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La creatividad y pensamiento computacional: una experiencia de formación integral a través de talleres de robótica en universitarios

Creativity and computational thinking: a comprehensive training experience through robotics workshops for university students

Criatividade e pensamento computacional: uma experiência de formação integral por meio de oficinas de robótica para estudantes universitários

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Resumen

El pensamiento computacional se ha popularizado no solo como una actividad relacionada con la programación de computadoras, sino también como una capacidad que cualquier persona puede adquirir para resolver problemas en su vida cotidiana. Por ende, la presente investigación aborda un estudio piloto para el desarrollo de la creatividad y el pensamiento computacional a través de un taller de robótica que forma parte de las actividades de formación integral de una institución de educación superior. En concreto, se efectuó un diseño cuantitativo de corte cuasiexperimental longitudinal mediante mediciones del pensamiento creativo al inicio y al final del referido taller. En este proceso, y como estrategia para la resolución de problemas, se incorporó el pensamiento computacional para que los estudiantes solucionaran pequeños retos siguiendo seis pasos: comprensión de la situación, identificación de la dificultad, descomposición en partes constituyentes, reconocimiento de patrones, selección de información relevante y diseño y ejecución de un algoritmo. Los resultados arrojaron un impacto positivo, ya que se observó un incremento en el pensamiento creativo, además de un fortalecimiento en la metodología activa para promover habilidades de pensamiento crítico y trabajo colaborativo.

Palabras clave: pensamiento computacional, robótica, creatividad, TIC y STEAM.

Abstract

Computational thinking has become popularized not only as an activity related to computer programming but also as a capacity that anyone can acquire to help solve everyday problems. Therefore, the present research reports on a pilot study for the development of creativity and computational thinking through a robotics workshop within the comprehensive training activities of a higher education institution. A quantitative quasi-experimental longitudinal design was implemented through measurements of creative thinking at the beginning and end of the robotics workshops. Computational thinking was integrated as a strategy for problem-solving in the Robotics workshop, where students were required to tackle small challenges following six steps: understanding the situation, identifying the difficulty, decomposing into constituent parts, recognizing patterns, selecting relevant information, and designing and executing an algorithm. The results are positive, as an increase in creative thinking was observed, in addition to a deeper understanding of active methodology to promote critical thinking skills and collaborative work.

Key words: Computational thinking, robotics, creativity. ICT and STEAM.

Resumo

O pensamento computacional tornou-se popular não apenas como uma atividade relacionada à programação de computadores, mas também como uma habilidade que qualquer pessoa pode adquirir para resolver problemas do seu dia a dia. Portanto, esta pesquisa aborda um estudo piloto para o desenvolvimento da criatividade e do pensamento computacional por meio de uma oficina de robótica que faz parte das atividades de formação integral de uma instituição de ensino superior. Especificamente, foi realizado um desenho quasi-experimental longitudinal quantitativo por meio de medições do pensamento criativo no início e no final da referida oficina. Neste processo, e como estratégia de resolução de problemas, foi incorporado o pensamento computacional para que os alunos pudessem resolver pequenos desafios seguindo seis etapas: compreensão da situação, identificação da dificuldade, decomposição em partes constituintes, reconhecimento de padrões, seleção de informações relevantes e design e execução de um algoritmo. Os resultados mostraram um impacto positivo, uma vez que foi observado um aumento no pensamento criativo, além de um fortalecimento na metodologia ativa para promover habilidades de pensamento crítico e trabalho colaborativo.

Palavras-chave: pensamento computacional, robótica, criatividade, TIC e STEAM.

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Introduction

Higher education institutions have recognized the prevailing need to provide comprehensive training to young university students. In response to this requirement, various strategies and actions have been implemented aimed at developing skills known as 21st century skills, which are aligned with the growing technological revolution driven by the integration of ICT in practically all areas of human life. For this reason, authors such as Méndez and Bermúdez (2023) maintain that computational thinking constitutes one of the fundamental skills of the 21st century.

Therefore, the purpose of this work is to explain how the implementation of comprehensive training workshops in higher education constitutes an ideal strategy to promote the development of computational thinking and creativity as essential skills in a transversal manner in university students.

