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# General proposal for a teaching-learning process for educational robotics based on Cuban pedagogical foundations

## Propuesta general de proceso de enseñanza-aprendizaje para la robótica educativa desde las bases pedagógicas cubanas

## Proposta geral para um processo de ensino-aprendizagem em robótica educacional com base nos fundamentos pedagógicos cubanos

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**ABSTRACT**

The Ministry of Education and the leadership of the country have proposed incorporating robotics education into Cuban educational institutions due to its potential to foster a culture of science and technological innovation. In its scientific work, a Ministry of Education sectoral project identified recreational institutions and higher education extension projects that promote the learning of educational robotics among children and adolescents. However, due to the novelty of the subject in the country, there is still no didactic approach based on Cuban Pedagogical Sciences. The objective of this article is to disseminate the general proposal for the teaching-learning process for educational robotics based on Cuban pedagogical foundations, as formulated by the project researchers. The research was conducted through a qualitative study, employing theoretical methods such as analysis, synthesis, generalization, systematization, and documentary analysis to structure its conclusions.

*Translated from the original in Spanish*

The empirical method used was the Delphi method, which uses the analysis of expert responses. The results showed the main similarities and differences between foreign and national didactic approaches. In addition, a general proposal for this process was presented regarding educational robotics in Cuba. The proposal was validated and refined using the Delphi Method for expert evaluation. Based on the results of the presented work, Cuba has a general proposal for a teaching-learning process for educational robotics, based on Cuban pedagogical sciences. Its implementation will provide a structured framework for the teaching-learning process of educational robotics.

**Keywords:** developer learning, teaching-learning process; educational robotics.

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**RESUMEN**

El Ministerio de Educación y la dirección del país han propuesto incorporar la enseñanza de la robótica en las instituciones educativas cubanas, por su potencial para fomentar una cultura científica y de innovación tecnológica. En su labor científica, un proyecto sectorial del Ministerio de Educación identificó instituciones recreativas y proyectos extensionistas de Educación Superior que promueven el aprendizaje de la robótica educativa entre niños y adolescentes. Sin embargo, debido a la novedad del tema en el país, aún no existe una didáctica fundamentada en las Ciencias Pedagógicas cubanas. El objetivo del artículo es divulgar la propuesta general del proceso de enseñanza-aprendizaje para la robótica educativa desde las bases pedagógicas cubanas, formulada por los investigadores del proyecto. La investigación se realizó mediante un estudio cualitativo, empleó métodos teóricos como el análisis, la síntesis, la generalización, la sistematización y el análisis documental, para estructurar sus conclusiones. El método empírico utilizado fue el método Delphi haciendo uso del análisis de las respuestas de los expertos. Los resultados mostraron las principales similitudes y diferencias entre las didácticas foráneas y las nacionales. Además, presentó una propuesta general para dicho proceso referente a la robótica educativa en Cuba. La propuesta fue validada y perfeccionada mediante el Método Delphi para la evaluación por los expertos. Por los resultados del trabajo presentado, Cuba dispone de una propuesta general de proceso de enseñanza-aprendizaje para la robótica educativa, basada en las ciencias pedagógicas cubanas. Su implementación ofrecerá un marco estructurado para el proceso de enseñanza-aprendizaje de la robótica educativa.

**Palabras clave:** aprendizaje desarrollador; proceso de enseñanza-aprendizaje; robótica educativa.

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*Translated from the original in Spanish*

**RESUMO**

O Ministério da Educação e a liderança do país propuseram a incorporação do ensino de robótica nas instituições educacionais cubanas, devido ao seu potencial para fomentar uma cultura de ciência e inovação tecnológica. Em seu trabalho científico, um projeto setorial do Ministério da Educação identificou instituições recreativas e projetos de extensão de ensino superior que promovem a aprendizagem de robótica educacional entre crianças e adolescentes. No entanto, devido à novidade do tema no país, ainda não existe uma abordagem didática baseada nas Ciências Pedagógicas Cubanas. O objetivo deste artigo é divulgar a proposta geral para o processo de ensino-aprendizagem de robótica educacional com base nos fundamentos pedagógicos cubanos, conforme formulada pelos pesquisadores do projeto. A pesquisa foi conduzida por meio de um estudo qualitativo, empregando métodos teóricos como análise, síntese, generalização, sistematização e análise documental para estruturar suas conclusões. O método empírico utilizado foi o método Delphi, que utiliza a análise de respostas de especialistas. Os resultados mostraram as principais semelhanças e diferenças entre os métodos de ensino estrangeiros e nacionais. Também foi apresentada uma proposta geral para esse processo referente à robótica educacional em Cuba. A proposta foi validada e refinada utilizando o Método Delphi para avaliação por especialistas. Com base nos resultados do trabalho apresentado, Cuba apresenta uma proposta geral para um processo de ensino-aprendizagem em robótica educacional, com base nas ciências pedagógicas cubanas. Sua implementação fornecerá uma estrutura para o processo de ensino-aprendizagem em robótica educacional.

