Caballero González, Y. A., & García-Valcárcel Muñoz-Repiso, A. (2017). Development of computational thinking and collaborative learning in kindergarten using programmable educational robots: a teacher training experience. In J. M. Dodero, M. S. Ibarra Sáiz, & I. Ruiz Rube (Eds.), Fifth International Conference on Technological Ecosystems for Enhancing Multiculturality (TEEM'17) (Cádiz, Spain, October 18-20, 2017) (Article 5). New York, NY, USA: ACM. doi:10.1145/3144826.3145353

# Development of computational thinking and collaborative learning in kindergarten using programmable educational robots: a teacher training experience

Yen Air Caballero González
GITE-USAL Research Group,
Education Faculty,
University of Salamanca
Paseo Canalejas, 169. 37008
Salamanca, Spain
ycaballero@usal.es

Ana García-Valcárcel Muñoz-Repiso
GITE-USAL Research Group,
Education Faculty,
University of Salamanca
Paseo Canalejas, 169. 37008
Salamanca, Spain
anagv@usal.es

## ABSTRACT

Nowadays, the teaching-learning processes are constantly changing, one of the latest modifications promises to strengthen the development of digital skills and thinking in the participants, from an early age. In this sense, the present article shows the advances of a study oriented to the formation of programming abilities, computational thinking and collaborative learning in an initial education context. As part of the study it was initially proposed to conduct a training day for teachers who will participate in the experimental phase of the research, considering this human resource as a link of great importance to achieve maximum use of students in the development of curricular themes of the level, using ICT resources and programmable educational robots. The criterion and the positive acceptance expressed by the teaching group after the evaluation applied at the end of the session, constitute a good starting point for the development of the following activities that make up the research in progress.

## CCS CONCEPTS

**• General and reference → Design •Applied computing → Education • Computer systems organization → Robotics • Social and professional topics → Computational thinking; Information technology education**

## KEYWORDS

Computational thinking, programming, robotics, collaborative learning, teaching-learning processes.

## 1 INTRODUCTION

The incorporation of information and communication technologies (ICT) in the educational field has allowed the emergence of an educational technological ecosystem, opening with this several opportunities for both teachers and students [1]. The new educational scenario is characterized by a ubiquitous access to information, learning methods with a strong component of collaboration and technology, and some participants with a higher level of criticality than the one that characterized the classroom in previous times [1],[2].

At present society requires individuals who can not only use technological tools in their activities, but through their use can produce momentous changes in processes and actions that are innovative, proactive and leaders with the ability to manage the Transformations demanded by the various productive sectors of an increasingly technological society [3].

The training of individuals with the necessary digital skills and competences to achieve an effective and efficient performance in this emerging digital society has given way to the development of more dynamic and participative techniques, methods and educational strategies [4]. The backbone of the transformation of the educational sector is the technological resources applied to the teaching-learning process. In this sense, Robotic Education (RE) is a technological current that is being used with great success in several regions, this is due in large part to the capacity of this educational technology to develop programming skills and computational thinking very necessary today day [3] [5].

The use of robotics and programming in the classrooms allow the development of meaningful learning in the participants, through collaboration and teamwork [6]. In this context students take part in work sessions whose objective is to solve the challenges and problems that arise, all within a playful and gamified environment.

The research related to this communication is in development and is based mainly on the training of programming skills and computational thinking in initial education students, using ICT resources and programmable educational robots. The theoretical foundations on which research is based are described in the article in Section II. The objectives of the research are presented in section III. The methodological approach to be used, the population covered by the study are detailed in section IV as well as the description of the experience of teacher training included in section V. Finally, the conclusions, acknowledgments and references used are presented.

## 2 CONTEXT

Nowadays the There are more and more voices within governments that propose the inclusion of learning programming or coding and computational thinking in the curricula of national education systems; this is the case in countries such as England which from the academic year 2014-2015 decided to include them as part of the academic curriculum of the primary and secondary education curriculum. Other states that have opted to make changes in the educational structures to incorporate this initiative are: Bulgaria, Cyprus, Denmark, Estonia, Greece, Ireland, Poland, Portugal, in Spain we find progress in the community of Madrid, Barcelona, Navarre, Galicia, Malaga and others. However, an important fact is the little concomitant that exists about the way to introduce the codification and the computational thinking in the curricular plans [7] [8].