A successful experience with robotics workshops is the one proposed by Gamito *et al.* (2019), who carried out a workshop with the Bee-Bot robot with university students. As a result, they observed that the introduction of robotics in the educational environment allowed students to explore a wide range of opportunities, foster vocations in science and technology, as well as stimulate STEM competencies. This was achieved through a constructivist teaching approach that integrates pedagogical content, computational thinking, creativity, communication skills and group work, while seeking to generate motivation and fun to achieve meaningful learning.

Likewise, the studies by Fernández *et al.* (2014) focused on examining the implementation of educational robotics laboratories at the Polytechnic University of Valencia with the purpose of improving the academic training of future professionals. These laboratories bring together students from various disciplines in work teams with the purpose of promoting interdisciplinary collaboration. The educational experience, specifically, focuses on solving real problems through robotics workshops, which makes it a transformative experience. Its objective is to bring students closer to the field of innovation, allow them to actively participate in projects and explore the field of university research. In this way, it was possible to familiarize students with the latest technologies on the market, overcome traditional classroom barriers and provide a broader and more applied perspective on their fields of study.

These types of experiences encourage technological innovation and critical thinking, and promote the development of computational thinking. That is, not only are capabilities promoted through the use of computer tools, but they also act as a stimulus for imagination and creativity in the construction of ideas in virtual environments (Huerta and Velázquez, 2021). In the words of Díaz-Barriga (2013), ICTs have left a marked mark in classrooms in recent years, as they have improved both the way in which they are integrated into the teaching process and the experience of acquiring knowledge for students and educators (Amin, 2018).

In summary, the comprehensive training workshop proposed in this work seeks to enhance not only the technical skills associated with computational thinking, but also critical thinking, problem solving and the capacity for innovation in students. These initiatives not only prepare students to face technological challenges, but also cultivate cognitive and creative skills that are essential for their comprehensive development and their ability to adapt in a constantly changing world.

Development of computational thinking in university students

According to Méndez and Bermúdez (2023), computational thinking is defined as a procedure to solve tasks through which the problem is abstracted and decomposed to be solved through logic, reasoning, imagination and creativity. According to Campbell and García (2022), computational thinking has two aspects of learning: one through programming and the other without using it, although both are based on problem solving. This type of thinking is not only limited to computer programming, but has also been applied in problem solving in other disciplines. For Pérez (2021), computational thinking can be promoted without the need to use computers, that is, through activities such as board games, story writing, metacognitive questions, among others.

For Vázquez (2019, cited by Campbell and García, 2022) “one of the 21st century skills that favors the analysis and relationship of new ideas for the organization and logical representation of procedures is computational thinking” (p. 48419), which can be applied at all educational levels in order for students to acquire the ability to handle technology.

Promoting creativity through robotics

As proposed by Guilford (1967) and Ballester (2002), the notion of creativity encompasses various dimensions, making it difficult to establish a universally accepted definition. Even so, it is usually linked to the concept of *divergent thinking,* a mental approach that involves exploring various possibilities to address a problem and trying to find the solution through the development of new ideas. In the field of psychological research, creativity is usually defined as the process that results in the creation of products that are original and useful (Runco and Jaeger, 2012).

Now, the relationship between the development of creativity through educational robotics is significant and stimulating, since the workshops are creative spaces that involve the design, construction and programming of robots with the aim of solving problems and designing projects. specific to prepare participants to face the challenges of an increasingly technological world.

Various studies, such as those by Jiménez and Cerdas (2014), Nemiro (2015) and Yang (2020), have positively assessed the effects of educational robotics in relation to creativity. According to Moreno (2012), educational robotics provides a favorable environment to support productive, creative, digital and communicative skills. Furthermore, it becomes a means for innovation by generating changes in the people, ideas, attitudes, relationships and approaches to action and thinking of both students and educators.

