VISUAL REVIEW | Vol. 17, No. 1, 2025 | ISSN 2695-9631
International Visual Culture Review / Revista Internacional de Cultura Visual
https://doi.org// .,40/4/-pct tgqs_j,t /7,3373

VISUAL PROGRAMMING AND PROBLEM-SOLVING TO FOSTER A POSITIVE ATTITUDE TOWARDS FORMATIVE RESEARCH

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KEYWORDS

Visual programming
Formative research
Engineering students
Problem-solving
Technological resources
Attitude towards research

ABSTRACT

The purpose of this article is to explore the use of visual programming alongside a problem-solving approach to foster a positive attitude towards formative research among engineering students at the beginning of their university studies. Classroom research activities were structured according to the four stages of the problem-solving method. These activities were carried out using an Arduino board, various sensors, and a visual programming environment. The results indicate that most students perceive their attitude towards formative research as high or very high.

Received: 03/ 10 / 2024
Accepted: 06/ 11 / 2024

1. Introduction

A mere 2.23% of university students in their final semesters elect to undertake a research project as part of their degree programme. This figure reflects the continued use of inadequate research methods in the development of research skills within the university classroom. This situation is particularly concerning in the context of engineering, where research competencies are crucial for the creation and development of innovative solutions to social problems. It is therefore crucial to implement didactic strategies that encourage formative research from the outset of university studies, with a view to addressing the needs of the wider community.

Formative research represents a pedagogical approach that integrates teaching and research, utilising the latter as an educational instrument for students to enhance and expand their knowledge base. This form of research is based on the pedagogical constructivist approach, which encourages the development of learning, research culture and reflection on the research process. Furthermore, formative research serves as a conduit for integrating the curriculum with pedagogical practice, employing a range of classroom strategies.

The combination of effective pedagogical approaches with educational technologies has the potential to enhance problem-solving abilities and competencies within the university context, particularly amongst students at an early stage of their studies. This approach has the capacity to foster creativity, inquiry and innovation, rather than feelings of frustration and discouragement amongst students. It is of the utmost importance to implement an age-appropriate curriculum and technologies. For instance, the incorporation of well-designed and integrated coding tasks within a collaborative, problem-based and/or thematic curriculum can facilitate and encourage inquiry-based learning experiences among students in higher education, including those in vocational colleges and universities.

Recent research has demonstrated the efficacy of interventions utilising educational electronic boards in the training of early-career engineering students. The utilisation of microcontrollers, programmable toys, educational robots and Arduino boards, in conjunction with block-based programming, has facilitated an expansion of the teaching approach in the classroom. The results of the authors' research demonstrate that these teaching and learning methods, in addition to enhancing practical and technical proficiency, also facilitate the development of academic and research skills in students.

1.1 Formative Research

Formative research is based on teaching methods and practices that have been tried and tested by institutions and university professors and which have demonstrated a certain effectiveness in the context of the pedagogical function of research. In order to meet this challenge, it is essential to implement a comprehensive and collaborative approach across all professional pathways, engaging teachers and students in a unified educational model within the university. (Lapa-Asto et al., 2019). Furthermore, the reading and writing practices employed during the review of scientific materials assist engineering students in the preparation of papers that adhere to scientific criteria and are suitable for submission to indexed journals (Alvarado et al., 2019). (Alvarado et al., 2020).

It is asserted by numerous authors that formative research, integrated into the teaching function, pursues a pedagogical objective and is conducted within a previously defined curricular framework. This type of research is distinguished by two key characteristics: it is conducted and supervised by a teacher in their capacity as an educator, and the participants are typically novices in research or those embarking on their initial research endeavours. Furthermore, the necessity of implementing a methodological approach, coupled with scientific assessment and continuous feedback, to cultivate fundamental research competencies in novice university students is underscored. (Llulluy-Nuñez et al., 2021; Zúñiga-Cueva et al., 2021).

Formative enquiry can be conceptualised as pedagogical approaches rooted in productive methodologies that focus on the learner as the architect of their own cognitive schema. This facilitates deep understanding through exploration and cultivates in students a favourable disposition towards learning and argumentation of the situation. Furthermore, it implements an educational framework centred on enquiry and scepticism, while fostering proficiency in conducting research. (Espinoza, 2020).

1.2. Attitude Towards Research

The curricula of engineering programmes at the university level demonstrate a growing interest in research, evidenced by an increase in the number of subjects dedicated to this field. Furthermore, the profiles of both teachers, who possess research competencies, and graduates, who have research-oriented skills, are noteworthy. These factors are reflected in the student's attitude upon completion of their professional training. Nevertheless, the cultivation of a positive disposition towards research is contingent upon the pedagogical approaches employed within the university classroom (Gálvez et al., 2019). The key agents responsible for fostering a positive disposition towards formative research are the instructor, who oversees and provides direction; the learners, who assume the role of researchers; and the curriculum, which serves as an abstract entity linking instructors and learners (Chacon, 2020).

The analysis of attitudes towards research, particularly within the context of scientific enquiry, is closely linked to the development of critical thinking. This in turn enhances students' capacity to actively generate knowledge, thereby driving research that is beneficial to their professional development. It is therefore crucial that students are integrated into research processes from the outset of their university career, as this approach will foster an attitude of enquiry and a commitment to research. (Cruz Tarrillo et al., 2021). In addition, the attitudes of students at the conclusion of their academic training are pivotal for social transformation, as they are linked to their inclination towards science and technology, which will enable them to gain knowledge that will facilitate societal advancement.

