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ICT Devices and STEM Education to Develop Problem-Solving Skills in Engineering Students

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ABSTRACT

Problem-solving is a crucial skill for engineering students, yet traditional instructional methods often fall short in effectively fostering it. This study proposes a STEM-integrated educational strategy that leverages Information and Communication Technology (ICT) tools and technology-based classroom projects to strengthen problem-solving skills in first-year systems engineering students. The methodology follows a quasi-experimental design with pre- and post-test evaluations conducted on 34 students from a public university in Peru. Projects were developed using Arduino-based hardware, sensors, and block-based programming (mBlock) to address real-world problems. Quantitative results show statistically significant improvements ($p < 0.05$) across all dimensions of problem-solving: understanding the problem, planning, implementation, and solution review. The most notable gains were observed in problem understanding and solution review. These findings underscore the effectiveness of STEM-integrated, ICT-supported interventions in developing problem-solving competencies, and have pedagogical implications for courses such as formative research, ICT, and project-based learning in engineering education.

1. INTRODUCTION

Problem-solving is an essential competency in engineering education and a key requirement for addressing real-world challenges [1, 2]. However, many first-year university students struggle to apply scientific and technological knowledge in practical contexts, largely due to the predominance of traditional teaching methods that limit interdisciplinary learning and the use of active methodologies [3, 4]. This gap is especially evident in public universities in Latin America, where access to integrative approaches such as STEM education and affordable technological resources remains limited [5].

STEM education has gained global recognition for its potential to foster critical thinking, collaboration, and innovation [6, 7]. However, many studies address STEM disciplines separately, without promoting interdisciplinary approaches that reflect the complexity of real-world problems [8, 9]. Moreover, there is limited empirical evidence on the application of integrative technological projects in early university courses, particularly in engineering programs in low-resource contexts [10]. These limitations highlight the need for innovative educational strategies that combine STEM integration, ICT use, and action-based methodologies to develop problem-solving skills from the outset of university education [11, 12].

This study addresses this research gap by proposing and evaluating an educational strategy that integrates STEM disciplines through the execution of technological projects using ICT tools. Its objective is to strengthen problem-solving skills in first-year systems engineering students. The proposal incorporates a novel methodology that combines block-based programming (mBlock), Arduino boards, and collaborative project development focused on real-world problems contextualized to the students' local environment [13]. This innovation stands out for its accessibility, replicability, and alignment with constructivist and experiential learning principles [14].

The main contributions of this research are both theoretical and practical. Theoretically, it reinforces the connection between STEM integration and the development of problem-solving skills, providing evidence of the effectiveness of ICT-mediated strategies [15, 16]. Practically, it offers a scalable model for designing educational interventions in engineering, applicable even in resource-constrained contexts. Additionally, it introduces a methodological innovation by applying a validated instrument—based on Pólya's problem-solving model—to measure skill development through STEM-based classroom activities.

2. RELATED WORK

2.1 STEM education or integration of STEM areas

The primary goal of education is to empower individuals to use knowledge to improve their lives. Yet, many graduates face challenges in applying academic knowledge to real-life contexts, often lacking the scientific and technological perspective needed for problem-solving in society [4]. In response, several scholars advocate for the integration of science, technology, engineering, and mathematics (STEM), an approach gaining momentum across educational levels [17].

STEM education aims to develop students' competencies to address societal issues by merging critical thinking, technological skills, and mathematical reasoning [18, 19]. Strengthening these skills from early stages enhances students' analytical abilities and enables them to actively contribute to community-based problem-solving [20].

The acronym STEM encompasses the following disciplines: Science (S), which involves the study of the natural world through observation, experimentation, and analysis [21]; Technology (T), which pertains to the use of tools, software, and technological processes to solve problems and enhance everyday life, including fields such as computing, software development, and electronic devices [22]; Engineering (E), which focuses on the design, construction, and maintenance of structures, systems, and products, applying methods to create efficient solutions [21]; and Mathematics (M), which studies numbers, shapes, and patterns, providing the language and tools for quantification, modeling, and problem-solving in the other STEM areas.

Rather than treating each discipline in isolation, STEM education promotes interdisciplinary learning and the meaningful integration of knowledge and skills. It is characterized as a student-centered approach that emphasizes teamwork and context-based learning across all levels of education [23]. However, integration should remain purposeful—more integration does not always lead to better outcomes unless it addresses real-world challenges effectively [24].

STEM is closely linked to problem-based and project-based learning methodologies, where students tackle authentic problems using technological tools like software, hardware, and digital platforms. This enables them to act as problem solvers, innovators, and logical thinkers while fostering technological literacy and self-sufficiency [25].

