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Developing IoT Activities Using the Problem-Solving Method: Proposal for Novice Engineering Students

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ABSTRACT

The inclusion of technological tools in the teaching-learning process in the university environment has not shown significant positive effects on the development of problem-solving skills. Therefore, it is essential to incorporate key methods in education, particularly in engineering, to help students strengthen their skills from the early years of university. The Internet of Things (IoT) emerges as a promising technological alternative to enhance teaching and learning processes in classrooms, while also fostering problem-solving skills in new university students. This study aims to propose a problem-solving method for implementing IoT activities in the classroom, targeted at first-year university students. The method is structured into four phases: understanding the problem, preparation of the plan, implementation of the plan, and solution review. The current study utilized a quasi-experimental design of the pre-test and post-test type, with intentional non-probabilistic sampling that was proportional to the number of students in the population. The results show that, by combining this four-phase method with technological resources (such as block-based programming with mBlock, Arduino boards, BME680 sensors, the ESP12F WiFi module, and MQTT client applications), out of the 73 students who participated in the IoT activities, 57, 49, 60, and 58 improved their skills in problem understanding, plan development, plan execution, and solution review, respectively. Additionally, it was observed that students developed the skill of plan execution to a greater extent, followed by solution review, problem understanding, and plan development. This teaching method aims to assist students who are starting their university studies in participating more effectively in IoT-related tasks and developing strong problem-solving skills. To meet these challenges, the teacher's role is crucial as they must supervise and provide continuous feedback.

1. INTRODUCTION

In recent decades, one of the primary goals of higher education institutions worldwide has been to develop students' cognitive skills—training individuals to articulate their ideas, critically evaluate others' arguments, and apply scientific reasoning to any subject in the curriculum. More importantly, the aim is to equip them to make sound decisions and solve problems effectively [1]. The challenges faced by educators in fostering professional competencies in universities require the design of educational scenarios that promote meaningful learning experiences. These experiences should enable students to confront relevant problems within their field of study successfully [2]. The teacher's intervention is crucial in guiding and modeling the processes involved, necessitating a didactic structure that elevates students' thinking. This approach helps students view content, as well as the professional world they are entering, through a lens that allows them to establish connections and make informed decisions about how to address complex problems [3]. For engineering students, the application of appropriate teaching methods for developing problem-solving skills is particularly important. Failing to do so may result in students rejecting tasks that demand higher cognitive abilities, such as programming, application development, and logical decision-making—critical skills for building technology to solve real-world problems [4].

Regarding problem-solving skills and research competencies in university students, it is important to note that in most universities the low percentage of students in the last semesters who choose the research project modality as work to obtain a professional degree is 2.23%, which is an alarming figure; this minority percentage of students who carry out research work is the result of the application of an inadequate strategy in the formation of problem-solving skills and research competencies from the first years of university studies [5]. This result is similar for engineering students, which is even more worrying, because engineering is related to the creation, production or development of innovative goods and services, artifacts, new materials, prototypes, machinery or procedures to help solve society's problems [6]. In this sense, it is important to strengthen students' problem-solving skills through teaching methods that guide them to solve problems from the first years of university. The main challenge is that beginning engineering students find traditional programming and IoT application development complex, which can limit their ability to understand and apply these concepts in practice to solve a real-life problem; faced with this reality, the present study seeks to solve this problem by proposing an accessible and friendly problem-solving method based on block programming, which facilitates understanding and allows the application of IoT activities in the classroom, and as a consequence develops problem-solving skills focused on the needs of the community where they live [7].

Motivating students in the classroom and continuously implementing effective educational strategies is a top priority in the field of education. Utilizing technological resources is a practical approach to promote cognitive skills, teamwork, and critical thinking [8]. These strategies, when applied in the teaching-learning process, enable students to acquire skills that are necessary to solve real-world problems in society [9].

Various studies have shown that the use of technological resources such as Arduino boards, sensors, computers, programming languages, etc., can significantly improve students' academic skills [10-12]. These resources also allow different solutions to be implemented and tailored to the context and needs of students. The availability of technological resources enables students to observe expected results instantly and refine their ideas by checking the proposed solutions [13, 14]. Block-based programming tools are also widely used in academic settings to develop programming and computational thinking skills. These tools are easy to learn, especially for beginners, and support a wide range of electronic devices such as microcontrollers, sensors, and actuators [15].

In recent years, there has been a growing interest in incorporating IoT technology into the field of education. Various authors have pointed out that its implementation can aid students in learning different disciplines that are related to science, technology, mathematics, and more. This can help instill interest in STEM areas [16]. Several academic experiences have shown the positive effects of IoT in education, creating interactive, collaborative scenarios and solutions for real-world problems [17]. In the 21st century, an important challenge in the educational field is to provide students with the right methods, approaches, and teaching tools to address societal problems [18]. In this context, IoT and block-based programming are essential technologies to generate practical knowledge and social sensitivity among students who are starting their engineering careers. These technologies can help students gain a better perspective of how the world works in the digital age [19].