In regard to the instruments utilized for the assessment of attitudes towards research, the scientific literature presents a multitude of proposals (Rojas et al., 2012). One illustrative example is the instrument designed by Castro (2018), which is composed of five dimensions: satisfaction and liking for research, appropriation of concepts, learning behaviours, systematic exploration and perceived skills. The instrument has been validated and its reliability has been confirmed, thereby providing a robust foundation for ongoing enhancement and ensuring its efficacy as a measure of attitudes towards research during the university education phase.

1.3. Visual Programming Environment

The visual programming environment is currently attracting interest as a method of teaching and reinforcing programming skills, as well as computational concepts and practices, particularly among novice students in higher education, especially those with limited computer literacy. A number of studies have demonstrated that visual-based programmes are a prevalent methodology for the development of competencies in disciplines such as computer science, information and communication technology (ICT), computation and computational thinking. These programmes are designed to facilitate the creation of solutions to real-world problems (Weese, 2016). Currently, there are numerous popular educational tools, including Scratch, mBlock and AppInventor (Makeblock, 2022), which permit students to engage in activities such as developing scenarios pertaining to local issues, applying knowledge in mathematics, science, engineering and technology (Harangus & Kátai, 2020; Romero et al., 2017). Furthermore, some tools are designed to enhance platforms such as Scratch and mBlock. To illustrate, AppInventor enables students to construct applications for mobile platforms. Similarly, there are tools designed to assess the activities conducted within these programming environments. Dr. Scratch is one of the most prevalent tools utilized for this purpose (Romero et al., 2017).

In academic contexts, educational robotics and visual programming environments are widely used tools to enhance students' competencies from an early age. These tools have been shown to offer benefits in a range of areas, including mathematics, logic, gender equality, and collaboration among students. Additionally, they facilitate the development of computational concepts and practices, as well as problem-solving abilities (Berland & Wilensky, (2015; Daniela & Lytras, 2018; Fronza et al., 2019; Suárez et al., 2018). However, one of the limitations of the use of educational robots is their high cost, which presents a significant barrier to their acquisition for use in educational settings. Furthermore, a significant proportion of these robots are designed with the primary intention of being used by male students.

Currently, there are solutions based on customised hardware prototypes with block-based visual programming interfaces, including electronic devices (microcontrollers, sensors, actuators, among other components), with the aim of strengthening students' skills to solve latent community needs. These solutions are, for the most part, comparatively inexpensive in comparison to commercial options (Fronza et al., 2019).

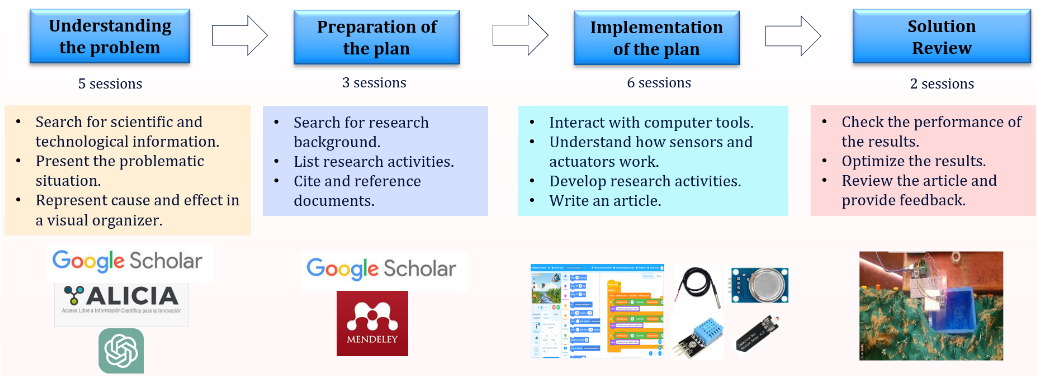
1.4. Problem-Solving Approach to Formative Research

In contrast to the problem-based learning (PBL) approach, there are multiple alternative methods for problem solving (Jeng et al., 2019; Kwon et al., 2021; Ubaidullah et al., 2021). Given the idiosyncratic nature of each problem, it is not possible to identify a single method that will invariably guarantee its resolution. Instead, a range of methods or approaches, comprising a set of steps, are proposed. Indeed, in any problem-solving process, four fundamental stages can be identified: problem statement, design of a plan, implementation of the plan and evaluation of the solution. These align with the proposal put forward by Polya (1945).

In recent years, a number of authors have conducted research into the potential of Pólya's problem-solving method as a tool for developing technological and scientific competencies among university students, particularly those pursuing engineering degrees. (Molina et al., 2020; Paucar-Curasma, Cerna-Ruiz, et al., 2023; Paucar-Curasma et al., 2022; Paucar-Curasma, Villalba-Condori, et al., 2023). These studies have considered the four stages of Pólya's approach, combined with technological tools such as Arduino, sensors, actuators and mBlock, and have demonstrated their efficacy as pedagogical strategies for addressing real-world problems. This approach enables students to enhance their analytical abilities and comprehension of problems, suggest alternative solutions, undertake tasks with the aid of technology, evaluate the outcomes achieved and, ultimately, translate their findings into a scientific and technological article as part of the classroom curriculum.