Conceptually to think that since 2006 Jeanette Wing [9] introduced the term computational thinking and that some strategies have been developed to achieve optimal use of the technologies associated with its implementation as they are: the internet, robotics, gamification and others, there is no definitive agreement on its conceptualization and even more on the characteristics that make it up. Among the arguments associated with computational thinking is that it "involves solving problems, designing systems and understanding human behavior, based on the fundamental concepts of computing" [9]. This researcher also considered that the PC should be a fundamental skill for all people and not exclusively for the computer professionals.

For the 2008 Wing [10], it expanded the concept, stating that this type of thinking should be a basic competence that every citizen would have to know to develop in the digital society; computational thinking is neither routine nor mechanical, it is a way of solving problems intelligently and imaginatively [3] [11].

For 2011, in the United States, the 'Association of Computer Science Teachers' (CSTA) and the 'International Society for Technology in Education' (ISTE) developed a concept that has been used as a basis for Secondary and pre-university teachers in this region [3][11]. These organizations propose that the PC is a problem-solving process that includes a series of characteristics such as: problem formulation, logical organization, data analysis, abstraction through models and simulations, automate solutions through thought algorithm, generalize and transfer this problem-solving process to a wide variety of situations.

In the business sector, we also find some projects that have been carried out and that seek to strengthen the education sector, the development of algorithmic or computational thinking and the skills related to programming and coding [12] [13] [14]. One of these is the initiative code.org [8] [15], a non-governmental organization based in the United States, formed by companies with high technology such as Amazon, Apple, Dropbox, Academia Khan, Facebook, Google and Microsoft, among others and is currently a great reference in the matter of introduction to the world of programming and algorithmic or computational thinking.

In the European region, we find the TACCLE 3 project [7], which focuses its support on the teachers of the school, developing their confidence and motivation with a series of resources and activities that can be used as help in the development of the computer curriculum including coding and computational thinking.

In addition, state policies have been created that have enabled diverse countries to provide educational centers with the necessary technological tools to enable students to develop the digital skills necessary for the information and knowledge society [16][17]. As an example, we can mention in Spain the School 2.0 program [18], which has enabled the technological equipping of classrooms in educational centers through the incorporation of digital whiteboards, computers and educational software. Also, it has been formed in the use of TIC's to the teachers what has generated the opening for the development of other initiatives in matter of educative technology [13][15][16][17].

### 2.1 Related Jobs

At present, there is a strong development of technologies associated with education, educational robotics experiences the emergence of a great variety of solutions, both in benefits and prices. One of the focuses of greater educational orientation are the middle and university levels; however, there are more and more developments in robotic technology applied to an early school age.

Some examples are: KIBO which is a robotic kit designed specifically for children 4 to 7 years old. It allows designers to attract both technical-minded children and those who are more connected to the arts and culture or physical activity [19][20]. On the other hand, Lego WeDo, a tool designed by the renowned brand LEGO; this allows users to build a robot according to models and guides, so they learn and develop their imagination [11].

A strong trend is the incorporation of programming languages, environments and mobile applications that allow the control of robotic devices. One of these programming environments that allow participants to enter into this fascinating world is the visual programming language developed by the MIT Media Lab, known as Scratch [11].

For the study to be developed aimed at an early school age educational community, the use of the Bee-Bot robotic kit was considered as this provides a more practical handling of the mechanical parts of the kit as well as a simple and friendly functionality, through of colors and an outer shell with a soft texture and resistant [11].

**Figure 1: Bee-Bot**

The Bee-Bot [11] kit is a very colorful and easy-to-use bee-shaped robot, specially designed for younger children (Fig. 1).

## 3 RESEARCH OBJECTIVES

The general objectives of this research are the following:

- Design and integrate in educational practice activities mediated by ICT resources and programmable educational robots for the development of computational thinking skills and collaborative learning in elementary school students.
- Analyze the impact of the integration of ICT resources and programmable educational robots in the development of computational thinking skills and collaborative learning in an initial education context.

### 3.1 Specific Research Objectives

Among the specific objectives to be achieved in the research are:

- Design educational activities mediated by ICTs and programmable educational robots for elementary school students.
- Integrate into the educational practice of elementary school student's activities designed with ICT resources and programmable educational robots.
- To determine the influence of the integration of ICT resources and programmable educational robots in the achievement of curricular objectives and collaborative learning in initial education students.
- To establish that characteristics or domains of Computational Thinking are strengthened with the incorporation of educational activities average by ICT's and programmable educational robots.
- Elaborate a proposal for action for the integration of educational activities mediated by ICT's and programmable educational robots in elementary school students.