**Palavras-chave:** aprendizagem do desenvolvedor; processo de ensino-aprendizagem; robótica educacional.

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## INTRODUCTION

In today's society, technological processes have a marked influence on the economic and social activity of countries. It is difficult to find an area of human activity that is not somehow related to technology; this phenomenon is growing exponentially. Teaching robotics is a tool that has proven beneficial for training new generations in a culture of science and technological innovation.

To facilitate understanding of the topic at hand, the authors describe what they consider to be robotics and educational robotics. Common and relevant ideas have been selected and presented.

Robotics is an interdisciplinary field concerned with the design, construction, programming, and operation of robots. The primary goal of robotics is to create autonomous systems that can efficiently, accurately, and safely perform repetitive, difficult, unpleasant, or dangerous tasks (Castro *et al.*, 2022; Rosero, 2024).

Educational robotics is considered a branch of robotics applied to the educational field, focusing on the design, development, programming, and operation of robots. Its distinctive feature is that it provides a multidisciplinary and meaningful learning environment (Castro *et al.*, 2022; Hernández *et al.*, 2024).

The evolution of educational robotics has been remarkable, and it has become a component of contemporary education. Its beginnings date back to the late 1960s. Since then, and in the following two decades (1970s and 1980s), the Logo programming language was created and developed. This innovation laid the foundation for integrating programming and robotics in educational environments (González *et al.,* 2020; Sánchez & Prendes, 2022).

During the 1990s, educational robotics began to be applied in education. Educational robotics kits such as Lego Mindstorms emerged, providing accessible tools for building and programming robots (Rosero, 2024; Sánchez & Prendes, 2022).

With the arrival of the 2000s, competitions focused on promoting skills such as teamwork, problem-solving, and creativity were established. At the same time, the Massachusetts Institute of Technology (MIT) launched the Scratch programming language, which expanded the possibilities for young people to develop technological projects intuitively (González *et al.,* 2020; Díaz & Salas, 2023; Rosero, 2024).

In the 2010s, the focus on education: Science, Technology, Engineering and Mathematics (STEM) promoted the integration of robotics into educational plans, to respond to the growing demand for technological skills in the contemporary world (Remond & Figueredo, 2020; Sánchez & Prendes 2022).

In the 2020s, educational programs focused on robotics and programming experienced a global expansion. This trend reflected a collective effort to equip future generations with key skills to face the challenges of an increasingly digital and technological society (Remond & Figueredo, 2020; Díaz & Salas, 2023; Sánchez & Prendes, 2022).

Global historical overview demonstrates the progressive consolidation of educational robotics as a learning resource. Its evolution, from simple mechanical tools to advanced technological platforms, has revolutionized teaching methodologies in diverse contexts.

In Cuba, children, adolescents, and young people have participated prominently in international programming and robotics competitions. Programming interest groups have been created, promoted by professors from the University of Computer Sciences (UCI) (Remond & Figueredo, 2020) and computer science teachers who taught the Scratch programming language as part of the Third Improvement Program of the National Education System (SNE). In addition, initiatives in recreational institutions such as the Havana Planetarium, the Technological Palace, the Youth Computer and Electronics Clubs, and the "Adolescents +" Project of the Office of the Historian of Havana promote the learning of programming and robotics.

Various higher education institutions, such as the José Antonio Echeverría Technological University of Havana (CUJAE), the University of Oriente, and the Marta Abreu Central University of Las Villas, have developed outreach projects that promote the teaching of programming and robotics. These initiatives underscore the commitment of the country to the development of these disciplines and their integration into various educational and recreational settings.

As can be seen from the above, regarding educational robotics with children and adolescents, in Cuba the activities carried out are primarily extracurricular. They adopt foreign teaching methodologies and, therefore, lack a unified pedagogical approach that considers the foundations of Cuban pedagogy. Although the country faces challenges inherent to the novelty of the subject and technological limitations, efforts to introduce educational robotics in educational institutions are notable, driven by government initiatives and the Ministry of Education (MINED), such as the creation of a sector-wide project to study this issue.