In light of the reviewed theory on formative research and the experience gained through research work in the classroom at the university level, it is proposed that Pólya's problem-solving method be employed, which is based on its four stages (Bordignon & Iglesias, 2018; Pólya, 1957). Together with a visual programming environment and electronic devices such as the Arduino Uno, actuators, sensors and the mBlock platform, it is proposed that these pedagogical tools be used to promote formative research in engineering students (Paucar-Curasma, Villalba-Condori, et al., 2023). This proposal is represented in Figure 1.

Figure 1. Problem-solving phases for the development of formative research



Source: Authors, 2024.

The proposed framework for the aforementioned figure is structured into four sequential parts, beginning with problem understanding, followed by plan development, plan implementation, and finally solution review. These are distributed across 16 sessions over an academic semester, during which investigative activities are carried out in the classroom under the teacher's guidance. Each stage involves the following activities:

Problem Understanding: This phase spans five sessions and requires students to undertake the following activities: search for scientific and technological information, identify the problem scenario, and represent cause and effect using a visual organizer.

Plan Development: This stage consists of three sessions, during which students perform tasks such as researching the background of the investigation, listing research activities, and properly citing and referencing documents.

Plan Implementation: Spanning six sessions, this phase includes activities such as engaging with visual programming (mBlock) and electronic devices (microcontroller, sensors, and actuators), understanding the functioning of sensors and actuators, conducting research activities, and drafting a scientific article based on the results obtained.

Solution Review: During the final two sessions, students verify the results' functionality, optimise the outcomes, and review the scientific article, focusing on feedback and improvements.

2. Research objectives

This study proposes an educational strategy based on a visual programming environment and the problem-solving method, aimed at fostering a positive attitude towards formative research among university students starting their systems engineering degrees in Peru. Classroom research activities will be conducted in accordance with the four stages of Pólya's method: "problem understanding, plan development, plan implementation, and solution review".

During each phase, students will carry out research activities under the teacher's guidance. Upon completing the classroom interventions, the levels of attitude towards formative research will be statistically evaluated. The evaluation will consider dimensions such as satisfaction and interest in research, appropriation of concepts and learning behaviours, systematic exploration, and perceived skills.

3. Methodology

3.1. Research Approach and Participants

This study employs a quasi-experimental design with a quantitative approach, utilising non-probability purposive sampling, and is based on the administration of pre- and post-intervention tests. The participants were students enrolled in the formative research course of the systems engineering degree programme at a public university in Peru. They were all in their first cycle and in their first semester of the 2024 academic year. The majority of the students are under the age of 21, with a total of six female and 28 male participants.

The instrument used to collect data on students' attitudes towards formative research is the one developed by Castro (2018). It comprises 25 items distributed across five dimensions: conceptual appropriation, perceived skills, learning behaviours, satisfaction and liking for research, and systematic exploration. The instrument has been validated and its reliability tested, thereby establishing it as a robust tool for continuous improvement and ensuring its utility in the assessment of attitudes towards formative research in university students. Furthermore, the internal consistency of the instrument was evaluated using Cronbach's alpha test, which yielded a value of ≥0.70 and adequate alpha values of ≥0.80. Table 1 presents the number of items and Cronbach's alpha reliability for each dimension of the instrument used to measure attitudes towards formative research.

Table 1. Instrument to measure attitude towards formative research

Dimensions of attitude towards formative research	Items	Cronbach's alpha
Satisfaction and enjoyment of the research	5	0,82
Conceptual ownership	4	0,83
Learning behaviours	4	0,80
Systematic exploration	5	0,71
Perceived skills	7	0,71

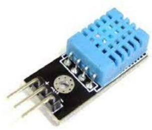
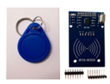
Source: Authors, 2024.

In order to ascertain the students' attitudes towards formative research, the instrument was administered at two distinct points in time: prior to and following the intervention (pre- and post-test), to a total of 34 students enrolled in the systems engineering course. The classroom intervention comprised the utilisation of technological resources and a problem-solving method based on four phases.

3.2. Research Topics and Technological Resources with Visual Programming Interface.

Table 2 delineates the research topics that have been proposed for investigation by the students in teams under the guidance of the teacher in the classroom. These topics are linked to tangible issues affecting the environment in which the students reside. Each research topic has been assigned a specific sensor to facilitate the research activities. For example, the group of students assigned the research topic with ID TI-1 will utilise the temperature sensor DTH11, in TI-2 they will employ the gas sensor MQ2, in TI-3 they will use the capacitive soil sensor, in TI-4 they will use the RFID module RC522, in TI-5 they will use the temperature sensor DS18B20 and in TI-6 they will use the ultrasound sensor HC-SR04; in addition to an Arduino board. To facilitate interaction with the electronic devices, a visual programming environment based on the mBlock platform will be employed. This software platform will enable students to readily develop graphical interfaces for monitoring purposes, in relation to the specific research topics assigned to each group.