According to Odorico *et al.* (2005), educational robotics represents an innovative way to take advantage of technology to implement creative solutions based on ingenuity and skills. This author also states that the introduction of technologies in the educational environment seeks to create interdisciplinary learning environments, where students can develop skills to structure investigations and address specific topics. The purpose is to train individuals with the ability to acquire new skills and offer efficient responses to the changing environments of the contemporary world.

Methodological framework

A descriptive quantitative study of a quasi-experimental longitudinal nature was carried out with the objective of analyzing the impact of the robotics workshop on the development of creativity in students, which made possible the collection of quantifiable data and the detailed description of the variables. Specifically, participation in the robotics workshop constituted the independent variable, while creativity levels was the dependent variable. For the measurement process, the standardized Torrance test (1974) was used, adapted by Jiménez *et al.* (2007).

Instrument design

To evaluate creativity, the Torrance Test (Torrance *Tests of Creative Thinking,* TTCT) was used, adapted by Jiménez *et al.* (2007), which consists of three subtests or games. The first, called "Compose a drawing", evaluates the characteristics of originality (ORI) and elaboration (ELAB). The second, "Finish a drawing", seeks to assess the skills of fluency (FLU), flexibility (FX), originality and elaboration. Finally, the third, "Game 3: the parallel lines", evaluates all the components of creativity.

The reliability of the instrument has been supported by the studies of Jiménez *et al.* (2007), where a score of 0.71 was obtained in the two-half Guttman test. Likewise, the Torrance test has already been validated in the Mexican population through the studies of Zacatelco (2013), who applied the Wilcoxon and Anova tests with positive results in both cases. The elements of creativity that were evaluated were the following:

- Originality (PD ORI): Evaluates the ability to generate unique and unconventional ideas.
- Fluency (PD FLU): Measures the number of ideas generated in a given period and reflects the ability to think quickly and energetically.
- Flexibility (PD FX): Evaluates the ability to change from one category to another and adapt to different perspectives and approaches.
- Elaboration (PD ELAB): Measures the ability to develop and expand ideas in a detailed and complete manner.

The overall creativity score (PC) was calculated using the following formula:

$$PC=\sum(PDORI+PDELAB+PDFLU+PDFX)$$

This comprehensive approach provides a complete view of the different creative dimensions of the participants, since the instrument is reliable and has been validated to measure their performance in various areas of creative thinking.

Procedure

Before the workshop, demographic data was collected and the Torrance pretest was administered. Then, during the workshop, observations were recorded about the specific activities that foster creativity. At the end, the post-test was administered again.

Analysis of data

A descriptive statistical analysis was carried out to examine trends in the development of creativity. Likewise, the results of the pretest and posttest of the creativity index from the workshop were compared using T-Student statistical tests, which are used to contrast the means of two measurements and determine if there is a significant difference between them. The formula for calculating the Student T-test for parametric samples depends on the type of experimental design and whether the variances of the two groups are considered equal or different.

Workshop implementation

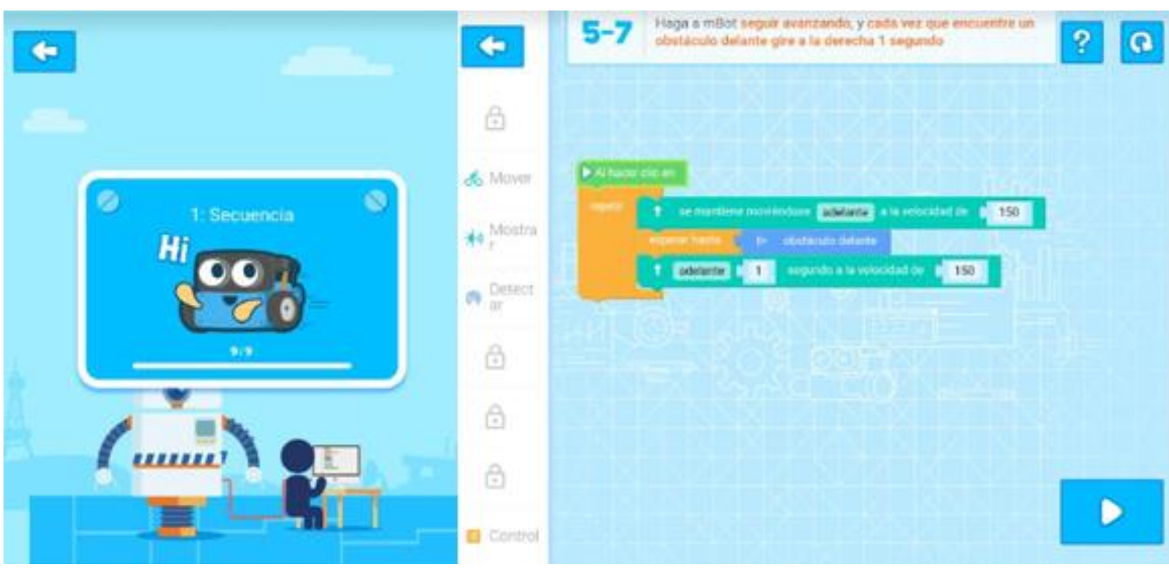
The robotics workshop was held during calendar 2023A, lasting 12 weekly sessions. Each session lasted one hour, divided into two moments. In the first, visual programming tools were introduced using the mBlock Blockly application in story mode. In the second moment, a challenge was posed that the participants had to solve using what they experienced in the story mode. These activities were designed to stimulate creativity, problem solving, computational thinking, and mBot robot programming.