## 4 RESEARCH APPROACH

This study will use as a research methodology the mixed methods approach, with the intention of being able to perform a more complete or more holistic analysis and evaluation of the subject under investigation; taking full advantage of the complementary nature of quantitative and qualitative guidance [21][22]. The quantitative orientation of the research will be developed in two phases, the first of non-experimental type, transversal, since the data will be collected at a single time or time.

The second phase of the quantitative orientation will be through a non-equivalent control group, including pretest and posttest.

The qualitative approach of the mixed methodology will allow to explore the formation of algorithmic, computational thinking skills and the development of collaborative learning in an open and participatory way, involving students and teachers in the process. Additionally, the triangulation of methods for data collection will be used, contributing to the study a greater variety, richness and depth in the analyzes that will be carried out.

### 4.1 Population

The population comprising this study will be made up of students with an initial educational level (early childhood education) of centers located in urban areas. In this sense and thanks to the support received from the management and teachers of the Maestro Ávila school, located in Salamanca, autonomous community of Castilla y León, Spain, to carry out the research in its facilities will work with students and teachers belonging to the child education groups.

In total, there are six groups of students, with a total of 131 students and 8 teachers distributed in first, second and third kindergarten. With the ease of access to groups of students and teachers, the total population will be used for the study.

For this communication, we will be based on the day of teacher training in which all the teachers who attend the children's level and who participate actively in the development of the curricular contents belonging to the study program have participated.

## 5 OVERVIEW OF THE EXPERIENCE: Robotics for Teachers

To achieve the proposed goal of this research by developing computational thinking and collaborative learning skills in preschool children using ICT resources and educational robot programming, it was necessary to have a group of teachers motivated and convinced of the potential of robotics within the classroom [6].

**Figure 2: Teacher training day**

For this, a training session "My first steps in Robotics" was organized in which teachers could learn about the characteristics of the robotics kit, experiment with the scenarios through the approach of solutions to challenges and problems, and then be able to evaluate the possibilities educational model presented by the Bee-Bot robotic kit (Fig. 2).

The teachers could see how the Bee-Bot robot was constituted, appreciated that it is programmed using the buttons that are placed on the top of the robot. Also, as an electronic device has buttons on and off and a control for sound, which allows to capture the attention of students. It was understood that Bee-Bot is a safe material to be used by young students.

The Bee-Bot kit can be purchased individually or with other accessories such as exercise mats and specific challenges. In the development of the study will use rug designed according to the contents of the curriculum that are intended to address, for example: sequencing, laterality, mathematics, colors.

In the training received the teachers learned in a similar work environment to the one that will be used with the students, verified the possible movements of the robot and stated that the team remembers up to 40 commands and executes scripts moving according to what the programmer has indicated [11]. Bee-Bot does not break easily, is easy to manipulate and does not require a computer, which allows it to be a very attractive option to start small children in the programming world.


**Figure 3: Buttons used for programming movements with Bee-Bot**

### 5.1 Description of experiences and resources used

After knowing the physical characteristics and the operation of the robot kit Bee-Bot, the experimental part was realized. In this section of the training day, the teachers performed basic robot movement exercises using sequential programming instructions using the buttons located at the top of the robot (Fig. 3). To facilitate learning, a poster was prepared which indicated the movements accepted by the robot. In addition, a carpet or stage was designed on which the robot was to move (Fig. 4).

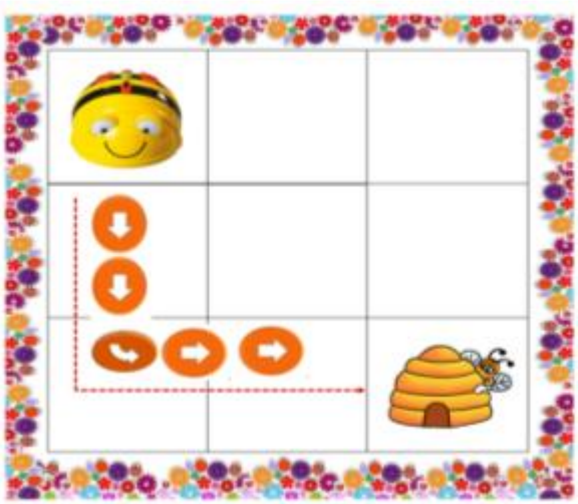

**Figure 4: Carpet or stage to carry out movements with Bee-Bot -Bot**

Another of the scenarios that were designed for teacher training consisted of a labyrinth, through which the robot had to move to solve the challenges or problems posed.