Table 2. Research topics and electronic devices

ID	Research topic	Description	Sensor	Photo
TI-1	Humidity and temperature monitoring in the university's computer laboratory.	Students will use the DHT11 sensor to measure humidity and temperature in the computer lab. This initiative ensures that the conditions in the laboratories are optimal for conducting experiments and research activities.	Sensor DHT11	
TI-2	Monitoring of air pollution in a market located in the centre of Huancayo.	Students will carry out air pollution monitoring in the central market. For this activity, the MQ2 gas sensor will be used to measure and record air pollution levels. This initiative is essential to safeguard the health of citizens.	Gas sensor MQ2	
TI-3	Soil moisture control to improve the efficiency of maize cultivation in the Cochas district.	Students will have the ability to monitor soil moisture control in agricultural maize fields through the use of a capacitive soil moisture sensor. This tool will facilitate crop-specific moisture monitoring, allowing farmers to implement appropriate measures to optimise maize production.	Capacitive soil moisture sensor	
TI-4	Access security monitoring in a company library	Students will carry out security monitoring in a company library, ensuring that access is restricted to authorised persons only. The main objective of this activity is to safeguard the integrity of the resources and documents stored there.	RFID module RC522	
TI-5	Water temperature monitoring at Ingenio fish farm	The students will monitor the water temperature in the fish farm with the aim of preventing stress in the trout. To do this, they will use the DS18B20 temperature sensor, which will allow continuous monitoring of the water temperature, ensuring that it remains within the optimal range for the health of these fish.	Temperature sensor DS18B20	
TI-6	Water level monitoring in the Paca lagoon, located in the province of Jauja.	Students will use the ultrasonic sensor to develop a water level monitoring system. The HC-SR04 sensor will be used, which will allow continuous monitoring of the water level.	Sensor ultrasound HC-SR04	

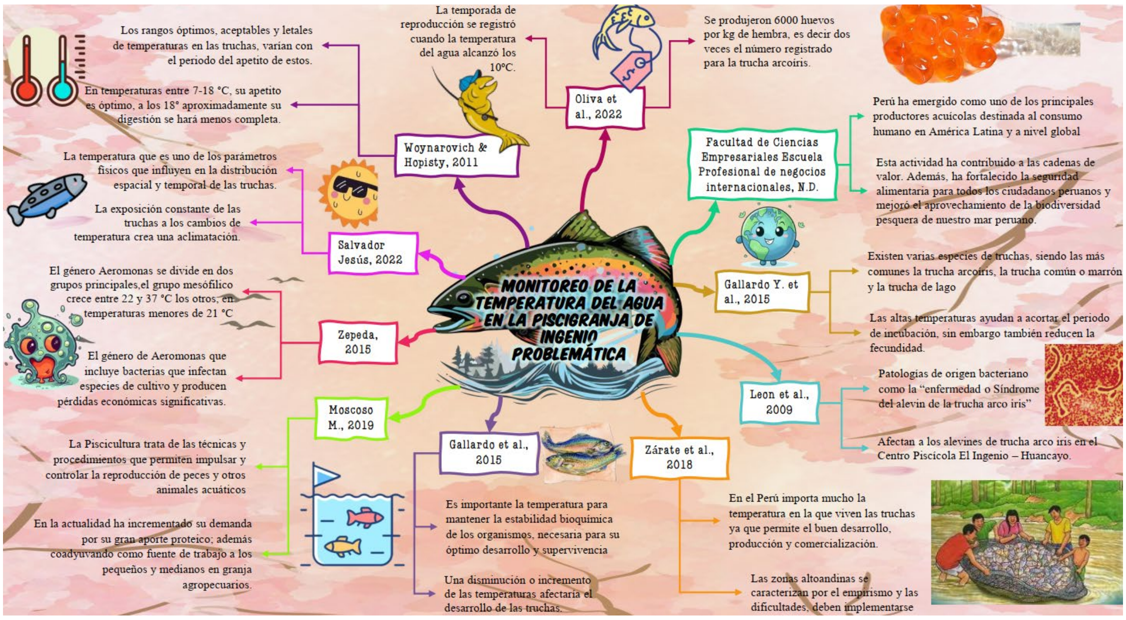
Source: Authors, 2024.

3.3. Development of Classroom Research Activities

The research activities were conducted over the course of the first academic semester of the year 2024, spanning a period of 16 weeks. These activities, conducted within the classroom setting and under the continuous guidance and feedback of the instructor, were based on the problem-solving methodology, comprising four distinct phases: firstly, the comprehension of the problem; secondly, the formulation and implementation of a plan of action; and finally, the evaluation of the solution. The activities developed by the students within this methodological framework are presented below.

a) In the phase of understanding the problem, a variety of activities were conducted with the objective of investigating the problem posed. A comprehensive search for information was conducted using reputable scientific sources, including Scopus, Google Scholar, SciELO and Redalyc. Subsequently, the information collected was subjected to analysis and synthesis in order to formulate the problematic situation pertaining to the proposed activity. Furthermore, a visual organiser was devised to facilitate the graphical representation of cause and effect, thereby enhancing the coherence and comprehension of the subject matter. Figure 2 depicts the cause-and-effect graphic representation of the research project entitled "Monitoring of water temperature in the Ingenio fish farm".

Figure 2. Graphical representation of the cause-effect of the problems identified.