The latest version 6.0 of the mBlock Blockly app offers two ways to learn how to use the mBot robot: story mode and create mode. It is recommended to start with the first option, which consists of 10 levels to learn to program using blocks. Each level has between 5 and 6 sublevels with an associated theme, where the student learns in a guided manner and progressively begins to add blocks to improve their skills and face challenges. As seen in figure 1, the blocks of some tool. If you make mistakes, the application will point them out and you will need to correct them to continue. To take advantage of the application it is necessary to connect the mBot using the Bluetooth connection of a tablet or cell phone. The levels are as follows:

1. Sequence
2. Speed
3. Repeat
4. Stop
5. Wait
6. Judgment
7. Conditions
8. Comparing
9. Light
10. Worth

Each section consists of different exercises aimed at teaching students how to program the mBot using blocks, addressing topics such as movements, turning lights on and off, using logical operators to repeat blocks, and obstacle detection.

Figure 1. Blocky mBlock tool (story mode)



Source: Makeblock (2023)

For the second moment, in which the participants were intended to solve a problem or challenge, the following six-step methodology was followed:

1. Understanding the situation.
2. Identification of the difficulty.
3. Decomposition into constituent parts.
4. Pattern recognition.
5. Selection of relevant information.
6. Design and execution of an algorithm.

Population and sample

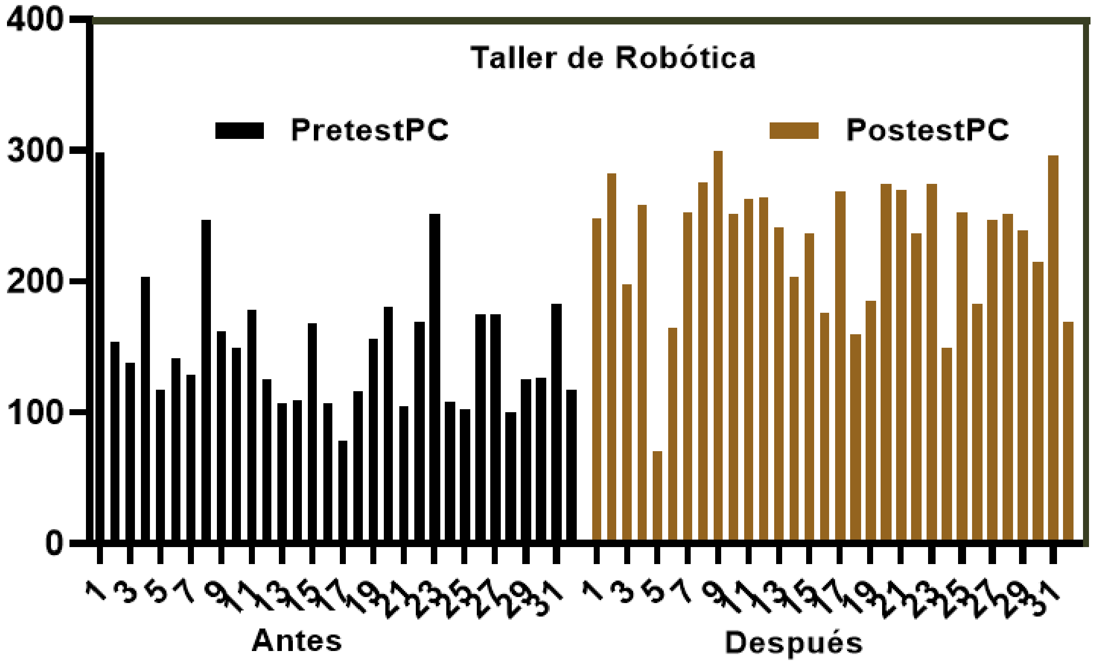
The population was made up of higher-level students who decided to enroll in the robotics workshop as an extracurricular activity to complement the credits of the comprehensive training. In total, 39 students enrolled, of which 32 students participated voluntarily, which corresponds to 82%. The sample was made up of students from various careers: 5 from public accounting, 7 from law, 8 from computer engineering, 5 from administration, 4 from psychology, 2 from dental surgeon and 1 from medicine.