For example, how does Bee-Bot move to reach the honeycomb? Using the movement buttons of the robot, the script was prepared and the necessary tests and adjustments were made, until the appropriate solution was found (Fig. 5).

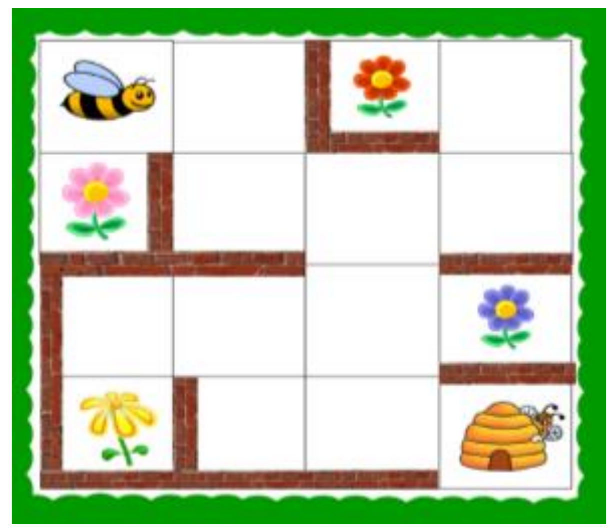

**Figure 5: Carpet or stage with the labyrinth challenge, to make programming sequences with Bee-Bot.**

In addition, several types of didactic materials were used during this training day: videos, posters, scenarios or mats, letters with examples of sequences; all this to facilitate the learning of the participants.

## 6 CONCLUSIONS

The development of this training day for teachers of child level has generated positive results regarding the acceptance and motivation to use educational activities mediated by programmable robots in students. By means of an opinion scale provided to them, they expressed their agreement that educational robotics allows the development of curricular objectives.

Likewise, they agreed that the activities developed through this technology allow the integration of students and the development of collaborative learning. For the last time teachers expressed that they were interested and motivated to use this technology as a resource within the classroom of children's level.

## ACKNOWLEDGMENTS

As for the first author, this research is possible thanks to a scholarship for research doctoral studies of the National Secretariat of Science, Technology and Innovation (SENACYT) and the Institute for Training of Human Resources (IFARHU) of the Republic of Panama. Also, our gratefulness to the teachers and directors of the Maestro Ávila School, located in Salamanca, autonomous community of Castilla y León.

This research work has been carried out within the University of Salamanca PhD Programme on Education in the Knowledge Society scope (http://knowledgesociety.usal.es).

## REFERENCES

[1] Valverde-Berrocoso, J., Fernández-Sánchez, M.R. y Garrido-Arroyo, M.C. (2015). El pensamiento computacional y las nuevas ecologías del aprendizaje. *RED, Revista de Educación a Distancia*. 46(3). Septiembre de 2015. http://www.um.es/ead/red/46.

[2] Graells, P. M. (2013). Impacto de las TIC en la educación: funciones y limitaciones. *3 c TIC: cuadernos de desarrollo aplicados a las TIC,* 2(1), 2.

[3] Barr, D., Harrison, J., y Conery, L. (2011). Computational Thinking: A Digital Age Skill for Everyone. *Learning & Leading with Technology*, 38(6), 20-23.

[4] García-Valcárcel, A. y Hernández, A. (2013). Recursos tecnológicos para la enseñanza e innovación educativa. Madrid: Editorial Síntesis.

[5] García-Peñalvo, F. J., Hernández-García, Á., Conde-González, M. Á., Fidalgo-Blanco, Á., Sein-Echaluce Lacleta, M. L., Alier-Forment, M., . . . Iglesias-Pradas, S. (2015). Learning services-based technological ecosystems. In G. R. Alves y M. C. Felgueiras (Eds.), *Proceedings of the Third International Conference on Technological Ecosystems for Enhancing Multiculturality (TEEM'15)* (Porto, Portugal, October 7-9, 2015) (pp. 467-472). New York, USA: ACM.

[6] Pittí Patiño, K. (2011). La robótica educativa como un entorno tecnológico que promueve el aprendizaje colaborativo. En Hernández, A. y Olmos, S. (Eds.). *Metodologías de Aprendizaje Colaborativo a través de las tecnologías, Salamanca*, Ediciones Universidad de Salamanca, pp. 185-194.