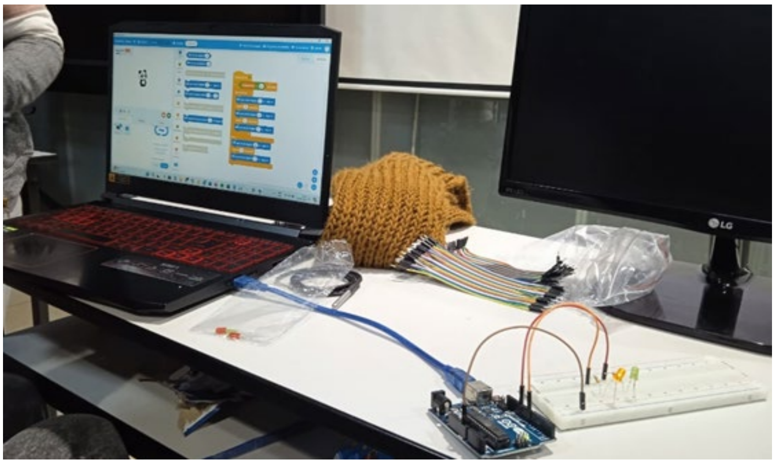
Source: Authors, 2024.

b) During the activity planning phase, a number of actions were undertaken with the objective of collecting relevant information pertaining to previous research on the topic under consideration. Following the collation of background information, an analysis was conducted to identify comparable activities, which in turn enabled the formulation of a list of specific activities (objectives). The proposed activities, which relate to the research topic "Water temperature monitoring in the Ingenio fish farm", are presented below.

- Formulate the problem related to trout farming based on water temperature.
- Research background information and previous models for guidance.
- Develop the first prototype using the DS18B20 water sensor and Arduino Uno board.
- Create the initial programming design using the mBlock application.
- Review and correct the prototype using mBlock programming.
- Review and refine the programming using the mBlock application.
- Review and finalise the prototype and programming in mBlock.
- Construct a model inspired by the research topic.
- Draft a scientific article.

c) During the implementation phase of the plan, the students employed a range of electronic devices to gain an understanding of the functioning of sensors and actuators. In this context, the students proceeded with the previously planned activities, developing a graphical interface in the visual programming environment mBlock. Furthermore, they delineated the context of the problem and commenced drafting the article, utilising the information available up to that juncture. Figure 3 depicts the electronic devices utilized during the execution of the classroom activities. The devices employed were: The following electronic devices were employed in the research entitled "Monitoring water temperature in the Ingenio fish farm": Arduino Uno, DS18B20 (water temperature sensor) and mBlock programming environment".

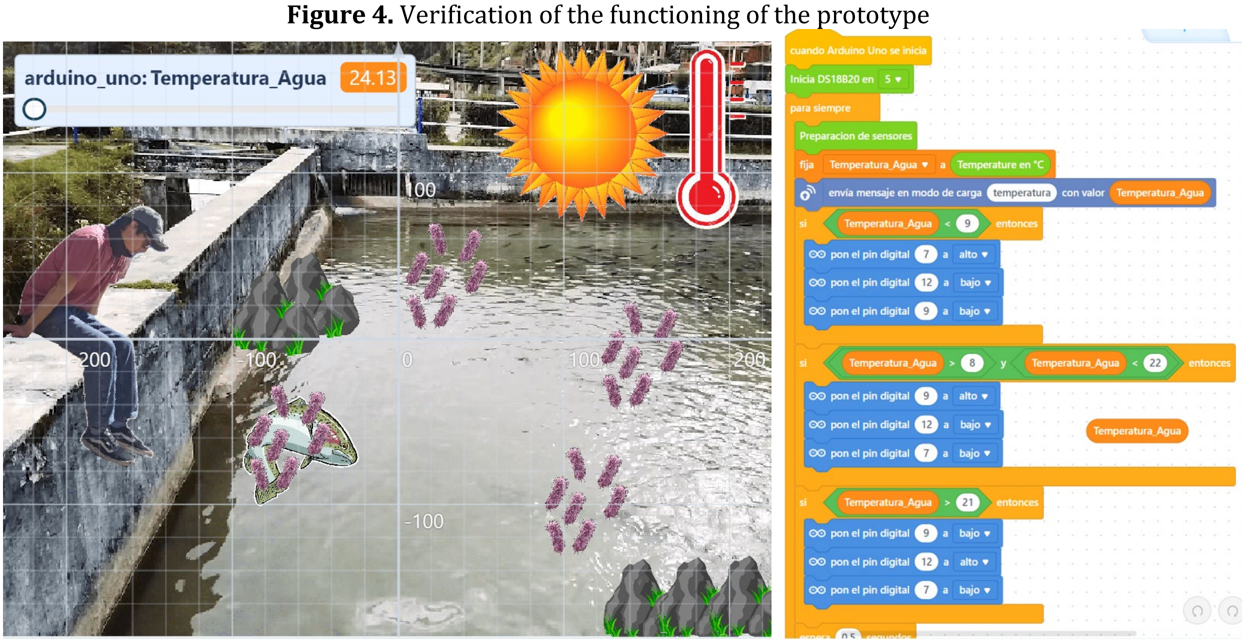
Figure 3. Use of electronic devices and mBlock visual programming environment



Source: Authors, 2024.

d) During the final solution review phase, the students conducted comprehensive checks of the results of their investigations, focusing on the proper functioning of the various components, including sensors and the graphical interface. Furthermore, the students evaluated the integration of these elements within a mock-up, thereby simulating the corresponding physical scenario. This phase involved the optimisation of the results through feedback provided by the instructor, who also supervised the completion of the academic paper. Figure 4 depicts the verification of the prototype's functionality, encompassing both the electronic components and the monitoring interface developed in mBlock.