Results

After carrying out the 12 comprehensive training sessions through robotics workshops during the university period, in which 32 students from various majors participated at the Los Altos University Center, notable progress was observed in the majority of the students., as shown in Figure 2, as evidenced in the pretest and posttest tests of the Torrance questionnaire. This progress was reflected in the increase in creativity, evaluated both at the beginning and at the end of the sessions.

It should be noted that the robotics workshops were held on Tuesdays from 2:00 p.m. to 3:00 p.m., between the months of January to May. These sessions included the participation of students from various disciplines offered by the Los Altos University Center.

Figure 2. Pretest-posttest creativity PC distribution

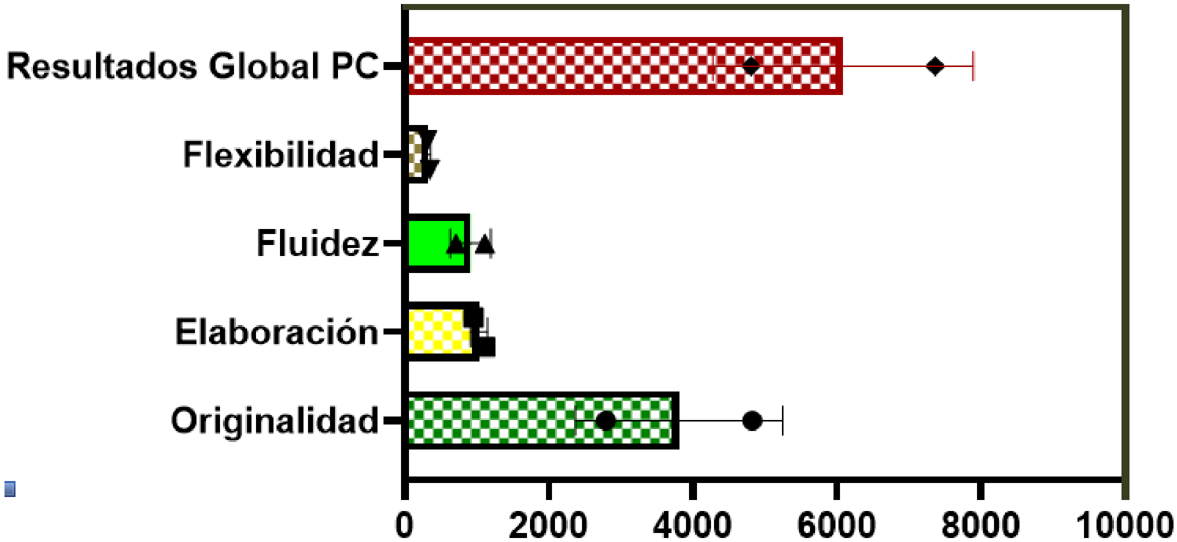


Source: self-made.