In its scientific work, this project produced the following scientific result: " General, Theoretical, Didactic, and Technological Foundations for the Introduction of Robotics Teaching in Cuban General Education." It formulates a pedagogical proposal based on Cuban pedagogical sciences, designed to structure a framework for learning robotics.

The foundation of theory and practice in relation to the teaching-learning process (TLP) in Cuba is the historical-cultural approach. According to this approach, the development of cognitive abilities and the acquisition of knowledge cannot be separated from the cultural and social environment in which they occur. Furthermore, it highlights the importance of social interaction and collaborative learning in individual development. It values not only academic results, but also skills, attitudes, and values (Navarro & Valle, 2024; Rico *et al.,* 2004).

In the historical-cultural approach, activity is recognized as the generative axis of learning. By assuming learning as an activity, its stages or moments of the teaching-learning process are considered under developmental conditions: motivational and orientation stage, execution stage, and control and evaluation stage. Likewise, the system of categories that distinguish the developing teaching-learning process (TLP) must be considered. Non-personal categories: objective, content, method, teaching media, forms of organization and evaluation (Rico *et al.,* 2004). Robots are a teaching medium and influence the remaining categories. Personal categories are expressed in the roles of the educator, the learner, and the group. The role of the educator and the group of learners in their processes of interrelation and communication in the learning activity is highlighted, as essential social mediators for individual learning; which constitutes the transition from the external to the internal, from the social to the individual.

In educational robotics, intuition is presented in a rapid perception of the object, idea, or project in its clear understanding (Sánchez & Prendes, 2022). Heuristic principles, rules, or programs that allow for the use of a procedure aimed at solving the problem at hand are useful. The heuristic method offers students avenues for independent problem-solving, streamlining mental and practical effort, and allowing them to independently solve other problems posed by practice.

At the international level, the analysis of various documents (Castro *et al.,* 2022; Cuéllar *et al.,* 2024; González *et al.,* 2020; Pincay & Cuero, 2024, Rosero, 2024), as well as the completion of a comparative study by the researchers of the aforementioned project, which covered eighteen countries, showed that there is no universal method for teaching robotics. This varies depending on the educational objectives, available resources and pedagogical preferences of each national context.

However, both the documentary analysis and the comparative study identified a trend towards integrating robotics into the teaching-learning processes. This process highlights the use of the *Maker methodology* (learning by doing), which promotes innovation through experimentation and design, and the multidisciplinary STEM approach as predominant in fostering the active and creative participation of students (Marín *et al.,* 2023). This interdisciplinary approach favors the development of technical, creative, and problem-solving skills, which are essential in teaching robotics (Cuellar *et* *al.,* 2024). Both are intertwined to offer connected and meaningful learning, where students develop key skills through the resolution of interdisciplinary projects and promote collaboration and the active use of technology (Pincay & Cuero, 2024).

Another trend in the methods used in the PEA of educational robotics internationally is the use of project-based learning (PBL). PBL is a comprehensive, systematic, rigorous, and reflective teaching-learning method that, in educational robotics, encourages the application of knowledge to practical situations, where students face challenges that require critical thinking and creativity (Recalde *et al.*, 2024; Ruiz & Ortega, 2022; Zambrano *et al.*, 2022).

Based on this analysis, the importance and necessity of this article are argued. The incorporation of a theoretical and methodological framework for the implementation of educational robotics in the PEA not only responds to the demands of a constantly evolving technological environment but also ensures that these educational tools are aligned with Cuban pedagogical foundations. This will maximize the positive impact on the students' comprehensive development and the preparation of future citizens capable of facing the challenges of an increasingly complex and technologically advanced society. Articulating these foreign and national pedagogical foundations in educational robotics activities constitutes both a challenge and an opportunity to guarantee quality education that contributes to the comprehensive development of students and the advancement of society as a whole.

In the aforementioned MINED sectoral project, a general methodological proposal for the robotics PEA was developed. In developing this proposal, the fundamental principles of Educational Sciences in the Cuban context were integrated and harmonized, to the extent possible, with the pedagogical approaches present in internationally applied teaching methods. This approach allowed for the establishment of basic principles that enhance the PEA, while respecting the pedagogical foundations of the Cuban educational system. This article aims to disseminate the general proposal for the teaching-learning process for educational robotics based on Cuban pedagogical foundations, developed by researchers of the MINED sectoral project. This proposal promotes a fundamental structure that gives coherence to the robotics PEA in Cuban educational and recreational institutions.

