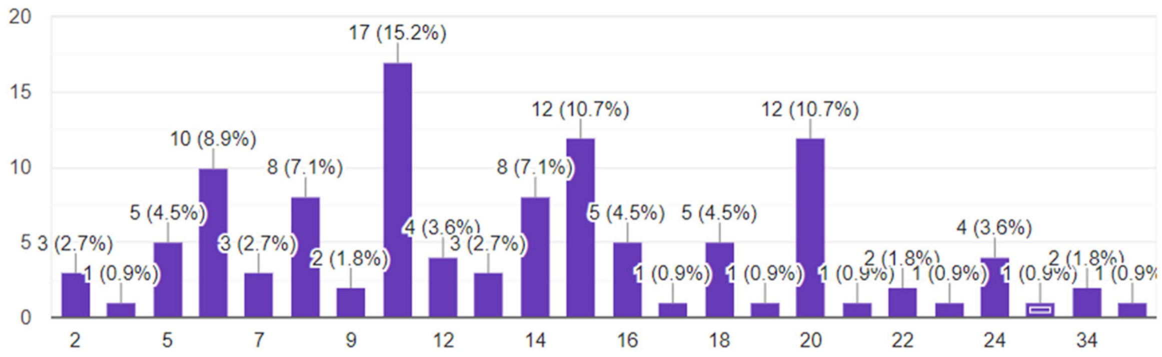

FIGURE 9 Weekly utilization of PC by the participants.

participants use the computer between 5 and 16 h a week. Based on these results, we can assume that the students use computers in their daily lives.

The Computer Attitude Questionnaire V5.22 [43] was used to gauge how significant and enjoyable computers are to the participants by asking them questions from the F1, F2, and F7 subscales. The subscales consist of the following questions:

CAQ-F1: Evaluates the participants' importance of computers

- I can learn a lot with the use of computers.
- I prefer online lessons.

CAQ-F2: Determines the sample's computer-related satisfaction.

- I like using a computer.
- Using a computer is tiresome.
- Using a computer is difficult.
- I like playing computer games.
- I prefer online lessons.

CAQ-F7: Assesses the level of computer-related anxiety.

- Using a computer is tiresome.
- Using a computer is difficult.

The sample had a mean score of 3.5938 on how important computers are, 3.9125 on how much they are enjoyed, and 2.1696 on how anxious they are about using computers. Based on these findings, we are able to make the reasonable assumption that the participants consider computers to be an important part of their everyday lives, and they use them with pleasure without stressing them. The breakdown of the score is presented in Table 2.

Likert-type questions based on the SCAPA questionnaire [22] and its subscales were used to assess the students' opinions about programming. The subscales consist of the following questions:

TABLE 2 Descriptive statistics of the CAQ-F1, CAQ-F2, and CAQ-F7.

	N	Min	Max	Mean	Std. deviation
CAQF1	112	1.50	5.00	3.5938	1.08123
CAQF2	112	2.00	5.00	3.9125	0.83214
CAQF7	112	1.00	4.50	2.1696	1.09986

SCARPA-1: Self-reported programming understanding

- I can explain what programming is.
- I can program a script.

SCARPA-2: Programming intrinsic value belief

- I like programming.
- Programming courses are enjoyable.

SCARPA-3: Programming utility value belief

- Programming will help me in everyday life.
- Programming will help me find a job after graduation.

SCARPA-4: Programming cost belief

- If I want to be good at programming, I'll have to sacrifice my time in other activities.

SCARPA-5: Programming persistence

- When programming becomes difficult, I quit.

SCARPA-6: Programming compliance

- I want to work hard to improve my programming skills.

The sample averaged 3.0537 on a test of self-reported programming understanding, supporting the assumption that most of the participants are unfamiliar with computer programming. In addition, the sample had a mean score of 2.4286 for programming cost belief, indicating that its members generally agree that programming incurs no significant expense. Also, with a mean score of 2.9464 on the programming intrinsic value belief, we may safely say that the students do not have very strong sentiments toward programming or the reverse. In accordance with this assumption, we were also guided by the mean of 2.5268 in our view regarding the programming utility value belief and by the mean of 2.8929 in programming compliance. More importantly, the group appears to have a tendency for perseverance in programming tasks, as seen by the slightly raised mean score of 3.6964. Each scale's standard deviation helps support the previously stated hypotheses and is given in Table 3.