In this article, the authors propose using block-based programming to teach IoT activities to beginning engineering students. The programming blocks are developed for wireless communication using the Arduino board, BME680 sensor, and ESP12F WiFi module.

2. RELATED WORK

2.1 Internet of Things

The Internet of Things (IoT) is a technology that connects physical objects such as humidity, temperature, and gas sensors to the internet. It transmits data to improve productivity, efficiency, and services in various sectors including agriculture, livestock, and mining. The main objective of IoT is to facilitate communication between different physical objects without the direct intervention of people. Connectivity plays a vital role in IoT as it allows universal connection of devices [20].

There are various models of IoT architecture with different layers. However, the most commonly used is the three-layer model consisting of the perception layer, network layer, and application layer [21]. The perception layer is responsible for collecting data and information. It is made up of sensors, actuators, and microcontrollers that interact with each other using various protocols such as I2C (Intern-IC bus), SPI (Serial Peripheral Interface) and UART (Universal Asynchronous Receiver-Transmitter) [22]. Different types of sensors can be used to collect information, including the DHT11 sensor for measuring humidity and relative temperature, the BMP180 sensor for measuring barometric pressure, the SGP30 sensor for measuring air quality, and others. However, the BMP680 sensor is one of the most popular multifunction sensors because it can measure the variables described by the other sensors [23].

To receive information from the sensors, the most commonly used electronic boards belong to the Arduino family. New models such as the Arduino Nano 33, Arduino BLE, and Arduino Every are emerging that integrate WiFi and Bluetooth [24]. Although the family of Arduino boards has been expanding, some boards such as Arduino Atmega, Arduino Nano, and Arduino Micro still do not have a wireless communication interface. For this reason, the ESP82266 microcontroller is typically included so that these boards can access the internet [25].

The network layer is responsible for transmitting and processing information from the perception layer. Various wireless technologies are used within this layer to transmit information from one device to another [26]. Bluetooth can transmit information up to a few centimeters, Zigbee or Wi-Fi can transmit up to a few meters, and LoRa or SigFox can transmit up to 15 kilometers.

The application layer provides important services to end customers through web and/or mobile applications. These services may include patient monitoring, monitoring of crops, livestock, machines, and many others [27-29].

2.2 IoT in education

IoT has a lot of potential in education. It can be used to support educational management, the teaching-learning process, and training programs related to IoT. Although there have been several studies on how IoT can be used as an important tool to support educational management and the teaching-learning process in the classroom, there is still little initiative in developing educational content related to IoT [17, 30].

The purpose of applying IoT in education is to create an ecosystem where students and teachers can have a deeper understanding of their environment and make changes using

IoT devices and applications in different sectors like agriculture, health, and education. IoT has influenced education in two ways: first, by incorporating different things such as home appliances, medical devices, vehicles, industrial sensors, etc. into the teaching-learning process, and second, by providing technical information on IoT device usage [20, 31, 32].

The use of IoT technology in education is aimed at facilitating active learning where students use IoT technology and their reference frameworks to suggest alternative solutions to real-world problems [33-35]. These educational techniques are similar to project-based learning, which involves proposing activities over a particular period to identify problematic situations, propose solutions, and evaluate results. By working in teams, students acquire knowledge and skills [36, 37].

In the university environment, IoT can be incorporated at different levels through project-based learning for students in their first and last cycles of study. In the initial years, project-based learning can introduce activities related to the fundamental IoT technologies that are suitable for students starting their university education [38]. These activities primarily include teaching IoT architecture, hardware platform installation, and IoT application development. Additionally, block-based programming is used to interact with IoT devices and develop applications. For the last cycles of the degree, hardware experimentation and practice on IoT are recommended using laboratory equipment [32, 39].

IoT facilitates the application of gamification methods by integrating sensors and connected devices to create immersive and engaging learning experiences. Students can engage in educational games or interactive challenges, making learning more enjoyable while increasing their motivation and engagement. Additionally, IoT provides a dynamic, data-rich environment that fosters the development of problem-solving skills through experimentation, access to real-time data, collaboration, and automation [40]. These tools enable students to confront real or simulated challenges, enhancing their ability to analyze situations, think critically, adapt, and devise creative, innovative solutions [41].

Problem-solving in IoT environments often involves overcoming challenges and experiencing failures. The necessity to adjust and refine solutions after setbacks teaches students the value of resilience and persistence. Through trial and error, students come to understand that failure is an integral part of the learning process, and continuous improvement of their solutions is essential [42]. Problem-solving is frequently associated with STEM fields (science, technology, engineering, and mathematics), and IoT offers a practical platform for students to apply their knowledge in these disciplines. They can work with sensors, connected devices, and smart systems to address problems that demand technical and analytical skills [43]. Access to IoT technology empowers students to identify technological challenges, develop innovative solutions, and test them in controlled environments.