## MATERIALS AND METHODS

The work presented was carried out through a qualitative study, using the following scientific research methods:

### Theoretical

Systematization: enabled the analysis and determination of the background regarding the introduction of robotics, both internationally and nationally. At the international level, a comparative study was conducted to analyze and understand the similarities and differences in educational practices across different contexts. Eighteen countries from different regions were analyzed regarding the PEA for educational robotics. The following were studied, placed in alphabetical order: Argentina, Australia, Botswana, Brazil, Canada, China, Colombia, Spain, United States, Finland, Germany, India, Japan, Kenya, Mexico, Namibia, United Kingdom, and South Africa. These countries represent a variety of contexts, which allowed for a fairly broad view of the topic under study.

The aspects assessed were: the methodologies used to teach robotics, whether it is part of the school curriculum, the educational level where it is introduced, the approach (whether it is an educational resource or a subject), and the type of funding provided. This analysis identified trends and best practices that can be applied to the PEA for robotics in Cuba. It also allowed for a better understanding of the data and their relationships, a deeper understanding of interpretations, and the development of a proposal that addresses the objective of the research.

A documentary analysis was conducted to determine the differences and similarities among the STEM approach, the *Maker* methodology, and developer learning. The review focused on theoretical and methodological sources from international and national curricula. MINED programs and curricula were included at different levels of education (Early Childhood Education, Primary Education, Junior-High Education, Senior-High Education), through the Computer Science discipline. In addition, related subjects were sought in the different grades and specialties of Technical and Vocational Education (Instrumentation and Control, Automation, Computer Science, Electronics, and Telephone Services). Information was also collected from newspapers and websites about the results of recreational and higher education institutions regarding the teaching of programming and robotics in Cuba.

The main limitation of this study was the few books or scientific journals that address the topic of teaching robotics or its practice with children and adolescents in the ages of the educational levels included in Cuban General Education.

**Empirical**

The Delphi method was used to evaluate the general proposal of the PEA for educational robotics. Thirty experts were selected from the provinces of Villa Clara (Marta Abreu Central University of Las Villas), Santiago de Cuba (University of the East), and Havana (Enrique José Varona University of Pedagogical Sciences, the MINED Educational Technology Directorate, and professors and researchers from the Central Institute of Pedagogical Sciences).

The experts were sent two surveys: one to calculate the K competence coefficient and another to determine their assessments of the components of the proposed conception. There were experts specializing in Technology and experts specializing in Pedagogy. They were presented with a table with the sources of argumentation: theoretical analyses carried out by you; experience gained; work by national authors; work by foreign authors; their own knowledge of the state of the problem abroad; their intuition. In addition, they were instructed to mark with an X the sources that they considered to have most influenced their level of knowledge about the processes of Technology or Pedagogy, depending on their specialty. They were given three options for each: high, medium, and low.

Data were obtained from the selections made, corresponding to a standard table. All the values obtained were then added together, resulting in the argumentation coefficient *ka* for each expert. Using the knowledge coefficients *kc as data,* and argumentation *ka,* the competence coefficient of each expert was calculated *(K).*

In the second table, the selected experts offered their opinion on each of the elements through five evaluation categories: 5-Very adequate (MA); 4-Quite adequate (BA); 3-Adequate (A); 2-Poorly adequate (PA); 1-Not adequate (NA).

Initially, the so-called cutoff points (C1 to C5) were established, which correspond to the five evaluative categories: MA-C1, BA-C2, A-C3, PA-C4, NA-C5. A cumulative frequency table was then constructed. It was then builtA table of cumulative relative frequencies. The quotient of this division must be rounded to the nearest ten thousandths. The last column is not needed, since there are five categories, and only four cutoff points are required. The cutoff points are obtained by dividing the sum of the values corresponding to each column by the number of components. N and P are the averages; therefore, NP is the average value that experts assign to each element of the system.

The cutoff points were used to determine the category or degree of adequacy of each element of the system. The image of each of the values in the cells of the table above was then found using the inverse of the normal curve. This process was repeated in three rounds of evaluation to reach a consensus.

Mathematical and statistical methods were used for the sign test, assuming normal behavior of the variable due to the 30 experts considered. The experts' competence coefficient (K), cutoff points, and the average value assigned by the experts in determining the category evaluated were determined.

## RESULTS

In determining the similarities and differences regarding the PEA for educational robotics internationally and nationally, eighteen countries were studied, covering different continents, so as to represent a variety of approaches and contexts, which allowed for a fairly broad view of the topic under study.