Globally, STEM education is seen as both an economic imperative—to train future professionals in a tech-driven world—and a moral imperative—to prepare citizens capable of addressing social, environmental, and climate challenges [7].

2.2 Problem solving and STEM education

Problem-solving is a fundamental intellectual skill that enables individuals to apply knowledge, reason strategically, and adapt to dynamic challenges [26, 27]. Beyond enhancing cognitive development, it cultivates critical thinking, metacognitive awareness, and a productive mindset, essential for innovation and adaptability in a changing world [1, 28]. In STEM contexts, problem-solving goes beyond trial and error, engaging students in analytical tasks that demand procedural fluency, strategic planning, and the application of scientific and technological knowledge [15, 16].

STEM education promotes this skill through active methodologies such as project-based and problem-based learning, which immerse students in real-world problems and interdisciplinary collaboration [11, 12]. These approaches emphasize teamwork, data analysis, prototype creation, and iterative testing—practices essential to science and engineering [29]. Effective integration of STEM areas enables students not only to reason scientifically and mathematically but also to design, build, and evaluate technological solutions within defined constraints [30]. The importance of STEM education lies in its ability to expose students to real-life problems and promote the integration of multiple disciplines in addressing these challenges.

A central framework applied in this study is Pólya's four-phase problem-solving model:
(1) understanding the problem,
(2) devising a plan,
(3) carrying out the plan,
(4) reviewing the solution.

This model provides a structured path to integrate STEM learning with real-world application [2, 31]. Our research builds on this model but extends it by incorporating low-cost ICT tools (e.g., sensors, block-based programming) in collaborative student projects tied to local community problems. For example, in the "understanding" phase, students explored scientific concepts and causal relationships. In the "planning" phase, they proposed alternative technical solutions. During "implementation," they developed algorithms and created prototypes using electronics and programming. Finally, in the "review" phase, they tested and validated solutions, reinforcing engineering and evaluation skills.

This study differs from prior work by explicitly linking each phase of the Pólya model to specific STEM competencies and by applying this integration in underserved university contexts. Figure 1 illustrates this interdisciplinary mapping, showcasing how STEM domains support problem-solving skill development.

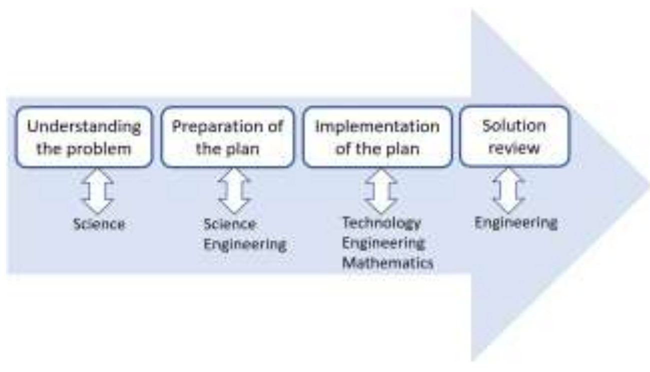


Figure 1. Problem-solving skills and STEM areas

2.3 ICT devices for teaching and learning in the classroom

Information and Communication Technology (ICT) encompasses hardware and software tools that, when integrated into education, enhance teaching and learning through interactivity and collaboration [32]. In the context of

STEM education, ICT plays a key role in the "T" dimension by promoting digital literacy, algorithmic thinking, and innovation.

Numerous studies demonstrate how low-cost ICT tools such as Arduino boards and mBlock environments support the development of problem-solving and programming skills. For instance, Curasma et al. [33] applied Arduino UNO, MQ135 sensors, and mBlock programming to develop student projects addressing environmental issues like indoor air pollution. Similarly, Paucar-Curasma [34] used these platforms in a university context to strengthen students' computational thinking through interactive narratives and simulations programmed in mBlock, integrating science concepts and sensor data visualization.

These tools help students connect STEM theory with hands-on application. Using components such as LEDs, buzzers, temperature sensors, and microcontrollers, students design prototypes that respond to real-life problems. The active use of block-based programming fosters creativity and inclusiveness, especially for those new to coding [13].

The integration of ICT in project-based learning not only enhances technical competence but also encourages teamwork, critical thinking, and social responsibility. When properly guided, students evolve from consumers of digital content to creators of technological solutions relevant to their communities [35, 36]. Therefore, it is essential to promote the use of technological resources from the early stages of higher education in order to foster a technological mindset in students. This approach equips them with robust knowledge and skills for developing interdisciplinary STEM projects that require critical thinking, problem-solving, creativity, and innovation.