2.3 Problem resolution

Problem solving, or solving a problem, is a cognitive process aimed at achieving a goal for the individual solving it. The problem-solving process involves cognitive factors such as planning, critical thinking, and the ability to make decisions based on one's arguments [43].

In scientific literature, problems and problem-solving techniques or methods have been contextualized. Each problem has its own unique characteristics, so there is no single procedure that guarantees its solution. Instead, there are several procedures that outline the steps or phases to follow in order to solve a problem [44-48]. Table 1 displays the problem-solving phases proposed by various authors.

Table 1. Problem-solving phase by various authors

Problem-Solving by Various Authors
By Ubaidullah et al. [49]
- Understanding/ definition
- Planning
- Design
- Codification
- Evaluation
By Jeng et al. [50]
- Recognition of the problem.
- Solution strategy development
- Organization of knowledge about the problem
- Solution evaluation
By Weese and Feldhausen [51]
- Simplifying the problem
- Dividing the problem into smaller parts
- List of steps to resolve
By Maharani et al. [52]
- Decision on the subject matter
- Solution formulation
- Division of complex problems
- Step-by-step design to solve the problem
- Identification to correct errors
By Kale and Yuan [53]
- Understanding the problem
- Plan and monitoring
- Execution
- Check/reflect
By Rabiee and Tjoa [54]
- Identification/understanding of the problem
- Breakdown of the main problem
- Solution development
- Implementation
- Validation
By Pedaste et al. [55]
- Problem identification
- Selection of strategies
- Strategy execution
- Review of results

Research has shown that in solving any problem, four stages or processes can generally be identified: understanding the problem, preparation of the plan, implementation of the plan, and solution reviewing [56, 57]. These 4 phases allow for the sequential resolution of identified problems. Utilizing Pólya's method for problem solving offers several advantages to students, including improvement of analytical capacity and understanding of the problem, reinforcement of skills in proposing strategies in an orderly and sequential manner, ability to successfully execute activity plans developed in the previous phase, and enhancement of critical evaluation skills for the product's functionalities and its validation.

Currently, the 4-phase problem-solving method is being used as an educational strategy in technological projects in classrooms (see Figure 1). This method involves the use of microcontrollers, sensors, actuators, and block-based programming. It has been observed to enhance various skills in students, including computational thinking, critical thinking, formative research, and problem-solving. These experiences have been documented in the university environment [58-62].

Figure 1. Four-phase problem-solving method

In the problem understanding phase, the student must ensure a complete understanding of the problem before attempting to solve it. This involves: identifying the core question, clarifying all relevant terms and concepts, determining which information is provided and which is pertinent to the solution, and relating the problem to similar experiences or issues [63].

In the preparation of the plan phase, after fully grasping the problem, the next step is to devise a strategy or plan for solving it. This may involve: considering various methods or approaches that could be applied, breaking the problem down into more manageable parts, and drawing on prior knowledge, formulas, or principles to guide the solution [64].

In the implementation of the plan phase, the student implements the plan developed in the previous phase. It is crucial to follow each step in a logical and orderly manner. This is where calculations or operations necessary to reach a solution are carried out, ensuring that each step of the process is executed methodically and reviewed thoroughly [65].

In the solution review phase, after arriving at a solution, it is important to review the work to ensure its correctness and assess whether the solution is reasonable. This includes: verifying that the answer meets the problem's requirements, checking the calculations or reasoning used, and reflecting on whether the chosen method was the most appropriate or if a more efficient solution exists [66].

An example that integrates all four phases is the problem of the "Implementation of a water level monitoring prototype in the Viñas reservoir in the city of Pampas, Tayacaja" [67]. In the problem understanding phase, the issue of water scarcity that could impact the city is identified, along with the cause-and-effect relationships such as the absence of rainfall and water wastage by residents. In the plan development phase, the goal is to monitor the water level to measure consumption; proposed activities may include installing a distance sensor to track water levels and programming a monitoring interface. In the plan execution phase, the planned activities are carried out, using technological resources like sensors, actuators, and microprocessors. Finally, in the solution review phase, the system's functionality is assessed, including the recording of data on the graphical interface and its usability.

2.4 Block programming and electronic devices

Block-based programming is gaining increasing attention as an effective tool for teaching and reinforcing programming skills and computational thinking, especially for beginner students or those entering higher education with limited computing experience. Research shows that block-based programming is widely used to develop skills in computer science, ICT, computing, and computational thinking courses [15]. There are several programs and tools employed in education today, such as Scratch, mBlock, and AppInventor [68]. These tools enable students to engage in activities like creating scenarios that address real-world problems in their community or city, applying knowledge from mathematics, science, engineering, and technology [69, 70]. Additionally, tools like AppInventor complement Scratch and mBlock by allowing students to create mobile-based activities. Tools such as Dr. Scratch are frequently used to evaluate the activities developed in block-based programs [69]. In the academic sphere, educational robotics and block-based programming have become widely used in developing skills at an early age, demonstrating benefits in disciplines like mathematics, logic, teamwork, and particularly in computational thinking and problem-solving [71-74]. However, the use of educational robots presents challenges, particularly due to their high cost, making them difficult for many educational institutions and students to afford. Another limitation is that most educational robots are predominantly designed for male students.