Figure 4. Verification of the functioning of the prototype



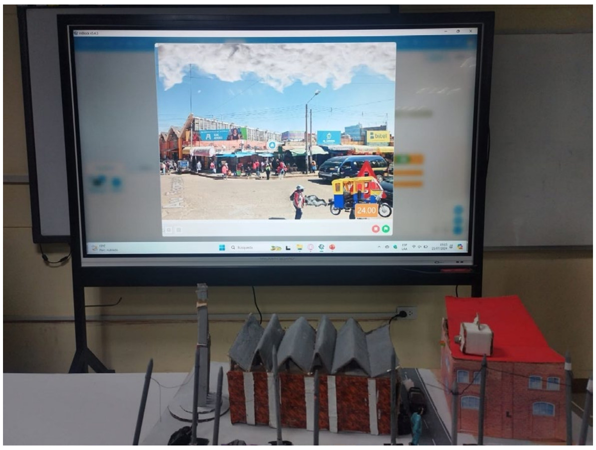
Source: Authors, 2024.

Figure 5 depicts the photographic documentation of the research activities conducted within the classroom setting during the 2024-I academic semester. The resulting prototypes encompass the integration of hardware and software components, collectively developed by six student-formed groups. The hardware component comprises an electrical circuit that integrates an Arduino board and a variety of sensors, including those for measuring environmental humidity and temperature, water temperature, soil humidity, radio frequency identification (RFID), ultrasound, and gas. In contrast, the software component is distinguished by a user-friendly graphical interface, designed in the mBlock visual programming environment, which enables the monitoring of the parameters collected by the sensors.

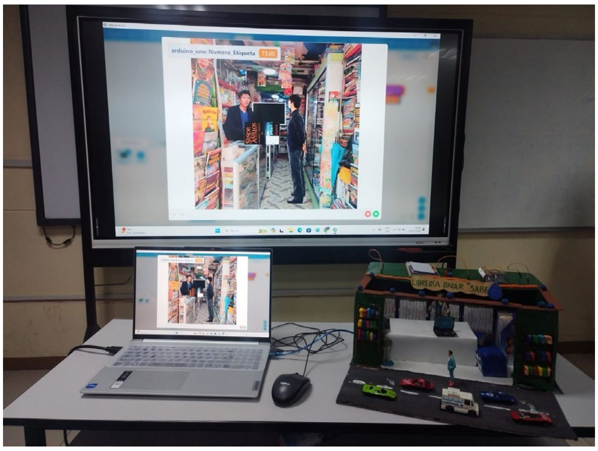
Figure 5. Prototypes developed within the research themes


TI-5


TI-3


TI-2


TI-1


TI-4


TI-6

Source: Authors, 2024.

4. Results

4.1. Analysis of Descriptive Statistics on Dimensions of Attitude Towards Formative Research

Table 3 presents a summary of the statistical data, including the mean, median and standard deviation, for the dimensions related to attitude towards formative research in newly enrolled systems engineering students.

Table 3. Summary Statistical Analysis

Dimensions	Mean		Median		Standard Deviation	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
Satisfaction and enjoyment of the research	3.53	3.82	3.00	4.00	0.788	0.716
Conceptual ownership	3.44	4.12	3.50	4.00	0.613	0.591
Learning behaviour	4.00	4.06	4.00	4.00	0.603	0.489
Systematic exploration	3.53	4.24	3.00	4.00	0.896	0.654
Perceived skills	3.15	3.88	3.00	4.00	0.500	0.537

Source: Authors, 2024.

The results of the assessment, as demonstrated in the table above, indicate a positive impact of the intervention on all dimensions, as evidenced by the increase in means and medians. In the majority of cases, the reduction in standard deviation indicates a greater uniformity of responses at the post-test stage.

4.2. Normality test Collected Data.

The statistical analysis commenced with a normality test of the collected data, utilising the Shapiro-Wilks test given that the dataset comprised fewer than 50 observations. Table 4 presents the p-values for the pre-test and post-test evaluations of students' attitudes towards formative research.

Table 4. Shapiro-Wilks Normality Test

	Pre-test	Post-test
N	34	34
Shapiro-Wilk W	0.954	0.941
Shapiro-Wilk p-value	0.160	0.065

Source: Authors, 2024.

As illustrated in the table above, the p-values obtained are 0.160 for the pre-test and 0.065 for the post-test. Both values exceed the significance level (0.05), thereby indicating that the pre- and post-test data follow a normal distribution.

4.3. General Hypothesis Test on Students' Attitudes Towards Formative Research

As the pre-test and post-test scores are distributed normally, a paired-sample Student's t-test was employed to assess the following hypothesis: "The utilisation of the problem-solving method and visual programming environments engenders positive attitudes towards formative research in systems engineering students."