Of the 32 university students involved in these robotics sessions, an increase was evident in 31 of them. Figure 2 shows the results obtained by the 32 students, as well as the performance before and after the application of the Torrance test.

In the pretest, similar results were identified in the majority of students, with scores that fluctuated between 110 and 120 points, while only 2 students reached 250 points. When comparing these results with the post-test, a significant increase in creativity is observed, as seen in figure #3, an average increase of 180 points is evident in the majority of higher education students. In fact, only Student 5 experienced a decrease in performance.

Figure 3. Result by component of creativity and the global PC value of the pretest-posttest

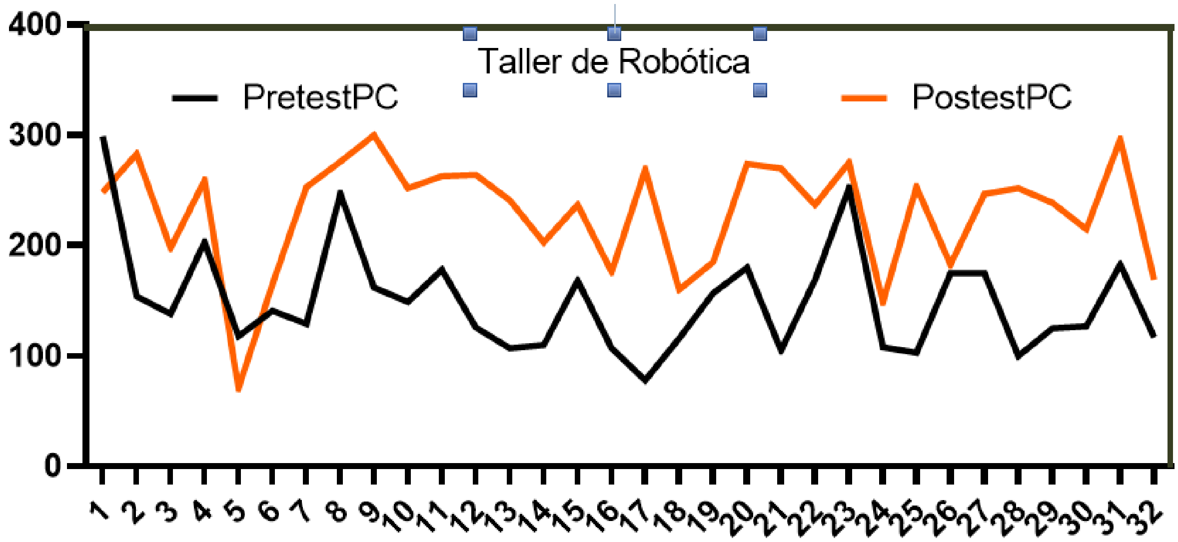


Source: self-made

Figure 3 presents the results obtained from the components of creativity. A significant increase in originality is observed, since the global score in the pretest was 2793 points, while in the posttest it reached 4823 points. Simultaneously, fluency experienced a positive improvement with an increase of 396 points. It should be noted that the preparation component experienced a decrease of -36 points.

Figure 4 shows the results obtained from the Torrance test, where the scores of each of the students can be clearly observed. The increase in creativity is evident after taking the 12 sessions of the robotics workshop, during which different practices were carried out, from the use of the mBot to the creation of challenges within the classroom. Likewise, you can see the result obtained by student 5, the only one who showed a decrease in creativity.

Figure 4. Comparison between the pretest-posttest of the global CP level of the 32 participants



Source: self-made

On the other hand, the Shapiro-Wilk normality test was performed for samples less than 50, and the result was p = 0.05 for the pretest and p = 0.007 for the posttest, which indicates that the data have a normal distribution. Therefore, the T-Student parametric test can be applied. When applying the T-Student statistical test, a value of p = 0.000 was obtained, which leads us to conclude that there is a significant relationship between robotics workshops and the development of creativity (table 1).