Currently, there are custom hardware prototype solutions with block-based programming interfaces that incorporate microcontrollers, sensors, actuators, and other components. These solutions are designed to strengthen skills and abilities in beginner students and are typically more affordable compared to commercial alternatives [71].

3. METHODOLOGY

3.1 Research approach and participants

The current study utilized a quasi-experimental design of the pre-test and post-test type, with intentional non-probabilistic sampling that was proportional to the number of students in the population. Seventy-three first-year students in the industrial engineering degree program during the 2023-II academic period at the Daniel Hernández Morillo National Autonomous University of Tayacaja in Peru took part in the study. The students' ages ranged between 17 and 19 years old.

An instrument has been developed to assess the problem-solving abilities of newly enrolled students at the professional school of industrial engineering (see Table 2). This instrument was adapted from the approach proposed by previous studies [57, 75] and structured based on the problem-solving phases outlined by Polya [56]. The method comprises four phases: understanding the problem, developing the plan, executing the plan, and verifying the solution. The instrument, which is based on Pólya's method, has been utilized in several research studies [56, 75-77].

The instrument used in this project was validated by three international experts, including one expert in education, one expert in computer science, and one expert in computer engineering [67]. It consists of 24 items, divided into four dimensions: problem understanding (7 items), plan development (5 items), plan execution (5 items), and solution review (7 items). Each item is rated on a Likert scale from 1 to 5, with 1 representing "no" and 5 representing "yes," and intermediate values indicating the degree of agreement or disagreement. Based on various statistical tests, the instrument's reliability is considered acceptable, with values exceeding $\alpha=0.70$ [57]. The instrument was used in pre- and post-tests, and the data was analyzed using SPSS software.

Table 2. Instrument to assess the problem-solving abilities

Problem Solving Phases	Items
Understanding the Problem	1. Do you read the project or work statement several times?
	2. Do you understand the statement of the project or work?
	3. Do you explain the problem of the project or work in your own words?
	4. Do you easily identify the cause and effect of the problem?
	5. Does it make it easy for you to represent the problem using a visual organizer?
	6. Do you easily identify the most important data of the problem?
	7. Do you identify a problem similar to the problem of your project or work?
Preparation of the Plan	8. Do you easily find a similar project or job?
	9. Do you recognize project activities slightly differently in another project?
	10. Do you find or identify any activity from another project that allows you to develop your plan?
	11. Do you decompose the solution to the problem into several parts?
	12. Do you identify the technological resources to develop your project activities?
Implementation of the Plan	13. Do you carry out or develop everything planned in the previous step of creating the plan?
	14. Do you use technological resources in the execution of project activities?
	15. Do you carry out activities or tasks step by step?
	16. Do you demonstrate that activities are executed in an orderly and sequential manner?
	17. Do you carry out activities in an orderly and sequential manner?
Solution Review	18. Do you review or check the performance of the solution results?
	19. Do you verify the operation of each component or part of the solution results?
	20. Do you analyze if there are other alternatives to solve the project problem?
	21. Does it make it easy for you to apply the results of the solution or part of it to solve the problem of another project?
	22. Does the solution cover all parts of the problem?
	23. Do you identify any component or part of the solution results to improve or optimize?
	24. Do you identify any component or part of the solution results to use or solve the problem of another project?

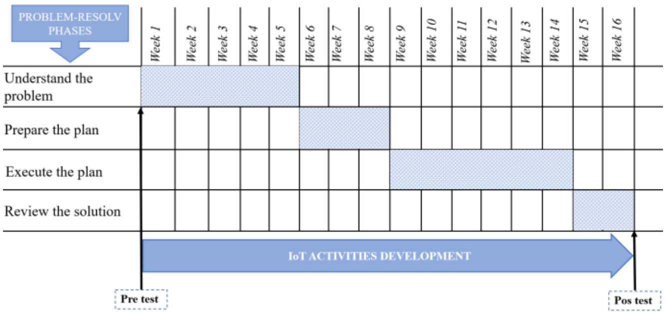

Figure 2. Time allocation for developing IoT activities

Figure 2 illustrates the time distribution for developing IoT activities based on the problem-solving phases, spanning 16 weeks (one academic semester). The problem understanding phase takes 5 weeks, the plan development phase 3 weeks, the plan execution phase 6 weeks, and the solution review phase 2 weeks.

The instrument was administered twice, before (pre-test) and after (post-test) the classroom intervention (implementation of IoT activities). The items were distributed via Google Forms, and the data was processed using SPSS software.

3.2 Proposal for IoT activities and use of technological resources

The IoT activity proposed is titled "Monitoring Environmental Parameters in the City of Pampas, Huancavelica Region, Peru." This activity addresses the city's need to monitor key environmental variables such as temperature, humidity, atmospheric pressure, air quality, and altitude. These measurements will enable informed decision-making to maintain desired values across various applications.