The next part of the first survey was based on the 4-H Robotics and GPS/GIS Interest Questionnaire [3] to find out more about the participants' robotics-related beliefs. There was a mean score of 2.5306 and a standard deviation of 0.89624 on this part of the survey, and we may infer that the sample has little prior knowledge of robotics and doesn't have any strong opinions about it. Additionally, the students answered that they had taken programming lessons before, with an average of 3.54 in the range of 1–5 and a standard deviation of 1.138. The following questions on the first questionnaire were meant to elicit previous knowledge of Python and Blockly and are quoted in Table 4.

These results support the notion that most participants had limited knowledge of Python and Blockly. The four programming questions that appeared at the end of the first questionnaire further supported this assumption. The participants were required to interpret the results of the execution of four brief and relatively straightforward programs, three of which were written in the Blockly environment and one of which was written in Python.

TABLE 3 Statistics of the SCARPA subscales that were utilized in the initial questionnaire.

	Min	Max	Mean	STD
Self-reported programming understanding	1.00	5.00	3.0357	0.91709
Programming intrinsic value belief	1.00	5.00	2.9464	1.18997
Programming utility value belief	1.00	5.00	2.5268	1.09429
Programming cost belief	1.00	5.00	2.4286	1.03727
Programming persistence	3.00	5.00	3.6964	0.76922
Programming compliance	1.00	5.00	2.8929	1.13389

TABLE 4 Statistics of students' background with Blockly and Python.

	Min	Max	Mean	STD
I can program in Python	1.00	5.00	1.96	1.150
I have heard of Blockly	1.00	5.00	3.09	1.418
I can program in Blockly	1.00	5.00	2.64	1.361

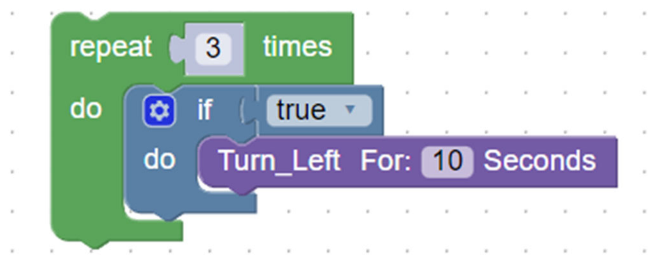

FIGURE 10 Blockly code 1.

TABLE 5 Frequency table of the answers (Blockly code 1).

	Frequency	Percent	Cumulative percent
Correct	47	42.0	42.0
Don't know	44	39.3	81.3
Wrong	21	18.7	100.0
Total	112	100.0	

The first Blockly code is displayed in Figure 10.

The students were given five answers, and they had to decide what the program would do. Table 5 quotes the results of this question. 42% of the students managed to answer correctly to the first question, which is considered incredibly easy.

The second Blockly code is presented in Figure 11.

The students were given four answers, and they had to decide what the program would do. Table 6 quotes the results of this question. 37.5% of the students managed to answer correctly to the second question, which is considered easy.

The third Blockly code is illustrated in Figure 12.

The students were given four answers, and they had to decide what the program would do. Table 7 quotes the results of this question. 36.6% of the students managed to answer correctly to the third question, which is considered moderate.

The first Python code is displayed in Figure 13.

The students were given five answers, and they had to decide what the program would do. Table 8 quotes the

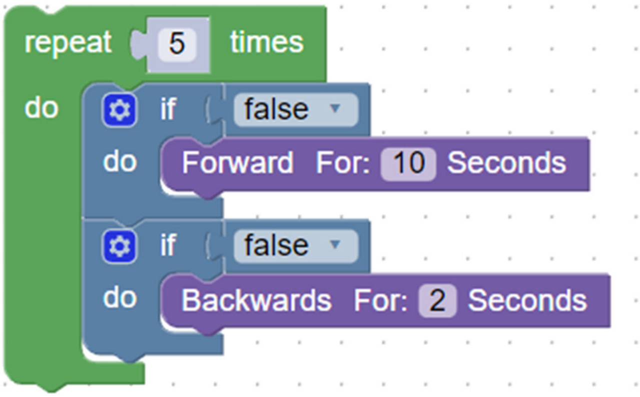

FIGURE 11 Blockly code 2.