Table 1. T-Student test for the pretest and posttest of the global PC result

Paired Samples Test					
	95% confidence interval of the difference				
	lower	Superior	t	gl	Sig (bilateral)
Pair 1 pretest-posttest	-100.55896	-59.19104	-7,876	31	,000

Source: self-made

This procedure helps determine if there is a significant difference between measurements taken before and after the intervention; In addition, it offers information about the effectiveness of the intervention.

Discussion

According to the global score of the creativity test, an increase of more than 50% was evident. These results are consistent with the findings of Yang (2020), who in his research found that educational robotics supports the development of various higher-order skills, such as metacognition and progressive creativity. In addition, an educational approach based on research, discovery and learning through mistakes and failures is promoted. Therefore, the data of our study are directly linked to the stated objectives.

On the other hand, it can be indicated that the workshops and laboratories where learning by doing is encouraged are excellent spaces for the development of creativity, innovation and computational thinking, which was evidenced during the experience by the interest on the part of the students, in addition to the generation of a collaborative environment. These findings coincide with those of Fernández (2014), who from a technological point of view observed advances in knowledge and interdisciplinary learning in similar laboratories. Students develop prototypes that address technical challenges and consider economic aspects, effectively using resources. This practical approach encourages the development of practical skills, competencies and attitudes to solve problems in multidisciplinary environments.

Regarding the development of creativity, it is a complex process, since a series of variables intervene that are not completely controllable (Almeida *et al*., 2008). This study, in fact, presented low levels in the flexibility component (-36 points in the global results between the pretest and posttest), which can be used for the design of strategies in robotics workshops, since flexibility is related to the ability to find solutions to the problems posed (Jiménez *et al*., 2007). In other words, it is necessary to implement activities that encourage students to raise new ideas and propose various solutions to the problem.

Likewise, the study data demonstrate that the presence of robotics represents multidisciplinary support for students of any career, since it allows them to increase their knowledge and acquire skills that they can implement in their professional and personal development. In fact, the results obtained indicate that, in terms of curricular content, robotics offers favorable results in increasing interest in taking the workshops (Berenguel *et al*., 2012).

Finally, it is important to remember that one of the limitations of this project, referring to robotics workshops, is the selection of the sample, since the university center offers the workshop with only 40 spaces distributed in two shifts. In short, the results, being from a limited population, cannot be generalized.

Even so, one of the advantages of the call for robotics workshops is that it was extended to the entire university community where this research was developed, which demonstrates that computational thinking is a generic competence.

Conclusions

With this work it was possible to verify that the applied robotics workshop allowed us to stimulate the students' problem-solving abilities, despite the fact that not all of them were pursuing computer science degrees. This shows that this educational experience represents a bold step towards more relevant and effective teaching in higher education, since students not only acquire abstract knowledge, but also materialize their ideas into tangible prototypes, following the learning-by-doing approach. That is, this methodology not only enriches academic training, but also strengthens critical thinking and improves creativity.

Therefore, it can be stated that educational robotics offers a varied and multidisciplinary alternative to promote STEAM learning by providing a practical experience, encouraging creativity, developing technological skills and preparing students for the challenges of the future.

In this sense, it has been proven that practical learning is a viable alternative in robotics workshops and STEAM learning, since it provides a tangible opportunity to apply theoretical concepts in a more real and fun environment.

Finally, in the posttest tests, an increase in creativity was found because the students had the opportunity to work on the design, construction and programming of robots.

Future lines of research

It is crucial to follow up on the educational robotics project to specify how it can allow them to improve their skills and knowledge. Specifically, we must investigate the way in which this multidisciplinary learning can be applied in various careers, especially when addressing the solution of real theoretical problems through the use of robotics as a facilitating tool for carrying out projects with impact in their context.

In addition, it is important to explore other lines of research, such as the interdisciplinary inclusion of tools such as Arduino, MicroBit and 3D printers to promote the *maker movement*, which is closely related to the development of STEAM skills and competencies, based on pedagogical approaches such as constructionism. and, in particular, *tinkering*. The latter is an approach that promotes experimentation, manipulation and informal play with objects and tools to understand how they work and find solutions to problems through the stimulation of exploration and curiosity.

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