For the execution of this activity, low-cost, illustrative, and intuitive technological solutions were selected. The devices used include the BME680 sensor for real-time monitoring of environmental variables (temperature, humidity, atmospheric pressure, air quality, and altitude), the Arduino Nano board, and the ESP12F WiFi wireless module. The measured data is hosted on an MQTT broker server (Mosquitto).

Block-based programming through the mBlock software was employed due to its user-friendly and intuitive environment, making application development both engaging and accessible. Students use mBlock to create a graphical interface representing the problem they are solving. Through mBlock, they interact with the BME680 sensor and ESP12F WiFi module to read the environmental parameters.

3.3 Development of IoT activity following the problem-solving method

An IoT project was proposed to monitor environmental parameters in the city of Pampas, located in the Huancavelica region of Peru. The project used the BME680 sensor to measure real-time environmental variables such as temperature, humidity, atmospheric pressure, air quality, and altitude. Additionally, the project utilized an Arduino nano board, ESP12F WiFi module, mBlock programming environment, and MQTT broker server (Mosquitto). The project followed a 4-phase problem-solving method in the classroom, which included understanding the problem, developing the plan, executing the plan, and reviewing the solution. Further details about the tasks carried out in each phase are provided below.

- Phase 1: Understanding the problem

The students started looking for scientific information about the issues related to the project. They used scientific search engines such as Google Scholar, ALICIA repository, and scientific databases like Scielo and Dialnet. These tools are easy to access and are helpful for beginner students. As a result, they were able to prepare a one-page document summarizing the issues and creating a cause-and-effect representation through mind maps with proper citations and references. This phase took about 3 weeks. Figure 3 shows the scientific search engines.

Figure 3. The scientific search engines

- Phase 2: Preparation of the plan

The students began by searching for similar activities or projects as antecedents. After identifying the activities to solve the problem, they listed the planned tasks below:

- Design the IoT scenario
- Implement the circuit with microcontroller and sensor
- Develop a programming routine in mBlock
- Configure the MyMQTT application
- Acquire data with sensors
- Show the variables collected in the MyMQTT application

- Phase 3: Implementation of the plan

The students started by designing the IoT scenario (see Figure 4). They identified the following electronic devices: BME680 sensor, Arduino Nano, ESP12F module, MQTT mosquito Broker, and MyMQTT application.

They set up the electrical circuit on a breadboard, which includes an Arduino Nano on the left side, a BME680 sensor in the middle, and an ESP12F on the right side. To connect the circuit, they used a supply voltage pin set to 5V for all three components (Arduino Nano, BME680 sensor, and ESP12F module), as well as the SDA (Serial Data) and SCL (Serial Clock) pins to establish communication between the components using the I2C protocol. They created a programming routine in mBlock to measure the variables of relative humidity, relative temperature, altitude, air quality, and atmospheric pressure using the BME680 sensor. They began by defining the start of the program with the orange block. Then, they initialized the BME680 sensor with the purple block and specified the number of variables to be sent to the Mosquitto Broker server through the ESP12F module using the green block. They included a "forever" block to ensure that the variables are constantly measured every two seconds. They added blocks for each variable to enable the sensor to collect the information and store it in predefined variables. Finally, the collected sensor data was transmitted to the ESP12F module using the green wireless communication blocks via the I2C protocol. Figure 5 shows the circuit and programming routine in mBlock.