TABLE 6 Frequency table of the answers (Blockly code 2).

	Frequency	Percent	Cumulative percent
Correct	42	37.5	36.6
Don't know	48	42.9	87.5
Wrong	22	19.6	100.0
Total	112	100.0	

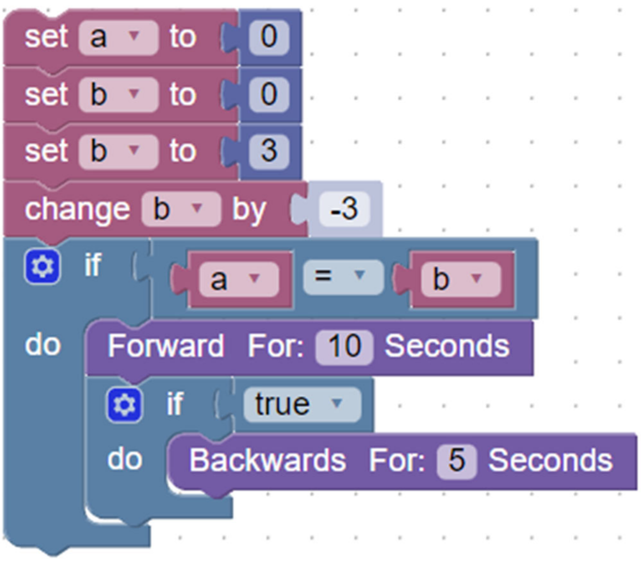

FIGURE 12 Blockly code 3.

TABLE 7 Frequency table of the answers (Blockly code 3).

	Frequency	Percent	Cumulative percent
Correct	41	36.6	36.6
Don't know	57	50.9	87.5
Wrong	14	12.5	100.0
Total	112	100.0	

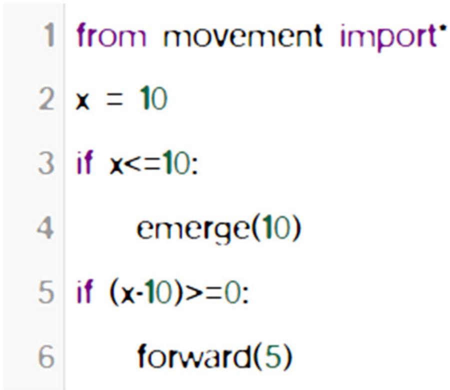

FIGURE 13 Python code.

TABLE 8 Frequency table of the answers (Python code).

	Frequency	Percent	Cumulative percent
Correct	15	13.4	13.4
Don't know	82	73.2	86.6
Wrong	15	13.4	100.0
Total	112	100.0	

results of this question. Only 13.4% of the students managed to answer correctly to this question, which is considered incredibly moderate.

RQ2 (Summary): What level of computer, programming, and robotics knowledge does the target audience possess?

All in all, based on the results of the first survey, it appears that most participants are familiar with computers but have less-than-adequate knowledge of robotics and computer programming. Some of them have moderate knowledge of block-programming, as they correctly answered the first three programming questions. However, only 13.4% could understand what the Python code was about. Because of these factors, they are ideal subjects for evaluating the EDUV platform's pedagogical efficacy in terms of both Python acquisition and learning satisfaction.

5.2 | Result analysis of the second survey and comparison

After a brief training on the platform, the Python programming language, and platform usage, the second questionnaire was filled out. It was designed to look at the advantages of the EDUV platform in education. Approximately half an hour was spent by the participants utilizing the website in tandem.

To begin with, the most tangible results are the code-based answers. Tables 9–12 compare the answers given before and after the teaching procedure on the same code.

RQ3: To what extent were they able to utilize the site's resources to advance their education?

As shown in Tables 9–12, for both the Python and Blockly environments, there has been a significant rise in the number of correct responses. Furthermore, after utilizing the EDUV platform, the number of "Do not know" replies dropped substantially. The Python programming questions, which were likely more challenging for the sample, further illustrate this finding. More specifically, the percentages of correct answers increasing are 50.0%, 55.4%, 43.8%, and 53.6% on the four code tests respectively. However, the Python test scored the lowest correct answer percentage at 67%. In all programming examples, the participants showed an increase in their performance compared to their first contact with this type of programming.

