

Robotics and development of Computational Thinking: A research with primary school children in Huancavelica, Peru

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Abstract

Different pedagogical approaches use programming skills to develop students' technological knowledge in schools leading mainly to the development of theory, all of this according to a traditional teacher-to-student knowledge transfer model. The purpose of the research was to understand the development of computational thinking of a group of 14 children, aged from 6 to 9 years old and all of them in primary school, using robotics from a constructionist perspective. The research approach is qualitative, which allowed us to follow up through observations (of) the actions performed by the students; starting with very simple activities, such as disassembling and assembling the Zowi BQ robot, then performing mechanical activities related to mathematical concepts and finally robotics activities, integrating programming with LEGO-WeDo 2.0. This intervention allowed the children to understand the basic fundamentals of computational thinking as a result of three educational projects. This research shows evidence of how students are able to understand the development of computational thinking by the design of sequences in the robots programming for problem solving and integrating areas of Science, Technology, Engineering and Mathematics; as well as strengthening their communication skills and creativity.

Keywords: Computational thinking, robotics, computer programming, information theory.

INTRODUCTION

Robots have become one more component in our society, gradually entering the different tasks of human life; in this context, children are already adapting to these changes; as a consequence, they should learn the fundamentals of robotics from an early age and to solve any problems of the real-life environment, It must be related to the development of computational thinking. In this sense, robotics should be integrated into the different levels of education, allowing students a deeper understanding of the different areas of science in education (Mubin et al., 2013).

In the context of the advancement of technology, it is necessary to internalize the potential of educational robots as a scenario for the development and improvement of learning in computer science, electronics, mechanical engineering, languages, mathematics and other areas of science. In this line, computational thinking (PC) appears as a very significant topic in the field of education and that is closely related to STEM (Science, Technology, Engineering and Mathematics) (Tsoy et al., 2017), this being a thought process involved in identifying problems and providing solutions; that is, all these issues are part of the computational thinking that involves the design of systems, problem solving and understanding of human behavior, turning to the fundamental concepts of computer science (Wing, 2006, p. 33).

In countries such as the United States, Japan, Korea and the European Community (Furber, 2012; Gander et al., 2013; INTEF, 2018), educational robotics, programming and computational thinking are part of the school curriculum; while in Latin America its incorporation is very incipient. In the Spanish context García-Valcárcel & Caballero-González (2019), demonstrate that it is possible to develop computational thinking skills with students from 3 to 6 years old in preschool stages. They also highlight the impression of the integration of robotics in the development of meaningful learning, referring to the formation of digital skills related to programming.

In Peru, in 2011, the Ministry of Education distributed robotics kits to 20732 educational institutions (Morales et al., 2018), 65% of which are located in rural areas with multi-teacher and multigrade participation in primary education; the results were not favorable, because a high percentage of robotics kits are unused by students due to lack of teacher training. In the Huancavelica region, a high percentage of educational institutions are located in areas of extreme poverty and social exclusion, students residing in these areas do not have technological resources at home, there is a digital divide with respect to students in urban areas; as a consequence, there is evidence of low levels of skills related to the use of ICTs (Quintanilla Córdor et al., 2019).

To contribute to the purpose, the article conducts a study on the use of educational robots with primary school children aged between 6 and 9 years in the province of Huancavelica, from rural schools with a training below comparative levels with schoolchildren who study in the schools of the capital Lima.

From the above, the objective of the research was to understand the development of computational thinking of 14 children from 6 to 9 years of age of primary education using educational robotics from a constructionist perspective.

Educational robotics

Robotics has a multidisciplinary nature and provides constructive learning in STEM environments, which is suitable for a better understanding of scientific and non-scientific knowledge (Vavassori Benitti & Spolaôr, 2017); in this sense, educational robotics constitutes a very important didactic resource for the development of an education focused on STEM areas (Ferrada-Ferrada et al., 2020). In this context, many researchers consider educational robotics as an important tool for the development of students' thinking and creativity (Sullivan, 2017), a tool for the development of knowledge, for the development of skills and a tool for learning (Eguchi, 2014; Papanikolaou & Frangou, 2009) and learning object.

The inclusion of robotics in the educational curricula of many countries, allows the integration of the teaching of robotics, programming and computational thinking. These components integrate the methodological-didactic approach of Science, Technology, Engineering and Mathematics (STEM); although there is no clear consensus on the nature of content and pedagogical interaction between STEM fields (Holmlund et al., 2018).