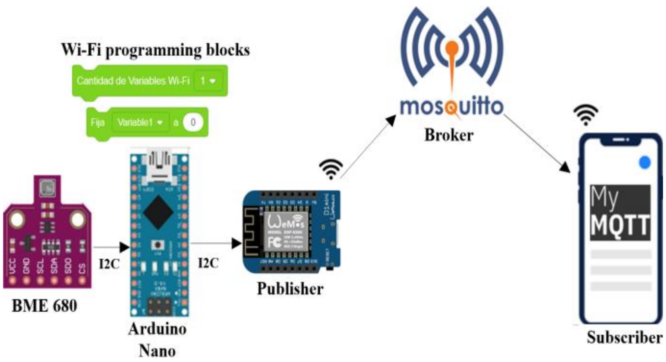

Figure 4. IoT scenario

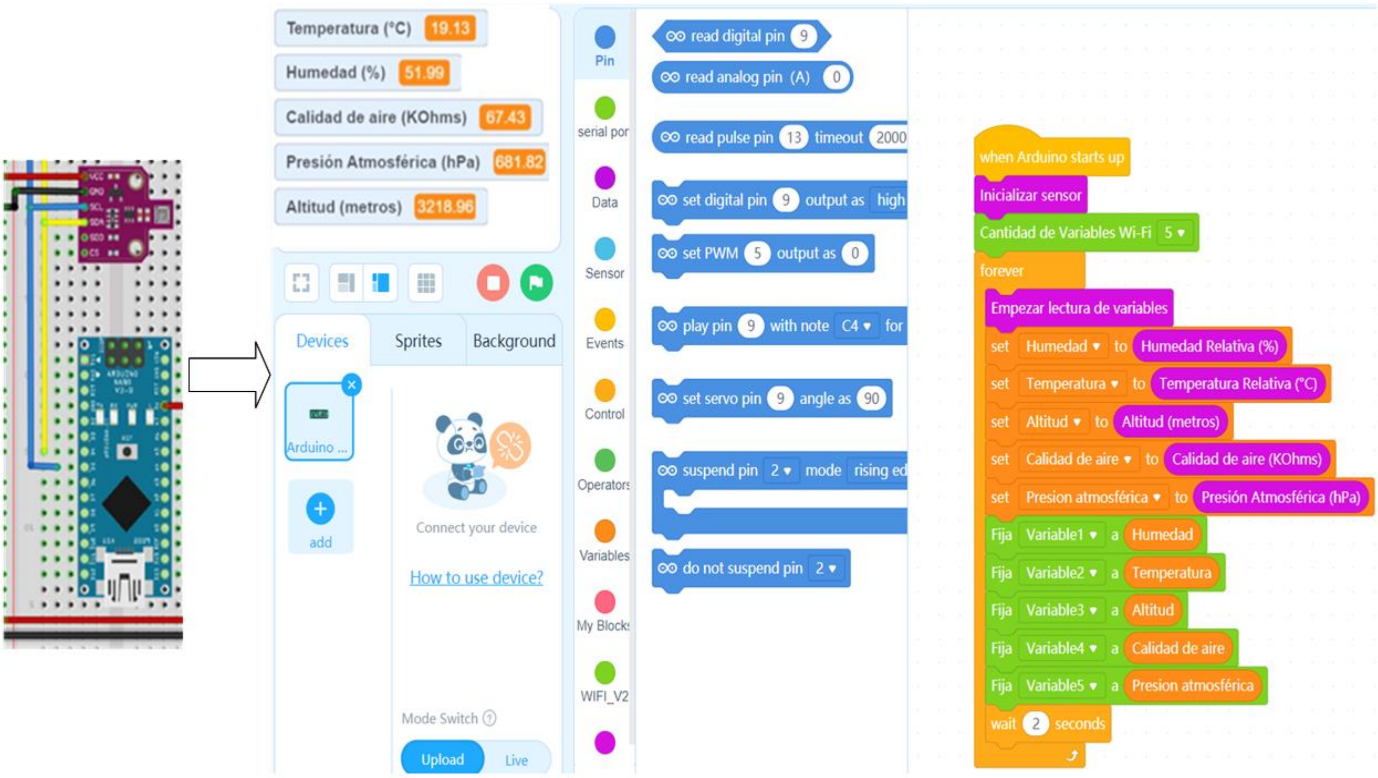

Figure 5. Programming routine in mBlock for an IoT scenario

They set up the MyMQTT application (see Figure 6) to conduct tests with the Mosquitto Broker server. The configuration involved defining a subscriber and setting the public host name as test.mosquitto.org and port 1883 for the MQTT protocol.

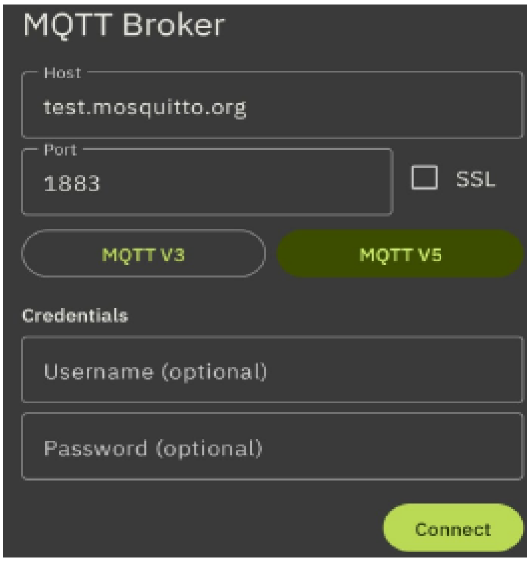

Figure 6. MyMQTT configuration

Figure 7. Information collected through the MyMQTT mobile app

- Phase 4: Solution review

In this phase, the implementation of the IoT scenario for data acquisition using the BME680 sensor was evaluated. On the left side, you can see the connection between the BME680 sensor and the Arduino Nano. On the right side, the block-based programming and the variables measured or collected (relative humidity, relative temperature, altitude, air quality, and atmospheric pressure) in the mBlock software are shown. The values measured at the time of the tests were: temperature (19.73℃), humidity (51.99%), air quality (67.43), atmospheric pressure (681.82), and altitude in meters (3218.90 masl).

The data collected by the MyMQTT application was evaluated (see Figure 7), which displays the information received by the MyMQTT application. The values of 5 variables are shown: V1 for relative humidity, V2 for relative temperature, V3 for altitude, V4 for air quality, and V5 for atmospheric pressure. These values are received by a subscriber using the MyMQTT application.