The results obtained were the following:

- The STEM approach is widely adopted in developed countries, such as the United States, Australia, the United Kingdom, and Japan. Countries such as Germany, Canada, and Finland have adopted this philosophy in technology-equipped workshops and laboratories.
- Project-Based Learning (PBL) is widely used worldwide as a method for teaching robotics to students of all ages.
- Regarding the incorporation of robotics into educational systems, it is observed that in developed countries, it is part of the official school curriculum, either as a subject or as an educational resource. In contrast, in developing countries, robotics tends to be introduced through pilot programs or extracurricular activities, rather than being mandatory. Most countries integrate it into primary and junior-high education, although in developing countries it is more common to find it in junior-high school.

- Finally, differences in the type of financing are also evident. In developed countries, financing is usually mixed, combining public and private resources. In developing countries, public financing predominates, often with support from international organizations or local initiatives.

These trends reflect the influence of economic, sociocultural, and political factors on the implementation of educational robotics. Active methodologies and an interdisciplinary approach are key to preparing students for the technological challenges of the future.

Based on these results and the documentary analysis conducted, numerous similarities were found among the STEAM model, the *Maker methodology,* and the developer teaching-learning model. The similarities were:

- All three approaches propose the implementation of productive and creative intellectual activity at all stages of the learning process.
- They encourage the search for meaning and ongoing problematization, which favors the achievement of quality learning.
- They aim for students to gradually assume responsibility for their own learning, which fosters the transition to self-learning, based on commitment and emotional involvement with the learning process and the growing ability to assess and monitor their own learning.
- They propose short-and-long-term strategic learning goals, establish action plans to achieve them, make decisions, and deploy strategic learning.
- They allow the student to understand their weaknesses and limitations as learners, as well as their strengths and capabilities, and to self-evaluate their processes, progress, and the results of their work.
- They emphasize the importance of adopting a positive attitude toward mistakes, analyze their failures and successes based on controllable factors; perceive effort as an essential factor in their results; and generally, have positive expectations about their learning.
- The learner is an active part of group communication and collaboration processes. This foster learning from the knowledge of others and understands that others can also learn from them. It fosters the appreciation of learning as a source of personal growth (not only intellectual, but also emotional, moral, and social).

However, two significant differences were found that should be considered from the perspective of knowledge acquisition, and this is where the teaching method derived from the historical-cultural approach gains clarity, especially considering the processes of human development.

1. Using the trial-and-error method:
    - STEM: integrates trial and error as a strategy to solve technical and scientific problems, using objective data to adjust processes and strengthen skills.
    - *Maker* Methodology: makes trial and error a central axis, allowing free experimentation and autonomous creativity as the main drivers of learning.
    - Developer learning: Uses learning from mistakes in a controlled, guided, and reflective manner, mediated by the educator, to ensure solid, conscious, and focused learning. It fosters deep understanding, the ability to transfer knowledge to solve new problems, and the development of analytical and critical skills.
2. The other key difference observed between the teaching methods used worldwide and those used in Cuba relate to the stages of the learning activity. Foreign methods focus directly on the moment of execution, leading to a neglect of the moments of guidance, control, and assessment of the activity.
    - STEM: proposes to provide an initial guidance structure, encourage practical application, and use objective results analysis for evaluation. However, in practice, there is a tendency to focus quickly on execution, especially in hands-on activities such as building or programming robotics projects, leaving less time for solid guidance or reflective evaluation at the end. This may be due to the dynamic and practical nature of the STEM approach.
    - *Maker* Methodology: prioritizes execution, with less attention to prior guidance and subsequent analysis. The emphasis is on the process of creation and free exploration.
    - Developer learning: carefully structures the three stages of the learning activity to guide the learner through each stage of learning, and ensures in-depth reflection at the end of the process. For the achievement of developer learning, addressing the guiding basis for action and control actions is a significant prerequisite. These allow for levels of generalization that foster a solid assimilation process. Thus, it is highlighted the importance of these actions as essential elements to guarantee an education oriented towards the full development of cognitive and formative skills.

In addition to using Project-Based Learning (PBL), it is considered important to apply heuristic methods to teaching robotics. These methods allow students to seek innovative solutions to complex problems. Together, PBL and heuristic methods not only enhance the acquisition of technical skills related to robotics but also promote the development of skills such as collaboration and communication, preparing students to be independent thinkers and problem-solvers in an increasingly technological world.

Based on the previously conducted analysis, a comprehensive proposal was designed to provide a general framework for the PEA for educational robotics, adapted to the specific foundations of Cuban pedagogy. The proposal is outlined below, focusing on two core aspects:

The first, focused on the general, non-personal characteristics of the teaching-learning process, consists of the categories of the developing PEA: objective, content, teaching methods, teaching media, forms of organization and evaluation.