[7] García-Peñalvo, F.J., 2016. Una breve introducción a TACCLE 3 - Codificación del Proyecto Europeo. *En 2016 Simposio Internacional sobre Computadoras en Educación (SIIE 16)*, F.J. García-Peñalvo y J.A. Mendes Eds. IEEE, EE.UU. DOI = http://dx.doi.org/10.1109/SIIE.2016.7751876.

[8] Román-González, M. (2015). Test de Pensamiento Computacional: principios de diseño, validación de contenido y análisis de ítems. In M. Á. Murga Menoyo (Ed.), Perspectivas y avances de la investigación (pp. 279-302). España: UNED.

[9] Wing, J. M. (2006). Computational thinking. *Communications of the ACM*, 49(3), 33-35. https://doi.org/10.1145/1118178.1118215.

[10] Wing, J. M. (2008). Computational thinking and thinking about computing. IPDPS Miami 2008 - *Proceedings of the 22nd IEEE International Parallel and Distributed Processing Symposium*, Program and CD-ROM, (July), 3717-3725. https://doi.org/10.1109/IPDPS.2008.4536091.

[11] García-Peñalvo, F. J., Rees, A. M., Hughes, J., Jormanainen, I., Toivonen, T., y Vermeersch, J. (2016). A survey of resources for introducing coding into schools. In F. J. García-Peñalvo (Ed.), *Proceedings of the Fourth International Conference on Technological Ecosystems for Enhancing Multiculturality (TEEM'16)* (Salamanca, Spain, November 2-4, 2016) (pp. 19-26). New York, NY, USA: ACM.

[12] García-Peñalvo, F. J.; Llorens-Largo, F.; Molero-Prieto, X.; Vendrell-Vidal, E. (2017). "Sección Especial: Educación en Informática sub 18 (EI<18)". *ReVisión (Revista de Investigación en Docencia Universitaria de la Informática)*, vol. 10, núm. 2, pp. 13-18.

[13] Zapata-Ros, M. (2015). Pensamiento computacional: Una nueva alfabetización digital. *RED, Revista de Educación a distancia*, 46.

[14] Zúñiga, M. E., Rosas, M. V, Fernández, J. M. y Guerrero, R. A. (2014). El Desarrollo del Pensamiento Computacional para la Resolución de Problemas en la Enseñanza Inicial de la Programación. *WICC 2014 XVI Workshop de Investigadores en Ciencias de la Computación*, 340-343.

[15] Kalelioğlu, F. (2015). A new way of teaching programming skills to K-12 students: Code.org. *Computers in Human Behavior*, 52, 200-210. https://doi.org/10.1016/j.chb.2015.05.047.

[16] Lee, I., Martin, F., y Apone, K. (2014). Integrating computational thinking across the K-8 curriculum. *ACM Inroads*, 5(4), 64-71. doi:10.1145/2684721.2684736

[17] Lye, S. Y., y Koh, J. H. L. (2014). Review on teaching and learning of computational thinking through programming: What is next for K-12? *Computers in Human Behavior*, 41, 51-61. doi:10.1016/j.chb.2014.09.012

[18] Gracía-Vacárcel, A., Basilotta, V. y López, C. (2014). Las TIC en el aprendizaje colaborativo en el aula de Primaria y Secundaria. *Comunicar*, 42, 65-74. https://doi.org/10.3916/C42-2014-06.

[19] Sullivan, A., Bers, M.U., Mihm, C. (2017). Imagining, Playing, & Coding with KIBO: Using KIBO Robotics to Foster Computational Thinking in Young Children. *In the proceedings of the International Conference on Computational Thinking Education, 2017*. Wanchai, Hong Kong.

[20] Sullivan, A., Bers, M.U., Mihm, C. (2017). Imagining, Playing, & Coding with KIBO: Using KIBO Robotics to Foster Computational Thinking in Young Children. I*n the proceedings of the International Conference on Computational Thinking Education, 2017*. Wanchai, Hong Kong.

[21] Hernández Sampieri, R., Fernández Collado, C. y Baptista Lucio, P. (2014). *Metodología de la investigación*. 6a ed. México, D.F. : McGraw-Hill Education.

[22] Johnson, R. B. y Onwuegbuzie, A. J. (2013). *Mixed Methods Research: A Research Paradigm Whose Time Has Come,* 33(7), 14-26.