Table 5 illustrates the outcomes of the hypothesis test for the various dimensions of attitudes towards formative research.

Table 5. Hypothesis test with t student

Hypothesis		
H0 = ""The use of the problem-solving method and visual programming environments does not promote positive attitudes towards formative research in systems engineering students".		
H1 = "The use of the problem-solving method and visual programming environments promote positive attitudes towards formative research in systems engineering students".		
Significance: 5%. **Decision**: p >= 5% H0 is not rejected; p < 5% H0 is rejected.		
Dimensions	**Student's t p-value**	**Decision**
Satisfaction and enjoyment of the research	0.035	The null hypothesis (H0) is rejected.
Conceptual ownership	0.001	The null hypothesis (H0) is rejected.
Learning behaviour	0.001	The null hypothesis (H0) is rejected.
Systematic exploration	0.001	The null hypothesis (H0) is rejected.
Perceived skills	0.001	The null hypothesis (H0) is rejected.

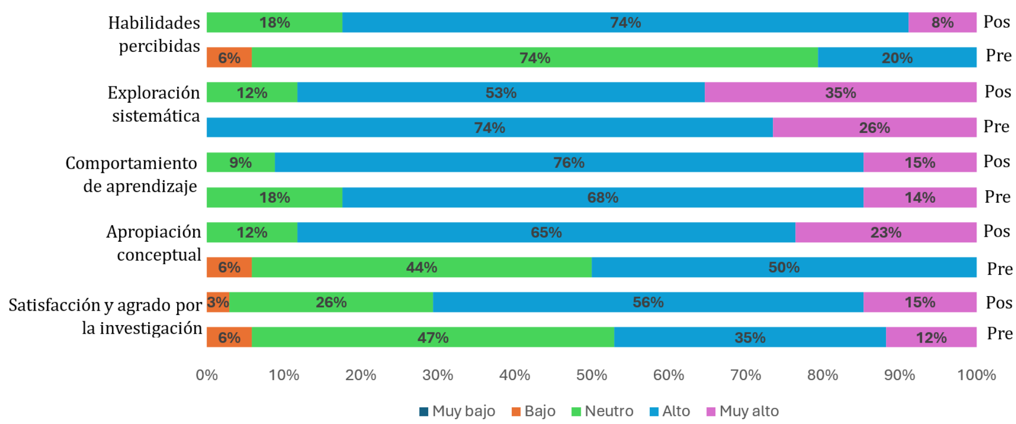
Source: Authors, 2024.

In all the dimensions evaluated, the p-values obtained are less than the 5% significance level, which leads to the rejection of the null hypothesis in each case. This indicates that, according to the data analysed, the use of the problem-solving method and the visual programming environment effectively promote a positive attitude towards formative research in systems engineering students, covering all the dimensions evaluated (conceptual appropriation, perceived skills, learning behaviours, satisfaction and liking for research, and systematic exploration).

4.4. Student Attitudes Towards Formative Research

Figure 6 illustrates the perceptions of systems engineering students regarding the dimensions of attitude towards formative research. Significant improvements in all dimensions are observed after the intervention, compared to the pre-test. Regarding perceived skills, 74% of students report a high perception. For the systematic exploration dimension, 35% report a very high perception, and 53% a high perception. In the learning behaviour dimension, 76% of students indicate a high perception. For conceptual appropriation, 65% report a high perception, and 22% a very high perception. Finally, in the satisfaction and interest in research dimension, 56% of students express a high perception after the intervention. These results demonstrate significant progress in students' attitudes towards formative research.

Figure 6. Students' perception of their attitude towards formative research



Source: Authors, 2024.

5. Discussions

The rapid advancement of science and technology requires that a number of students at the university level be encouraged to cultivate a positive attitude towards scientific research and technological development from the outset of their professional careers. It is of great importance to facilitate the active involvement of young people in scientific and technological research during their academic and professional training. The term 'attitude' conceived as a behaviour that combines psychological and social factors, has been studied in various disciplines, highlighting its importance in education and its impact on students' performance in different activities.

At present, numerous Latin American countries employ a variety of pedagogical techniques to cultivate research competencies in their students. However, some of these methods prove ineffective for those who have recently commenced their higher education studies (De Cruz Casaño, 2016; Rojas-Betancur & Méndez-Villamizar, 2013). (De la Cruz Casaño, 2016; Rojas-Betancur & Méndez-Villamizar, 2013). Nevertheless, scientific research indicates that specific approaches, such as problem- and project-based learning, are conducive to fostering positive attitudes towards inquiry (Fernández & Duarte, 2013; Pinto & Cortés, 2017). This study demonstrates that the integration of visual programming environments and electronic devices with the problem-solving approach enhances the research attitude of systems engineering students. The assessment of this attitude was based on dimensions such as satisfaction, concept appropriation, learning behaviours, methodical exploration and perceived skills (Blanco & Alvarado, 2005; Rojas et al., 2012). These findings emphasise the importance of active participation in research activities for its development.