Fundamental characteristics of each one:

Goals

- Reflect the practical nature of the teaching-learning process.
- Be specific, measurable, achievable, and applicable.
- Focus on the process, not just the end result.
- Adapt them to the available resources, the students' needs and level, as well as their potential.
- Organize joint collaborative actions among students.

The contents must

- Include basic concepts of robotics, programming, robot design and construction.
- Solve problems in the context in which it develops and also at the macro social level (country, world).
- Stimulate imagination, fantasy and creativity.
- To wield in them the notions, concepts, theories and laws of science.
- Promote the development of values and ethics.
- Promote the independent and critical use of technologies and encourage the transition from user to creator of technologies.

Teaching methods

- They should be interactive, practical and motivating.
- They depend on the objectives, the learning needs, the level, the stage of the process, and the predominant type(s) of content.
- The proposal is Project Based Learning (ABP) complemented by heuristic methods.

Teaching media

- Using technology to promote teaching and learning in an integrated and interdisciplinary manner.
- It is the link among what is designed, what is developed, what is programmed and reality.
- They facilitate the understanding and application of the study content of the disciplines that are integrated.
- Technology is not an end in itself but a means to achieve objectives.
- It must meet safety standards and be accessible to all students.

Forms of organization of the process

- The teaching-learning process must be developmental.
- The direction of the student's cognitive activity must be flexible.
- It is not a traditional teaching process, and can take different organizational forms depending on the circumstances.
- Plan how, when, and for what purpose the robot will be used, so that it contributes significantly to the development of intellectual problem-solving skills.
- This medium easily distracts students, and they can lose focus on what the educator is saying, so preparation and training are required in the management of PEA with the integration of this medium.
- Robot programming should contribute to the learners' intellectual development and should never be used against such development. nor of development and social good.
- Projects can have a variety of times for their solution and not necessarily be solved in one class, it can be in a set of them.
- It should encourage collaborative learning and teamwork.

Assessment

- It should not be done in a conventional manner, since the PEA is not.
- It should be flexible and individualized. Its purpose is to provide individual feedback with the level of support they require.
- It must be done through joint reflection and in a systematic manner, identifying and showing the general errors that appear.

The second core aspect has to do with the general structure of the teaching-learning process for educational robotics, determined by the activity stages: motivation and orientation, execution, control, and evaluation.

First moment: motivation and orientation.

This initial phase should be carried out within the general group. Helping students achieve a conscious and reflective understanding of their learning process requires educators, during preparation, to ensure motivation, a connection between prior and new knowledge, and active participation in analyzing the conditions for solving the robotics problem or challenge and its possible solutions.

The relationship with prior knowledge will allow for restructuring and the emergence of a new level of generalization. This will foster a more robust assimilation process, with greater possibilities for generalization and development, expressed in the ability to transfer knowledge to new situations; that is, to operate successfully in activities at the application and creativity levels.

Second moment: execution.

The students are grouped into small groups. The central moment consists of posing a problematic situation or challenge. This can be posed by the teacher or by other students.

In this second phase of the activity, students must generate ideas and discuss possible solutions. This requires researching and planning the path to follow, determining which mechanical and electronic components they will use, determining how these components interact with the environment, how they can be programmed to respond to stimuli, and providing a solution to the challenge. Propose a design that integrates the components.

In your research, you can look for previous projects or similar solutions that others have implemented. This will give you ideas and concrete examples of how to address your own challenge. Keep a clear record of the information gathered, which will be useful for project execution, its final presentation, and for solving future projects. This phase should conclude with the development of a general procedure to guide the work to be done.

Once the robot is built, the groups test it in real-life situations. Adjustments must be made based on the results.

Third moment: control and evaluation.

This session should be held in the larger group. Each group presents their project, explaining their process, decisions made, and how they addressed challenges. The remaining groups can ask questions and offer constructive feedback.

At this point it is necessary:

- Reflect on the strategies used to solve the proposed problem.
- Conduct a retrospective and prospective analysis of the solution found, both from a technical learning perspective, including design, construction, and programming, as well as from a teamwork, interpersonal, and problem-solving perspective.
- Identify successes, seek new knowledge, failures, areas for improvement, and oversights during the development of the challenges undertaken, and exchange strategies, solution algorithms, and lessons learned that will help lay the groundwork for the next challenges to be solved.

To validate the general PEA proposal for educational robotics, experts assessed it using the Delphi method.

The selected experts provided their opinions on each of the proposed aspects using five evaluation categories: 5-Very Adequate (VA); 4-Fairly Adequate (FA); 3-Adequate (A); 2-Slightly Adequate (SAD); 1-Not Adequate (NA) (Figure 1).