Therefore, promoting the use of technological tools such as Arduino and mBlock from early stages of higher education is crucial for fostering a technological mindset. This approach enables students to develop interdisciplinary STEM competencies, supporting innovation and sustainability in real-world contexts [37-39].

3. METHODOLOGY

3.1 Research approach and participants

This study employed a quasi-experimental design with pretest and posttest measurements, framed within a quantitative approach. The participants were students enrolled in the formative research course during the first semester of the systems engineering program at a public university located in the Andean region of Peru. The course lasted 16 weeks, with 4-hour weekly sessions, and was aligned with the pedagogical objectives of enhancing problem-solving skills, computational thinking, and the development of technological competencies from the early stages of the academic cycle. Notably, some of the study's co-authors also served as instructors for the course. The sample consisted of 34 university students, including 28 men and 6 women, reflecting a representative enrollment distribution in the program—particularly in rural contexts where the gender gap in STEM fields remains significant [40]. Although the imbalance in group size may limit some comparative analyses, all available participants were included in the study. The average age of the students was 18 years.

The instrument used to collect data on problem-solving skills corresponds to Paucar-Curasma [41] and consists of 24 items divided into 4 dimensions: understanding the problem, elaboration of the plan, execution of the plan, and review of the solution. The problem understanding dimension is made up of 7 items, the plan elaboration dimension of 5 items, the plan execution dimension of 5 items, and the solution review dimension of 7 items. Each item is rated using a Likert scale, where 1 is "never," 2 is "almost never," 3 is "sometimes," 4 is "almost always," and 5 is "always." The instrument was validated by 3 international experts: 1 education expert, 1 computer science expert, and 1 computer engineering expert; internal consistency was also determined using Cronbach's alpha test. The tests were conducted three times in 2020, 2021, and 2022, obtaining 0.957, 0.965, and 0.924, respectively.

In our study, data collection on problem-solving skills was carried out by applying the instrument in two pre- and post-test times to a total of 34 students of the systems engineering degree; The pre-test was applied before the classroom intervention (STEM integration and the use of ICT devices in the execution of classroom projects) and the post-test after the intervention. Table 1 shows the items of the instrument to measure problem-solving skills and the results of the Cronbach alpha test.

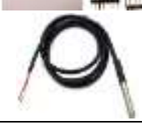
Table 1. Instrument to measure problem-solving skills

Problem-Solving Skills	Items	Cronbach's Alpha	
		Pre	Pos
Understanding the problem	7	0.875	0.930
Preparation of the plan	5		
Implementation of the plan	5		
Solution review	7		

3.2 Proposal for technological projects and ICT devices

Table 2 presents the technological projects proposed for group development by Systems Engineering students. Each project was designed to address real-world problems relevant to the students' local context, thereby promoting a contextualized approach to formative research. Each group was assigned a specific sensor to carry out their investigative activities, including the DHT11 temperature and humidity sensor, MQ2 gas sensor, capacitive soil moisture sensor, RFID RC522 module, DS18B20 temperature sensor, and HC-SR04 ultrasonic sensor.

Table 2. Technological projects and ICT devices

Technological Projects	Sensor Used	Photo
Environmental monitoring of humidity and temperature in the university computer lab	DHT11 digital temperature and humidity sensor	
Assessment of air pollution levels near the main market area in Huancayo	MQ2 gas detection sensor	
Automated soil moisture regulation system for corn cultivation in Cochas	Capacitive soil moisture sensor	
Implementation of secure access control in a commercial bookstore	RFID reader module RC522	
Water temperature monitoring system in a fish farming facility in Ingenio	DS18B20 waterproof temperature sensor	

Measurement of water levels in Paca Lagoon, Jauja province	Ultrasonic distance sensor HC-SR04	

All projects utilized an Arduino board as the hardware platform, along with the block-based programming environment mBlock. This environment was used to develop monitoring applications or interfaces to track key variables—such as temperature, humidity, air quality, soil moisture, and water temperature—associated with each technological project, enabling real-time data visualization and interpretation.

3.3 Methodological sequence for the development of technological projects through problem solving

The planning of classroom activities was structured around the four phases of Pólya's problem-solving method: understanding the problem, preparation of the plan, implementing of the plan, and reviewing the solution. These sessions were conducted over 16 academic weeks and progressively reinforced the dimensions of students' computational thinking. The activities were integrated into the formative research course, taught during the first year of the systems engineering program, with a weekly workload of four hours, totaling 16 sessions. All activities were carried out in the classroom under the continuous supervision and feedback of the instructor (co-author of this study).