The variable information was sent from the programming blocks created for the Arduino Nano. The Arduino Nano received the information on the variables mentioned above. Through the I2C communication protocol, it was forwarded to the ESP12F. The ESP12F published the information to the Mosquitto MQTT server over Wi-Fi networks. Subsequently, Mosquitto sent the information to the subscriber MyMQTT (MQTT client mobile application).

4. RESULTS

4.1 Analysis of descriptive statistics of problem-solving skills

The statistical summary of problem-solving skills is shown in Table 3.

The results presented in the table above indicate improvements in all assessed skills following the intervention. Increases in both the means and medians suggest a positive overall effect. Notably, the standard deviation also increased in all cases, indicating greater variability in scores after the intervention.

4.2 Normality test of the collected data

In order to verify the positive impact of IoT activities on the development of problem-solving skills, a sample of 73 students underwent the Kolmogorov-Smirnov normality test to determine the type of statistical test (parametric or non-parametric). The analysis was conducted using SPSS software, as shown in Table 4.

Based on the results of the normality tests, it has been established that data sets with a P-value less than 0.05 (significance level) demonstrate a non-parametric distribution. Therefore, the Wilcoxon test will be used to analyze the pre- and post-test relational samples. The aim of the analysis is to determine whether there is a significant improvement in the problem-solving skills of beginning engineering students.

Table 3. Statistical summary analysis

Problem-Solving Skills	Mean		Median		Standard Deviation	
	Pre-Test	Pos-Test	Pre-Test	Pos-Test	Pre-Test	Pos-Test
Understanding the problem	19.0	19.6	19.0	19.5	2.09	2.67
Preparation of the plan	16.9	17.9	17.0	17.5	2.34	2.64
Implementation of the plan	25.0	26.9	25.0	26.0	3.57	3.62
Solution review	24.7	26.6	24.5	28.0	2.95	3.61

Table 4. Kolmogorov-Smirnov normality test

Pre-Pos Test	Understanding the Problem	Preparation of the Plan	Implementation of the Plan	Solution Review
Improvement	57	49	60	58
Equal	14	21	11	13
No Improvement	2	3	2	2
P-Values	0.000	0.000	0.000	0.000

4.3 Testing about the development of problem-solving skills

Table 5 displays the results of the Wilcoxon test for 73 students, showcasing the skills of understanding the problem, preparing the plan, executing the plan, and reviewing the solution.

Table 5. Wilcoxon signed rank test

Pre-Pos Test	Statistic	gl	P values
Understanding the problem	0.301	73	0.000
Preparation of the plan	0.302	73	0.000
Implementation of the plan	0.307	73	0.000
Solution review	0.315	73	0.000

From the results of the Wilcoxon test, out of the 73 students who participated in the development of IoT activities in the classroom: Regarding the ability to understand the problem, 57 students experienced improvement, 14 remained the same, and 2 experienced a worsening; for plan development skills, 49 students showed improvement, 21 remained the same, and 3 experienced a worsening; for the ability to execute the plan, 60 students showed improvement, 11 remained the same, and 2 experienced a worsening; for the ability to review the solution, 58 students showed improvement, 13 remained the same, and 2 experienced a worsening.

In Figure 8, the grouped column chart illustrates the comparison of problem-solving skills that beginning engineering students have improved through IoT activities in the classroom. The graph indicates that students have shown the most improvement in Execution of the Plan, followed by Review of the Solution, Understanding the Problem, and lastly Preparation of the Plan.

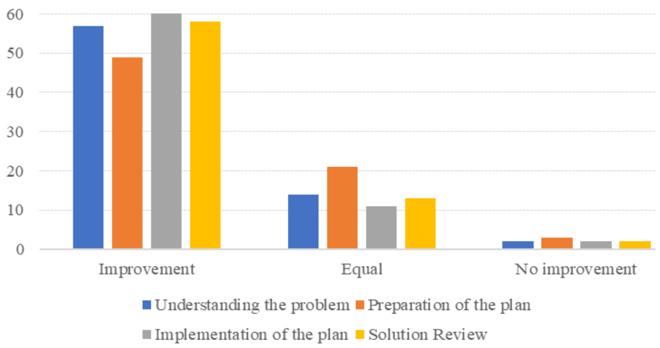

Figure 8. Comparison between problem solving skills

5. DISCUSSION

Block-based programming and electronic devices are excellent tools for students to carry out activities simply and intuitively without putting a lot of cognitive loads on them [78]. It is not just a coding tool, but it is also a pedagogical strategy, which helps beginning students to strengthen their cognitive abilities. The visual programming environment of mBlock and Scratch allows students to propose alternative solutions in problem-solving and represent the context of the problem [79]. These block-based tools generate stimulation and motivation in students, making them think critically and creatively [14, 80, 81].

Block-based solutions are appropriate for beginning students in higher education when used as pedagogical approaches in the teaching-learning process. It becomes even better when these activities are integrated into the curriculum and combined with electronic devices such as the Internet of Things (IoT) that help students generate thinking capacity in solving problems [82].