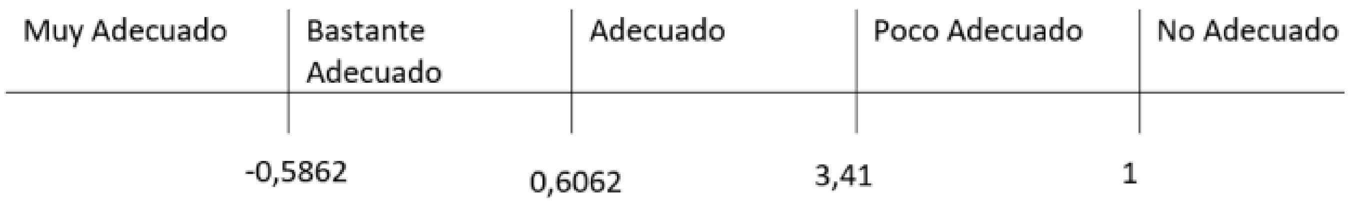


**Figure 1.** The cut-off points were determined as follows

The average score (NP) given by experts to each component is all between the cut-off points -0.5862 and 0.6062; therefore, all components are rated in the category: Fairly Adequate.

Statistical processing of the data, analysis of the responses, and the recommendations made by the experts allowed us to assess the consensus among them regarding each element. In the analysis of the responses regarding the characteristics of the PEA, 23% of the experts determined the proposal to be Very Adequate. Forty-seven percent (47%) ranked it Fairly Adequate, and the remainder (30%) ranked it Adequate. Regarding the overall structure of the PEA, 20% ranked it Very Adequate, 47% Fairly Adequate, and 33% ranked it Adequate.

After statistical analysis, it was determined that both aspects were rated as fairly adequate. The results of the survey administered to the 30 experts are shown in the following graphs (Figure 2):

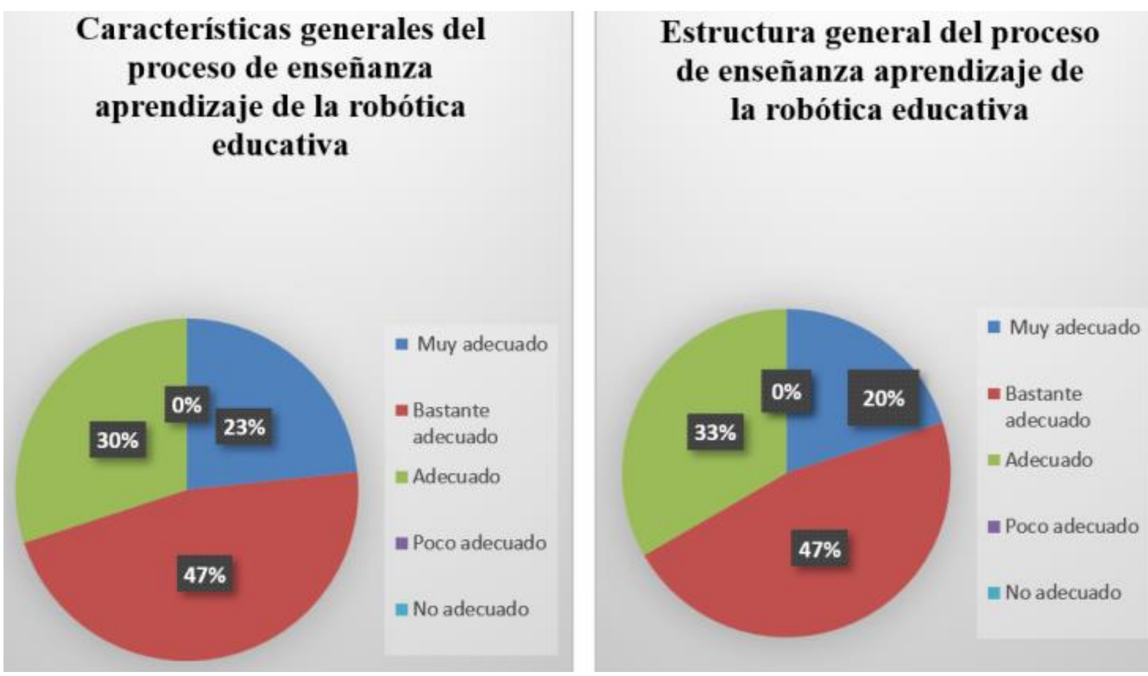


**Figure 2.** Results of the survey applied to the 30 experts

The analyses conducted by the experts, along with their suggestions for improvements and changes, allowed us to refine the initially presented proposal for the PEA for educational robotics. The changes made were as follows:

- In explaining the general characteristics of PEA for educational robotics, information was expanded and bibliographical references were added to make the information presented more understandable.
- Regarding the general structure of the PEA for educational robotics, the explanation of the first stage of the process was expanded.