- Understanding the problem (5 sessions): Students explored their assigned problem using tools such as ChatGPT, Scopus, and SciELO. They created descriptive information sheets with scientific citations using Mendeley and constructed visual cause-effect diagrams through graphic organizers.
- Preparation of the plan (3 sessions): They identified scientific background, analyzed prior experiences, and designed feasible activities contextualized to their local environment, taking into account the technical viability and the use of Arduino boards with sensors.
- Implementation of the plan (6 sessions): Students received hands-on training in using Arduino boards and corresponding sensors, assembled circuits, and programmed monitoring applications in mBlock to track variables such as air quality, soil moisture, and water temperature. They also built scale models to demonstrate their proposed solutions.
- Solution review (2 sessions): Students evaluated the performance of the models, optimized their results based on teacher feedback, and finalized their written reports. The developed solutions addressed real-world problems such as the impact of air pollution on respiratory health, risks in aquaculture due to water temperature fluctuations, and challenges in agriculture related to soil moisture—validated through sensor use and visual programming.

Figure 2 presents the activity schedule along with the technological resources used in each phase, providing a clear view of the classroom workflow and instructional organization.

3.4 Execution of technological projects integrating STEM areas for the development of problem-solving skills

The implementation of technological projects integrating STEM disciplines was carried out within the formative research course during the first academic semester of 2024, targeting first-year students in the systems engineering program. Throughout the 16-week term, a series of classroom-based activities were developed to foster problem-solving skills—specifically: understanding the problem, planning, implementation, and solution review. These activities were conducted under continuous supervision and feedback from the course instructor. Table 3 presents the activities conducted for one of the technological projects, illustrating how STEM integration supported the progressive development of students' problem-solving abilities.