In the methodological and didactic part, educational robotics can take two forms: the first, that robotics is related to issues of artificial intelligence, robot mechanics and others, which are the learning objects in the study center; the second, is when robotics is used as a learning tool to develop STEM (Eguchi, 2014; Papanikolaou & Frangou, 2009). In addition to teaching students technology and other school subjects, educational robotics can also impart skills to develop engineering topics and problem-solving skills (Wing, 2006).

Computational Thinking (PC)

For the research work, we start by taking a look at the proposals made by different researchers; in this regard Wing (2006), defines as a set of skills and abilities ("mental tools"), usual in computer science professionals, but that all human beings should possess and use to "solve problems", "design systems" and, surprisingly, "understanding

human behavior" (Adell Segura et al., 2019; Sáez-López & Cózar-Gutiérrez, 2006).

The PC is a fundamental skill of the student and professional in any discipline, because it is an approach that allows solving problems in an innovative way (Picado-Arce et al., 2021). In the student, the PC generates the ability to make various types of analysis, creativity, innovation, to generate divergent-abstract thinking that allows facing a problem in a simpler and more creative way. The PC is a methodology that is based on the basic concepts of computer science, solving frequent problems and performing tasks of daily living. This new way of approaching everyday problems allows us to solve with solvency problems that are sometimes very complex for a person (Basogain Olabe et al., 2015, p. 3); in that sense, it is important to promote the development of creativity in children (Medina Sánchez et al., 2017).

Concepts and indicators of computational thinking

Being the PC a cognitive process that involves logical reasoning and through which problems are solved; Therefore, students must achieve the following capabilities:

- The ability to think algorithmically;
- The ability to think in terms of decomposition;
- The ability to think in generalizations, identifying and making use of patterns;
- The ability to think, in abstract terms, choosing good representations;
- The ability to think in terms of evaluation (Csizmadia et al., 2015, p. 6).

Hence, it must be understood that the teaching and integration of PC concepts are related to the improvement of the student's analytical skills, providing a better understanding of problem solving through programming; it also improves women's attitudes and confidence towards programming (Espino Espino & González González, 2016). Consequently, the PC is a basic and fundamental skill that any person or individual must have in the digital reality and that should be considered part of the common subjects or disciplines (reading, writing, arithmetic or music) as a basic package in the development of the analytical-instrumental skills of any student.

Research shows that computational indicators are based on (3) key dimensions: Computational Concepts (concepts that interact with as programming is performed: cycles, iteration, parallelism, etc.), Computational Practices (develop programming practices while interacting with concepts: debugging projects or remixing the work of others) and Computational Perspectives (the perspectives of how they see their environment around them). (Arranz de la Fuente & Pérez

García, 2017). Hence, the PC proposes four levels or categories that can help solve different problems.

Step 1) Decomposing — Actually, it's splitting a problem into something much simpler. Many times, big problems consist of small problems, all together they make the problem bigger.

Step 2) Patterns—Sometimes when a problem has many small parts, you'll notice that those parts have something in common. If they don't have it, then maybe they resemble to a greater or lesser extent something that has already been solved before. If you show these patterns, it becomes simpler to understand the different pieces that make up the problem.

Step 3) Abstraction—Once you recognize a pattern, you abstract (ignore) details in which several different things differ, and using this is like generalizing and getting a solution that works for several problems at once.

Step 4) Algorithms—When a solution is complete, you can make a description that allows you to process it step by step, so that the result is easy to obtain.

Being the research work of qualitative cut and a structuring of the research process with projects that go from a basic level to reach a complex level according to the relevant age; It begins with the presentation of robots in an exploratory way; Then, with the development of an activity on the operation of the gears, the application and use of the gears in the modeling of the garbage collection vehicle. At each stage of the research the level of complexity was presented taking into account the basic fundamentals of robotics.

Finally, the research is based on Seymour Papert's theory of constructionism (Alimisis & Kynigos, 2009; García et al., 2016), with projects in different areas of science (Abelson et al., 1975), such as mathematics, computer science, electronics and mechanics, addressing the development of the PC through the use of educational robotics with students from 6 to 9 years of age from different educational institutions of Huancavelica; the activity was carried out in the Educational Robotics laboratory of the Faculty of Education Sciences of the National University of Huancavelica with two types of educational robots: BQ Zowi and Lego WeDo 2.0.