TABLE 9 Comparison of the pre- and posttest percentage of Blockly code 1 answers.

	Percent (Before)	Percent (After)	Difference
Correct	42.0	92.0	50.0
Don't know	39.3	1.8	−37.5
Wrong	18.7	6.2	−12.5
Total	100.0	100.0	0.0

TABLE 10 Comparison of the pre- and posttest percentage of Blockly code 2 answers.

	Percent (Before)	Percent (After)	Difference
Correct	37.5	92.9	55.4
Don't know	42.9	1.8	−41.1
Wrong	19.6	5.3	−14.3
Total	100.0	100.0	0.0

TABLE 11 Comparison of the pre- and posttest percentage of Blockly code 3 answers.

	Percent (Before)	Percent (After)	Difference
Correct	36.6	80.4	43.8
Don't know	50.9	3.6	−47.3
Wrong	12.5	16.0	3.5
Total	100.0	100.0	0.0

TABLE 12 Comparison of the pre- and posttest percentage of Python code answers.

	Percent (Before)	Percent (After)	Difference
Correct	13.4	67.0	53.6
Don't know	73.2	13.4	−59.8
Wrong	13.4	19.6	6.2
Total	100.0	100.0	0.0

RQ4: How does the EDUV Platform stimulate the student's creativity and motivation?

The participants filled out two questionnaires, one before the utilization of the platform and one after. A paired-sample *t*-test was used to look into how the platform affected participants' beliefs. All the results are statistically significant, as indicated in Table 13, and we may infer that the participant's preconceptions about programming were altered for the better after they used the EDUV platform. As we can conclude from the mean and *T* values, the platform had a significant positive impact on the participants. This is also supported by the Sig. values, which stand at a very low level. Furthermore, the results of the paired sample *T*-test showed that the EDUV platform had a beneficial influence on the samples' perceptions of robotics and motivated them to look for chances to further their robotics education. It is noted that the t score for the 4-H-related questionnaire exhibits the highest value, while the Sig. value is the lowest one. This finding allows us to assume that the EDUV platform had the greatest impact on the participants' beliefs toward robotics.

6 | CONCLUSIONS

Getting students motivated and committed to their education can be a challenging process, and this challenge is compounded when the education is delivered online. Robotics facilitates the expression of pupils' creativity and inventiveness. The employment of ER alters the conventional structure of teaching, shifts the spotlight to the learner, and places group-based learning in the spotlight. In this paper, an underwater vehicle was presented that can be used in secondary education via an online platform to stimulate creativity and increase the engagement of the students. This platform has twofold utilization: programming in Python or with Blockly, while the underwater vehicle is customizable and inexpensive. The primary objective was to assess the impact of this integration on students' motivation,

TABLE 13 The dependent *t*-test analysis of the beliefs of the sample about programming, based on the SCAPA and 4-H Robotics and GPS/GIS Interest questionnaires before and after the use of the educational underwater vehicle platform.

	Paired differences						
				95% confidence interval of the difference			
	Mean	Std. deviation	Std. error mean	Lower	Upper	*t*	Sig. (2-tailed)
Self-reported programming understanding (SCAPA)	1.30804	0.76301	0.07210	1.16517	1.45090	18.143	5.44×10^{-35}
Programming intrinsic value belief (SCAPA)	1.02679	0.76181	0.07198	0.88414	1.16943	14.264	7.43×10^{-27}
Programming utility value belief (SCAPA)	0.70982	0.67663	0.06394	0.58313	0.83651	11.102	10^{-19}
Programming cost belief (SCAPA)	−0.64286	0.78105	0.07380	−0.78910	−0.49661	−8.711	3.25×10^{-14}
Programming persistence (SCAPA)	0.43750	0.54988	0.05196	0.33454	0.54046	8.420	1.49×10^{-13}
Programming compliance (SCAPA)	0.87500	0.85028	0.08034	0.71579	1.03421	10.891	3.15×10^{-19}
Pair 1 4H–4H after	1.33163	0.58517	0.05529	1.44120	1.22207	24.083	6.91×10^{-46}

creativity, and engagement. Surveys were administered before and after the utilization of the EDUV platform to gauge its effects on student outcomes.