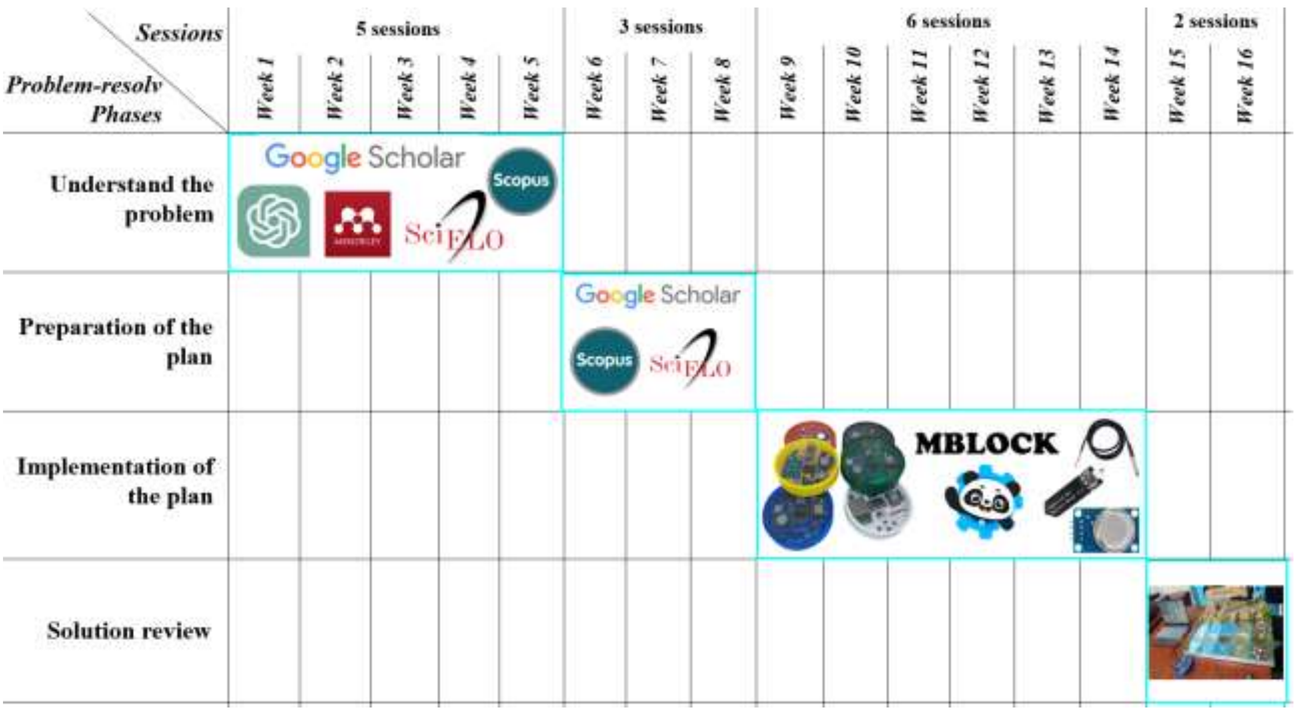
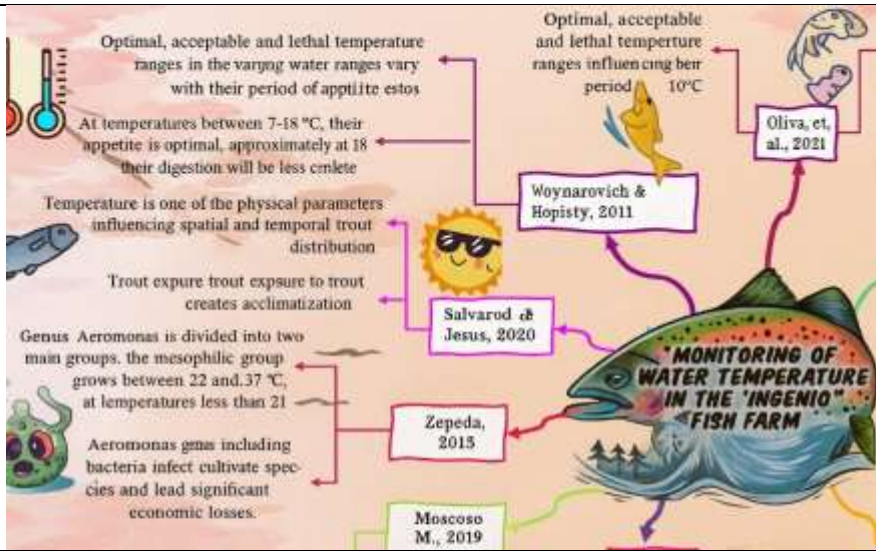
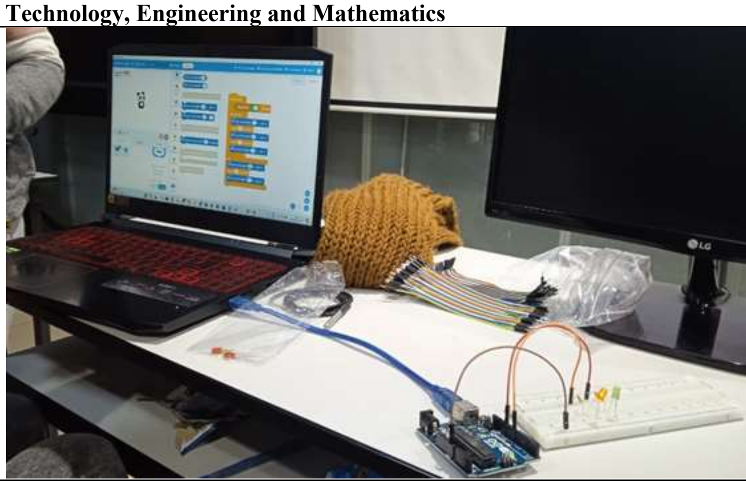


Figure 2. Activity schedule according to the problem-solving phases

Table 3. Activities carried out for the development of problem-solving skills integrating STEM areas

Project: "Monitoring Water Temperature in the Ingenio Fish Farm"		
		Science
Understanding the problem	Students investigated the survival of trout at different water temperatures using databases such as Scopus, SciELO, and Redalyc. They synthesized key information and visualized cause-effect relationships through graphic organizers.	
		Science and Engineering
Preparation of the plan	They reviewed scientific literature on trout breeding and technological monitoring solutions. Based on this, they defined objectives and designed a prototype using the DS18B20 sensor with Arduino Uno, accompanied by a preliminary mBlock program.	● Formulate the problem regarding trout breeding based on water temperature. ● Research background information and examine previous models for guidance. ● Create the initial prototype using the DS18B20 water temperature sensor and Arduino Uno board. ● Develop the first programming design utilizing the mBlock application. ● Review and refine the prototype through mBlock programming. ● Revise and enhance the programming using the mBlock application. ● Finalize the prototype and programming corrections in mBlock. ● Construct a model inspired by the study topic. ● Prepare a scientific article documenting the findings.
		Technology, Engineering and Mathematics
Implementation of the plan	Students developed a functional interface in mBlock to monitor temperature, implemented the circuit with Arduino and the sensor, applied Cartesian concepts to position elements in the interface, calculated area/perimeter of the fish pond, and used logic in programming movements of objects (trout, bacteria, etc.).	
		Engineering
Solution review	The complete system—hardware and software—was tested and validated. The model simulated temperature variations, and improvements were made based on teacher feedback. The prototype was finalized and deemed fully operational.	