MATERIAL AND METHODS

It is an evaluative research work, for this purpose Robotics workshops were implemented for 14 primary school students in the Huancavelica Region (table 1). Participation was negotiated with schools, teachers and their parents. The confidentiality of the participants is safeguarded. The

children come from different educational institutions (5 schools in the region). The economic conditions of the participants are poor or very poor.

Table 1 Age of participants by sex and age

Age	Girls	Children	Total
6 years	1	3	4
7-8 years	3	2	5
9 years	2	3	5
Total	6	8	14

These workshops are monitored through observations of children in the process of developing the activities.

To this end, and based on the theory of competencies in robotics and computational thinking, the team implemented a set of tests and records. The tests consist of a diagnostic mini-interview to assess some previous knowledge about robotics, the observation on the type of volitional approach to these devices and the assessment by observation of the achievement of some skills, such as the description and assembly of a robot and the construction of projects with gears. The observation log includes testimonies from study participants, notes from the researcher, and photographs. These tests were validated by experts, so they are relevant to the children involved in the research.

The activities take place in the month of February 2022 for 4 weeks (one project per week: Tuesday and Thursday from 09:00 hours to 13:00 hours). At the beginning of the activities, two entrance questions were asked to each of the participants. The first question was what is a robot?, this question is aimed at allowing participants to describe about the robot and its components or elements of these; The second question was why does a robot move?, this question is aimed at verifying how much they know about the internal elements or components that act so that a robot can move; Also, how much they know about programming.

In this type of activity, the emotions of those who start with robotics are closely related to knowing how robots are composed (Bruni & Nisdeo, 2017); in this sense, the interest that children have in manipulating and touching is observed; they even ask and make comments among themselves in a low voice, referring to the different robots that are presented to them.

Project 1, Exploration of Zowi.allows you to explore the Zowi robot in groups of 02 children, in order to explore and then disassemble to see the components of the internal part of the robot and, then, reassemble said robot. Finally, the activity was to program so that the Zowi robot can perform movements.

Project 2, Connection and interaction between gears, allows to generate movement of a structure through the use of an element that interacts as a connector between two or more gears; this design allows to explain the basic concepts of pulleys and gears, making use of the WEDO 2.0 kit. This activity concerns finding the ratio of rotation of two gears in relation to the number of teeth of each of them; In addition, the types of movements: rotating and linear.

Project 3, Garbage Collection Vehicle, allows participants to design a garbage collector taking into account the basics of pulleys and gears; in addition, this project promotes solving a problem of recycling garbage and caring for the environment.

After conducting the workshops, the development of each of the participants is evaluated with an instrument described above. The analysis is a report that includes the initial diagnosis, the context of the workshops and the way in which the participants manage to conceive the concept of computational thinking at each level of the CP according to age.

RESULTS AND DISCUSSION

As a result of the programmed activities, results are obtained according to the four levels of computational thinking. In the first moment, the children do the exploration of the Zowi robot, which allows them to observe, manipulate and then disarm to explore the internal part of the robot, since initially it causes curiosity in them to see the mechanism of the internal part and reassemble and then give orders through programming (figure 1).

Figure 1 Disarmed and armed with a Zowi BQ robot



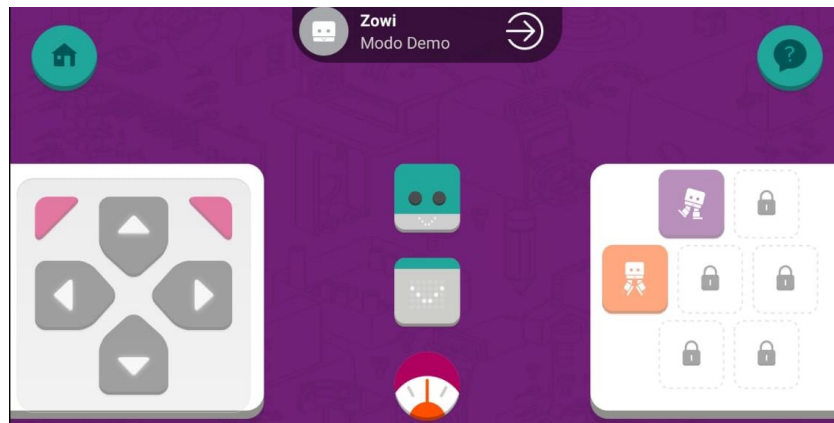
In the process of the activities, the children observing make the following comments:

Jhon: "There are only some cable connections and small boxes that give movement to the robot"

Jose: "The boxes make the robot's legs move, but you can't see the inside"

The children were filled with excitement at the disassembly of the robot Zowi; They expected to observe something much more visible in terms of the part of the systems hidden inside the engines; However, it was a bit disappointing to find not very visible elements of the robot's internal components. To show what they expected, they are presented with a robot made of balsa wood that has the same internal structure of a servo motor. Again the children, in this aspect, did observe with great attention the whole structure of the robot, because they appreciate how the system of discs, pulleys, the motor, the battery and the connections to give movement to the robot works. Then they reassemble the Zowi robot and perform the basic programming by pressing the buttons (Figure 2) to walk, dance, dodge obstacles, emit sounds and gesticulate, managing to understand the concept of sequentiality. In this case, the programming is Zowi.