The dimension of satisfaction and liking for research can be defined as the positive emotions and feelings that university students acquire towards formative research, as manifested in their moods and expectations (Rojas et al., 2012). Following the classroom intervention, which incorporated the four-phase problem-solving method, visual programming with mBlock, and electronic devices such as the Arduino board, sensors and actuators, it was determined that 56% of the students exhibited a high level of satisfaction, while 15% considered it to be very high. These findings suggest a notable level of satisfaction, which can be attributed to the utilisation of technological tools and the provision of effective guidance throughout the research process. This approach enabled a deeper comprehension of the concepts and their practical realisation in addressing societal challenges (Acosta-Corporan et al., 2022).

The term “conceptual ownership in research” is used to describe the management of beliefs, thoughts, knowledge and processes related to formative enquiry (Rojas et al., 2012). Following the development of the classroom activities, which employed a four-phase problem-solving method and made use of the mBlock visual programming environment and electronic devices, it was found that 65% of the students exhibited a high level of perception in this dimension, while 22% reported a very high level of perception. These findings demonstrate a notable degree of conceptual appropriation, indicating the beneficial influence of the research activities on the cognitive disposition towards formative research. This finding is consistent with the results of previous studies conducted at Peruvian and international universities (Cruz Tarrillo et al., 2006).

The dimension of learning behaviours can be defined as the inclination of students to engage in a range of activities in a premeditated manner, with the objective of acquiring knowledge and skills that reinforce the process of formative research. (Rojas et al., 2012). Following the intervention, 76% of students rated this dimension highly, indicating a notable advancement in their learning behaviours. These results can be attributed to the strategy implemented in the classroom, which integrated electronic devices and visual programming with mBlock to address contextualised problems for students. There is a substantial body of evidence from previous studies that this type of educational methodology increases students' motivation and encourages them to overcome new challenges (Paucar-Curasma, Villalba-Condori, et al., 2023).

The capacity for systematic exploration is reflected in an individual's ability to investigate and evaluate situations, analysing their causes, effects and consequences. This involves activities such as planning and organising ideas (Rojas et al., 2012). Following the intervention, it was observed that 35% of students rated this dimension highly, while 53% rated it very highly. These results can be attributed to the investigative activities conducted during the comprehension stage, wherein students identified the problematic situation and established cause-and-effect relationships. In this phase, the authors posit that relevant scientific information is collected to address the problem, utilising technological resources (Molina et al., 2020; Paucar-Curasma, Cerna-Ruiz, et al., 2023).

The dimension of perceived skills refers to the self-perception of university students regarding their own competencies, whether cognitive, metacognitive, psychomotor or socio-affective, within the context of formative research. (Rojas et al., 2012). Following the intervention, the results demonstrate that 74% of students exhibit a high level of perception in this dimension. This is attributed to the skills acquired through investigative activities based on the four phases or steps of the problem-solving method and the visual environment for programme development. These activities, focused on problem-solving in the students' everyday environment, address areas such as agriculture, animal husbandry, aquaculture and the environment, fostering skills such as critical and computational thinking, among others. (Karmawan & Djamilah, 2024; Neo et al., 2021; Pluhár & Torma, 2019).

6. Conclusions

The implementation of the problem-solving method, which covers the understanding of the problem, followed by the elaboration and implementation of the plan and finally by the revision of the solution, together with the visual programming environment mBlock and the use of electronic devices such as Arduino boards, sensors and actuators, has demonstrated that the attitude of systems engineering students towards research is highly positive. The results indicate that the educational proposal is suitable and effective for implementation in formative research courses at universities in Peru.

Despite the inclusion of formative research courses in engineering degree programmes at most universities, both nationally and internationally, the various strategies employed by lecturers, which encompass both qualitative and quantitative approaches, have not always succeeded in fostering a positive attitude towards research among students. It is therefore essential to implement more appropriate methods that integrate electronic devices, the use of visual programming such as mBlock and the four-phase problem-solving method. These strategies are aligned with the fundamental principles of engineering, which are concerned with the resolution of societal issues.

The attitudes of students towards formative enquiry are markedly shaped by the implementation of systematic interventions at each stage of the problem-solving process. In the comprehension phase, students investigate scientific data, formulate hypotheses and construct visual organisers to identify causal relationships. Subsequently, during the planning phase, students engage in background research, record activities and manage appointments. During the execution phase, students engage with electronic devices, utilise visual programming tools and compose a scientific article. Finally, in the review phase, the students analyse the results, make any necessary adjustments to their writing and optimise the created prototypes. The diverse range of classroom activities outlined above serve to cultivate a positive attitude towards research among students.

The visual programming environment plays an important role for students entering university. It facilitates conceptual learning, simplifying the understanding of fundamental concepts of programming and logic, which are essential for research. It fosters creativity, allowing students to experiment and create without the barriers of textual code, thereby promoting innovation in research projects. It develops collaborative skills, including group components, stimulating synergy between students and teamwork. It also stimulates critical thinking by solving problems in a visual way, thereby developing analytical and logical/critical thinking skills, which are essential for scientific research. The visual programming environment stimulates critical thinking by solving problems visually, thereby developing analytical and logical/critical thinking skills, which are essential for scientific research. Furthermore, it facilitates the adaptation of technology in various academic disciplines, allowing for the integration of technology in multiple areas of knowledge. It also provides a barrier-free introduction to programming, which allows students with no programming background to acquire digital competences, which are crucial in an increasingly technological world. Finally, it prepares students for future challenges by introducing them to programming from an early age, thus preparing them to face advanced technological challenges in their academic career.

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