4. RESULTS

4.1 Analysis of descriptive statistics of problem-solving skills

Table 4 presents a statistical summary of the four dimensions of problem-solving skills before and after the intervention.

Table 4. Statistical summary analysis of problem-solving skills

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

The results in Table 4 show an improvement in all four assessed skills following the intervention, as reflected by increases in both the mean and median values. This suggests that the learning strategy implemented during the formative research course positively impacted students' problem-solving abilities.

However, it is also observed that the standard deviation increased in all dimensions after the intervention. This rise in variability suggests a wider dispersion of scores among the students. In practical terms, while some students made notable progress and reached high levels of performance, others showed more modest improvements. This heterogeneity could be attributed to differences in students' prior knowledge, motivation, or engagement with the problem-solving activities. It may also reflect the differentiated pace at which students internalize and apply new skills when using technological tools and engaging in STEM-based learning.

These results imply that although the intervention was effective on average, future strategies might benefit from including personalized support or scaffolding mechanisms to reduce variability and promote more equitable learning outcomes.

4.2 Normality test of the collected data

The statistical analysis began with a normality test using the Shapiro-Wilk statistic, as the sample size was fewer than 50 participants. Table 5 presents the p-values obtained from the pre-test and post-test assessments of problem-solving skills.

Table 5. Shapiro-Wilk normality test

Statistic	Pre Test	Pos Test
N	34	34
W of Shapiro-Wilk	0.983	0.991
Value p of Shapiro-Wilk	0.864	0.993

Since both p-values are above the significance level ($\alpha = 0.05$), the data are considered to follow a normal distribution in both tests.

4.3 Hypothesis testing on the development of problem-solving skills

Given that the data follow a normal distribution, a paired sample t-test was conducted to evaluate the following hypothesis.

All p-values are below the 0.05 significance threshold; thus, the null hypothesis is rejected in every case. These results indicate that the implementation of technological projects integrating STEM disciplines significantly improves problem-solving skills in systems engineering students.

In addition to statistical significance, Sullivan's d was calculated to estimate the effect size for each skill. Values ranged from 0.43 to 0.61, indicating a moderate effect [42]. This reinforces the practical significance of the intervention, showing that the educational strategy had a tangible and meaningful impact on student performance.

Taken together, the results empirically support the research hypothesis, demonstrating that project-based STEM-integrated methodologies are effective for enhancing problem-solving competencies in first-year engineering students.

4.4 Assessment of the development of problem-solving skills

Figure 3 illustrates the progression of problem-solving skills among systems engineering students across four dimensions: understanding the problem, developing the plan, executing the plan, and reviewing the solution.

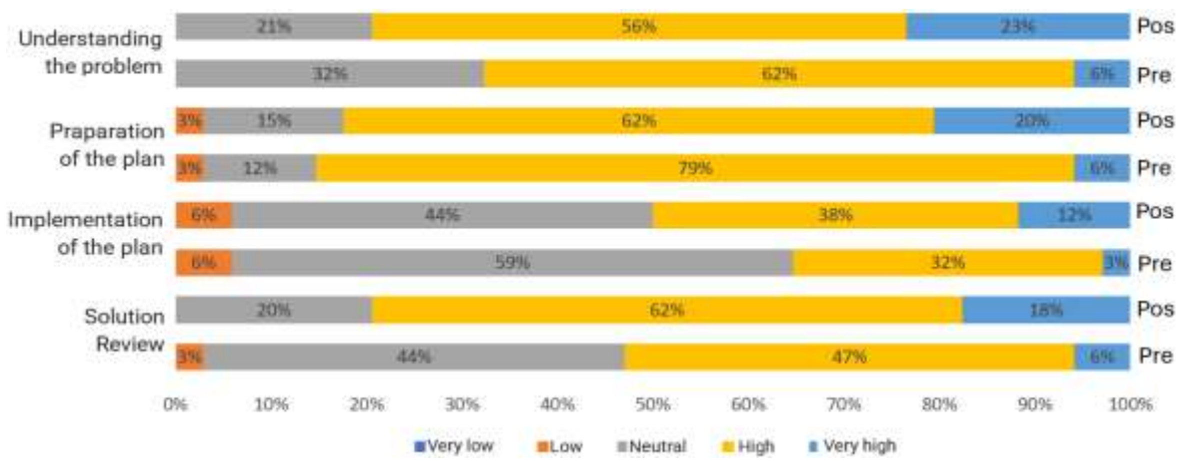


Figure 3. Assessing the development of problem-solving skills

Following the intervention, students demonstrated a significant improvement in their ability to understand problems. Specifically, 23% of the students reported a "Very High" level of comprehension, while 56% indicated a "High" level. These results reflect a strengthened capacity to analyze, contextualize, and conceptualize complex problems.