To examine the platform's viability, a group of Greek students used the online platform in combination with the EDUV. They filled out a questionnaire before the utilization and a questionnaire after. From these questionnaires, we extracted some data regarding the students' attitudes toward robotics, programming, and EDUV. All of the aforementioned data lead us to think that the EDUV platform enthralled the research participants and had a favorable impact on their perceptions about robots and programming. The platform was fully used by the participants to help them deepen their grasp of programming. Additionally, it motivated them to look for additional chances to expand their programming and robotics expertise.

The findings of this study reveal that the implementation of the EDUV platform resulted in significant enhancements in students' programming knowledge and skills. Noteworthy progress was observed in participants' performance in both Python and Blockly environments, coupled with a notable increase in self-confidence, as indicated by the reduction in instances of “do not know” responses. These outcomes suggest that the platform effectively contributed to the improvement of students' programming competencies. Furthermore, the EDUV platform exerted a positive influence on students' attitudes and perceptions regarding programming, robotics, and computer utilization. The results of paired-sample *T*-tests underscored the substantial impact of the platform in reshaping students' beliefs and augmenting their motivation and interest in the domains of programming and robotics.

In summary, the integration of EDUV with the programming learning platform offers a promising approach to enhance high school students' motivation, creativity, and engagement within the realm of programming and robotics education. As elucidated by the results obtained in the conducted surveys, this integration substantially enhances students' motivation, programming skills, and attitudes toward robotics. Moreover, the platform's flexible combination of block-based and text-based coding contributes to a dynamic and engaging learning environment. This approach is aligned with the broader trends in contemporary education, emphasizing the pivotal role of technology in fostering student engagement and skill development, particularly in STEM disciplines. The EDUV platform's cost-effective design and adaptability further underscores its potential to bridge the gap between traditional classroom education and the demands of the digital era. In conclusion, the convergence of ER and innovative programming platforms not only empowers students with critical skills but also ignites their passion for STEM subjects, offering a transformative educational experience in an ever-evolving digital landscape. Subsequent research and the wider implementation of such innovative educational tools hold the potential to contribute substantively to the amelioration of educational outcomes, particularly in the context of online and blended learning environments.

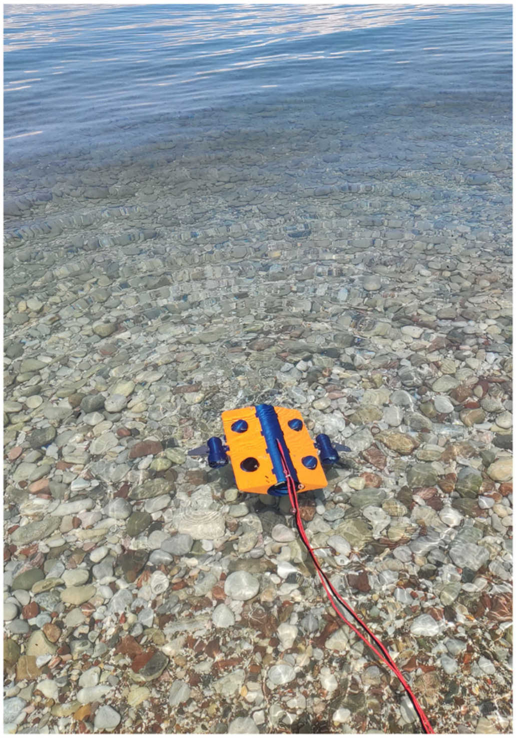

FIGURE 14 Photograph of the educational underwater vehicle's deployment.

Future work involves the deployment of the robot at a pool to avoid weather conditions and test its ability to be unsupervised. This application might be useful for schools with a pool.

A photograph of the vehicle deployed at a coast is provided in Figure 14.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request. Instructions, 3D models, and code can be found in the github repository https://github.com/MariosVasileiou/EDUV.

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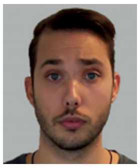

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