The 4-phase problem-solving method is a didactic method to develop IoT activities in the classroom aimed at beginning engineering students, allowing them to generate skills in problem understanding, plan development, plan execution, and review of the solution [60-62]. In the phase of understanding the problem, the students searched for scientific information, consulting scientific databases, to then pose the problematic situation of the project; In the plan development phase, the students reviewed the background and proposed the tasks to be developed in the classroom; In the plan execution phase, students developed algorithms, programmed sensors, configured actuators and built a graphical interface in mBlock for monitoring variables (relative humidity, relative temperature, altitude, air quality and atmospheric pressure); in the solution review phase, the students evaluated the operation of the implemented IoT scenario, such as reading the magnitude of the variables; thus the interaction with the IoT web platform. These activities developed in the classroom allowed us to strengthen the cognitive capacity and social sensitivity of the students.

The greatest number of beginning engineering students who have improved their problem-solving skills through the development of IoT activities in the classroom was the skill of Implementation of the plan (60 students), followed by Solution Review (58 students), Understanding the Problem (57 students) and finally the skill of Preparation of the plan (49 students); these results were possibly due to the fact that in the Implementation of the plan phase, practical tasks were carried out [61, 83]; for example, they developed algorithms, developed block-based programs to interact with sensors and actuators, built problem scenarios in the block-based programming environment, tested the operation and feedback from the classroom teacher; in the Solution Review phase, the students checked the total functioning of the results of the IoT activities and received feedback from the classroom teacher; in the problem understanding phase, the students collected information about the project problem by accessing the bibliographic database, to then represent it in mental maps; finally, in the improvement of the skill of Preparation of the Plan, there is a smaller number of students, this result was possibly due to their condition as beginner students, because they showed difficulties in proposing alternative solutions, because they are topics technicians, who are just beginning to know the operation of electronic devices and block-based programming. After classroom interventions with IoT activities and block-based programming, students will be prepared to use advanced technologies and develop more complex projects utilizing code-based programming languages and IoT devices applied to sectors such as agriculture and beyond [84-86].

During the application of the educational strategy through the use of the 4-phase problem-solving method, technological resources, and block programming environment, the teacher plays an important role in the classroom, so he must supervise and provide constant feedback; Because otherwise the strengthening of students' problem-solving skills would not be achieved; Even more so would be counterproductive, because most students are interacting with electronic devices and programming tools for the first time; If constant monitoring is not carried out in the development of classroom activities, students could distance themselves and show disinterest in the development of their projects in the classroom.

6. CONCLUSIONS

Problem-solving is a crucial skill that individuals need throughout their lives. Acquiring this ability early—starting in college, or even in basic education—equips students to face the challenges they will encounter in academic settings, daily activities, research, and more. Developing this skill allows students to build self-confidence and cultivate self-directed learning capabilities, such as effective time management, leveraging personal experiences, and voluntarily finding ways to address various problems. Problem-solving not only sharpens cognitive abilities but also fosters behaviors like driving innovation and staying competitive in the rapidly evolving landscape of the 21st century. Additionally, it enables individuals to critically assess solutions by applying their knowledge.

When integrating IoT activities into university classrooms, it is essential to instill science, technology, engineering, and mathematics (STEM) practices that encompass conceptual knowledge, epistemic practices, and social norms. For instance, classroom interventions have shown that executing IoT activities requires students to understand limitations, design optimal solutions for specific contexts, and even build prototypes to apply in their communities. This approach boosts students' confidence, helping them realize they can contribute to solving real-world problems in their community or city. Moreover, these activities foster cooperation and teamwork, with students demonstrating improved communication skills, interpersonal harmony, and collaboration during classroom exercises.

The use of technological resources, such as the Arduino board, WiFi module, BME680 sensor, and mBlock, during classroom activities further strengthened the integration of science, technology, engineering, and mathematics (STEM) disciplines among students. These tools enabled students to create innovative solutions by involving research into the problem, utilizing electronic devices and programming environments, performing steps for engineering tasks, and applying mathematical calculations in the design of solutions. This combination of activities helped to enhance and solidify students' skills, fostering a positive attitude towards technological research and development, which are foundational pillars for engineering students.

In terms of problem-solving skills, students demonstrated significant improvement across all areas. The largest gains were seen in the Implementation of the plan skill, followed by Solution Review, Understanding the Problem, and finally, Preparation of the Plan.

This research was conducted in a university setting, with the participation of industrial engineering students at a public university in Peru. However, this approach can be adapted for students in other fields, such as education, humanities, health, environmental studies, and more. It is recommended for use in general studies courses such as formative research, ICT, university work methods, information management, algorithms, and experimental methods.

The study's limitations include the sample size, which consisted of industrial engineering students, many of whom were students of one of the authors, allowing for the execution of the study over a single academic cycle. Additionally, the use of a single sensor—capable of measuring multiple environmental parameters—may have limited the scope of the research.

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