In the dimension of plan development, the percentage of students reaching a "Very High" level rose to 20%, and 62% remained at a "High" level. This indicates enhanced skills in designing structured and context-appropriate strategies for addressing the problems previously identified, grounded in scientific and technical analysis.

Regarding the execution of the plan, 12% of the students achieved a "Very High" level and 44% sustained a "High" level. These findings reveal a moderate yet relevant improvement in applying technical solutions, including programming and the integration of sensors and digital tools, to real-world scenarios.

Finally, in the review of the solution, 18% of students reached a "Very High" level and 62% a "High" level, indicating a notable development in their ability to critically evaluate the effectiveness of their proposed solutions. This also reflects greater autonomy and reflective thinking, essential for iterative improvement and validation of technological prototypes.

5. DISCUSSION

This study demonstrated that the implementation of technological projects integrating STEM disciplines—along with the use of technological resources such as sensors, Arduino boards, and block-based programming environments—significantly contributed to the development of problem-solving skills in first-year engineering students. Through a structured approach based on the phases of the problem-solving method—understanding the problem, planning, executing, and reviewing the solution—key competencies were fostered to face the challenges of the 21st century. This section discusses the results achieved in each evaluated skill, incorporating a critical analysis of the study's limitations and the implications for curriculum design.

First, the skill of understanding the problem showed significant improvement following the intervention. This ability, which involves analyzing and breaking down complex situations, was enhanced through activities such as searching for scientific information in databases (Scopus, SciELO, etc.), preparing descriptive summaries with reference managers, and creating graphical cause-effect representations [43]. The findings revealed that a considerable percentage of students reached high and very high-performance levels [44]. These outcomes align with previous studies emphasizing the positive impact of STEM approaches on students' critical understanding of problems, particularly when visual and technological tools are incorporated [45, 46]. These findings are further supported by the visual representation in Figure 3, where a significant proportion of students demonstrated "High" or "Very High" levels in this skill. The descriptive statistics in Table 4 also show an increase in both the mean and median scores for problem understanding after the intervention, indicating a consistent pattern of improvement aligned with the activities designed in the first phase.

Regarding planning, there was a notable increase in students' ability to design viable strategies. By reviewing scientific literature and previous experiences, students proposed contextualized activities adapted to their local environment [47]. This finding is supported by Kelley and Knowles [6], who argue that STEM integration strengthens strategic thinking, particularly when supported by educational technologies such as sensors and visual programming. Students applied science and engineering concepts to define coherent solution pathways. The improvements in planning abilities are also evident in Figure 3, where over 80% of students achieved high-level scores. Furthermore, the standard deviation presented in Table 4 suggests slightly increased variability, possibly due to different levels of prior knowledge in designing strategies, which highlights the importance of differentiated instruction in future interventions.

In terms of plan implementation, moderate but consistent improvements were observed in students' ability to apply technical solutions. They designed circuits, assembled prototypes, and developed monitoring interfaces using mBlock [38]. They also conducted applied mathematical calculations, such as using Cartesian planes and determining the area and perimeter of their models. These actions demonstrate effective integration of knowledge from technology, engineering, and mathematics. As Thibaut et al. [14] and Savec [5] point out, the use of ICT resources in educational environments enables students to bring ideas to life in a tangible, efficient, and motivating way. s shown in Figure 3, while the "Very High" category saw a moderate rise, a large percentage of students still achieved high levels of performance. The values in Table 4 and Table 6 confirm the statistical significance of these gains ($p = 0.041$), reinforcing the claim that students were able to apply their knowledge to build functional prototypes with real-world applications.