Figure 2 Interactive programming platform of the Zowi BQ robot



When disassembling the Zowi robot, 6-year-olds fail to express themselves on the decomposition category; however, children between 7 and 9 years of age manage to identify this category, that the robot is composed of many components and each of them fulfill different functions. In addition, in terms of programming they understand that there is the notion of patterns when they perform programming sequentially.

From here, project 2 is developed, which concerns the connection and interaction between gears with WeDo_Lego parts (figure 3 (a)). Children explain the number of turns made by the disc or small gear that comes into contact with the large gear (small 8-tooth gear and large 24-tooth gear). From these activities, participants recognize the role that the gear system plays in the behavior of robots.

As for the number of turns that a small gear makes in relation to the large gear, most children can identify that a small gear makes more turns than a large gear when they are in contact; However, regarding the mathematical concept of reason, they fail to identify the numerical value

based on the number of teeth that the gears have when one of them makes a complete turn; since in this relationship reason fulfills as an operator to expand or shrink (Sánchez Ordoñez, 2013).

The third project is related to the preservation of the environment; students develop a design of a robot that performs such action. Being a fairly complex process, children manage to design and build a single robot model with some difficulty (figure 3 (b)).

Figure 3 Gear system construction and garbage collector robot design



The robots built have a certain characteristic, since it has been induced to a single model, because the children could not design their projects, but they could understand that, from the proposal, the gear systems are part of the robots.

Table 2 Identification of programming activities carried out by children

Age	Observation of activities	Quantity
6 years	There is an incipient conceptualization of the process of breaking down the whole into parts. They fail to recognize patterns.	4 (28%)
7-8 years	The participants manage to understand the decomposition process, but regarding the patterns only three manage to identify the patterns, while two participants are in the process of understanding the patterns in the construction of the robot and programming.	5 (36%)
9 years	They understand certain patterns in the construction of the robot, as well as in programming; At the same time they understand the process of breaking down their components into parts.	5 (36%)

So far, the research work has been proposed, sequencing the projects from a basic level to reach a much more complex level taking into account the basic fundamentals of robotics.

Taking into account the ages of the participants ranging from 6 to 9 years, as well as the experience of performing activities for the first time in the field of robotics, the children manage to achieve the proposed

objectives regarding the decomposition and composition of the components of the robots; then, they understand certain patterns when performing construction and programming. This type of activity highlights the cognitive development in children that allows them to use programmable robots (INTEF, 2018).

Discussion

In robot construction and programming, sequences are described as a series of moments that must be performed to successfully perform a particular task (Brennan & Resnick, 2012; García-Valcárcel & Caballero-González, 2019); In this process, computational thinking describes the execution or action that the robot must do according to each instruction assigned to it during programming (Bers et al., 2014).

Consequently, with experiences through educational robotics activities, according to age, it is possible to develop computational thinking skills from early school stages (García-Valcárcel & Caballero-González, 2019); relating the basic fundamentals of robotics and STEM.

In this context, the development of a person's PC is developed through scheduled activities; these promote, communication, observation, guidance so that the child solves the task at a real level (Medina Sánchez et al., 2017); since children tend to orient their skills to feel emotions and have certain feelings towards robots that have humanoid or animal characteristics (Melinverni et al., 2021);

CONCLUSION

The study demonstrates the possibility of developing computational thinking skills in children through robotics activities from early school stages, as well as students from very poor economic conditions (students from households with high poverty rates). In addition, the research shows the impact that teaching robotics has on the meaningful learning process, promoting the development of digital skills such as programming.

Educational robotics allows the possibility of integrating different educational areas in an interdisciplinary way such as science, technology, engineering and mathematics (in English STEM) (Tsoy et al., 2017); in the experience, children manage to develop mechanical activities in interrelation with mathematics (gears), as well as relate to computing and develop the ability to sequence, Sort and schedule.

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