By expanding on these aspects, the document was refined, providing greater theoretical support, offering tools, and enhancing the knowledge of educators and educational structures that use these resources. It also allows for a better understanding of the pedagogical foundations that guide PEA for educational robotics based on the basic principles of Educational Sciences in Cuba.

## DISCUSSION

Having a general reference for the teaching-learning process of educational robotics based on national pedagogical foundations is essential for establishing a structure for teaching robotics in Cuban General Education; a completely new topic at the educational levels covered by this subsystem of the National Education System. The research, the results of which are presented in this article, delves into the developmental approach to the teaching-learning process for educational robotics. It is conceived as a complement and enrichment of foreign methodologies adapted to the national context.

In developing the general proposal for the Educational Robotics Program (PEA), a study was conducted that provides a comparative overview of the methodologies used for teaching educational robotics in different countries. The differences found among them are based on their level of economic development. This allowed us to understand the challenges of accessibility and financing in disadvantaged contexts and to identify relevant factors that determine the quality of the PEA for educational robotics. This is the case of specialized teacher training and the use of practical and interdisciplinary approaches such as the multidisciplinary STEM approach and Project-Based Learning (PBL).

Among the limitations of this part of the study is that the selection of eighteen countries may not represent global diversity, which could bias the conclusions. However, the results remain valid and relevant, as the study identifies trends that provide guidelines for developing a general PEA process model for educational robotics in Cuba and a basis for future research.

Another significant aspect of the work is the presentation of a comparative analysis of the STEM model, the *Maker methodology,* and the developmental model of teaching and learning. Its relevance lies in the fact that it demonstrates common principles, such as productive intellectual activity, self-directed learning, and strategic assessment of the learning process. The convergence of these approaches reinforces the need for an education that integrates different disciplines and methodologies, fostering critical and reflective thinking and student autonomy. Furthermore, the importance of group collaboration and social learning is highlighted, suggesting that the complementarity of these educational models impacts not only cognitive development but also the emotional and social growth of students.

The analysis of the models also identified two fundamental differences: the use of the trial-and-error method and the moments of the learning activity. The clarity provided by the didactics derived from the historical-cultural approach to human development is highlighted, suggesting that the Cuban perspective emphasizes reflective and structured processes under conditions of collaboration, as opposed to the autonomous experimentation predominant in foreign models. The difference in methods suggests that the *Maker methodology* and the STEM approach promote creative autonomy but lack a knowledge consolidation process. In contrast, developer learning strengthens analytical skills and allows for greater knowledge transfer to new problems.

One of the limitations in this regard is the lack of empirical evidence. Further research is needed to analyze their practical implementation, impact, and the strategies needed to adapt these approaches to diverse educational contexts.

Another significant aspect of the work presented is that it proposes, based on the findings presented above, a general model for the PEA of educational robotics, grounded in the specifics of Cuban pedagogy and structured according to the PEA developed. Its value lies in its systematization of the categories: objectives, content, teaching methods, the ways in which the process is organized, teaching aids, and evaluation. Robots are a teaching aid and influence the remaining categories.

The adaptation of the developer approach to robotics teaching is innovative, as it emphasizes structured and guided learning, in contrast to the more exploratory models used in other countries. Furthermore, the complementary use of PBL and heuristic methods reinforces active student participation and promotes meaningful learning.

The development of a general PEA proposal for educational robotics is of vital importance in the national context, where its implementation in general education is essential due to its impact. This effort is crucial because it allows the pedagogical principles and values of the Cuban educational tradition to be articulated in the teaching of robotics. This ensures that teaching focuses not only on the development of technical skills but also on the comprehensive development of students. Furthermore, it is a coherent and contextualized proposal that serves as the basis for the development of new specialized PEA proposals for the different disciplines of the general curriculum that involve educational robotics as a learning tool.

The originality and value of the findings lie in the identification of the characteristics and components of the process, designed and based on an updated, coherent, and contextualized conceptual framework. The proposal presented can serve as a theoretical and methodological reference for the introduction of robotics teaching in Cuba and serve as a basis for future research.

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**Conflict of interest**

Authors declare no conflict of interests.

**Authors' contribution**

The authors participated in the design and writing of the article, in the search and analysis of the information contained in the consulted bibliography.



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