The solution review phase also showed significant progress. Students verified the performance of their prototypes, optimized results based on teacher feedback, and prepared scientific reports. This skill is essential for validating technological solutions and fostering reflective thinking. The literature supports that critical evaluation of outcomes is a core part of the problem-solving cycle, especially in projects that integrate STEM disciplines [1, 21, 48]. The quantitative improvement in this skill is not only demonstrated in the analysis of Figure 3, which shows a clear concentration in the "High" and "Very High" categories, but is also statistically validated in Table 6 ($p = 0.001$). These results confirm that students developed the ability to evaluate and refine their technological solutions, a crucial component of the engineering design cycle.

Table 6. Hypothesis testing using student's t-test

Hypothesis		
H0 = "The implementation of technological projects that integrate STEM disciplines does not enhance problem-solving skills in systems engineering students."		
H1 = "The execution of technological projects that integrate STEM disciplines enhances problem-solving skills in systems engineering students."		
Significance Level: 5%		
Decision Rule: If $p \geq 5\%$, do not reject H0. If $p < 5\%$, reject H0.		
Problem-solving skills	Students p-value	Decision
Understanding the problem	0.022	Reject H0
Preparation of the plan	0.021	Reject H0
Implementation of the plan	0.041	Reject H0
Solution review	0.001	Reject H0

However, this study is not without limitations. The sample size was relatively small (34 students), which limits the generalizability of the results. The research was conducted at a single public university in the Andean region of Peru, where students often have limited access to technology before entering higher education. Additionally, the absence of a control group prevents full isolation of the intervention's effect. Future research should consider more robust experimental designs and larger, more diverse samples to validate these findings.

Lastly, the results of this study have important implications for curriculum design. Integrating technology-based, problem-solving projects grounded in STEM disciplines during the early stages of university education promotes not only technical competencies but also transversal skills such as critical thinking, creativity, and collaboration. Therefore, it is recommended that engineering education programs incorporate active methodologies, educational technologies, and interdisciplinary approaches to prepare professionals capable of addressing complex social, economic, and environmental challenges with innovative and context-sensitive solutions.

In sum, the data visualizations and statistical tables included in this study play a critical role in illustrating the progression of students' problem-solving competencies. They offer empirical support to the qualitative interpretation of results and reinforce the value of implementing integrated STEM-based interventions in the early stages of engineering education. The coherence between figures, tables, and the discussion highlights the robustness of the findings and provides a strong foundation for future curricular reforms.

6. CONCLUSIONS

Problem-solving is an essential skill that individuals require throughout their lives. Developing this competency early in higher education—and ideally from basic education—equips students to face academic, personal, and professional challenges with greater autonomy and confidence. It also fosters self-directed learning, efficient time management, and reflective thinking, which are essential for adapting to new and complex scenarios in the 21st century.

This study demonstrated that the execution of technological projects integrating STEM disciplines—supported by tools such as Arduino boards, sensors, and block-based programming environments—significantly strengthened students' problem-solving skills, especially in understanding the problem, preparing the plan, implementing the solution, and reviewing results. Most participants achieved high or very high proficiency across these areas.

Furthermore, the integration of science, technology, engineering, and mathematics within classroom projects allowed students to research real-world problems, design and prototype technological solutions, and apply logical and mathematical reasoning. These experiences promoted not only academic development but also collaborative behaviors, communication skills, and a sense of agency in solving community-based issues. These outcomes validate the relevance of incorporating interdisciplinary STEM-based activities into the curriculum of early university education.

This intervention was applied to first-year students in a systems engineering program at a public university in Peru. Although promising, the study has certain limitations: the small sample size, absence of a control group, and restriction to a single institution may affect the generalizability of the results. Future research should consider expanding the sample, involving multiple universities, and adopting a quasi-experimental or longitudinal design to better assess long-term impacts.

The graphical representations and statistical tables included in this study, particularly those related to the development of problem-solving skills, provide clear evidence of students' progression across the four stages of the problem-solving method. These visual elements not only illustrate individual improvements but also support the broader conclusion that interdisciplinary, project-based STEM learning is an effective approach for enhancing key competencies in first-year university students.

Given the growing need to align engineering education with real-world challenges and 21st-century competencies, the results of this study underscore the importance of embedding STEM-integrated, problem-solving activities into curricular and institutional policies. Educational institutions and policymakers are encouraged to invest in teacher training, infrastructure, and curricular innovation to replicate and scale such interventions in diverse academic settings.

Despite these limitations, the findings suggest a high potential for transferability. The proposed approach can be adapted to a wide range of academic disciplines—including education, health sciences, humanities, and environmental studies—and implemented within general courses such as formative research, ICT, logic, or scientific methodology. Future studies should explore the adaptation of this intervention model across diverse educational contexts to validate its scalability and effectiveness.

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