Development of computational thinking through BlocksCAD, Blockly and problem-solving in mathematics

Desarrollo del pensamiento computacional a través de BlocksCAD, Blockly y la resolución de problemas en matemáticas

Ángel-Alberto MAGREÑÁN-RUIZ, PhD. Associate Professor. Universidad de La Rioja (*angel-alberto.magrenan@unirioja.es*).

Rubén-Arístides GONZÁLEZ-CRESPO,PhD. Professor. Universidad Internacional de La Rioja (*ruben.gonzalez@unir.net*).

Cristina JIMÉNEZ-HERNÁNDEZ. PhD candidate in Mathematics at Universidad Politécnica de Valencia (*cjimher@doctor.upv.es*).

Lara ORCOS-PALMA, PhD. Associate Professor. Universidad de La Rioja (*lara.orcos@unirioja.es*).

Abstract:

The development of computational thinking has become one of the educational priorities in several countries around the world. In this article, two experiences are described in which two block programming tools are used. The first experience only used BlocksCAD, while the second added the use of Blockly and the work on some mathematical algorithms in a maths classroom. The number of participants in the experience was twenty-eight in the group that only used Blocky and thirteen in the group that combined the use of both tools, all of them of the third year of secondary education (between 14 and 15 years old) in a school in Spain. The results show that, although the use of BlocksCAD alone allows an increase in the development of CT, if other resources such as Blockly are also used in the mathematics classroom, the effect is multiplied. In addition, considering the satisfaction results of the participants in the experience, together with the possibility of printing their own creations through 3D modelling (a fact claimed by the students themselves), this encourages us to continue using both tools and even to try to combine them with other tools and to design experiences that encompass entire academic courses or, at least, entire trimesters.

Keywords: computational thinking, problems, mathematics, mathematical modelling, technologies, BlocksCAD, Blockly, Secondary, Spain, education, 3D printing, group comparison, satisfaction.

Resumen:

El desarrollo del pensamiento computacional se ha convertido en una de las prioridades educativas en varios países del mundo. En este artículo, se describen dos experiencias en el aula en las que se utilizan dos herramientas de programación por bloques. En la primera, solo se empleó BlocksCAD. En la segunda, se trabajó, además, con Blockly y con varios algoritmos matemáticos. El número de participantes en la experiencia fue de veintiocho en el grupo que solo utilizó Blockly y de trece en el que combinó el uso de ambas herramientas. Todos ellos cursaban tercero de educación secundaria (entre 14 y 15 años) en un colegio de España. Los resultados muestran que, si bien el uso de BlocksCAD ha permitido, por sí solo, incrementar el desarrollo del PC, la combinación con otros recursos como Blockly en el aula de matemáticas puede multiplicar su efecto. Además, los participantes expresaron su satisfacción con la experiencia. Como propuesta de futuro, se plantea la posibilidad de que el alumnado pueda imprimir sus propias creaciones mediante modelado 3D, algo que ellos mismos pidieron. Esto nos animaría a seguir utilizando ambas herramientas e, incluso, a intentar combinarlas con otras y diseñar experiencias que abarquen cursos académicos o, al menos, trimestres completos.

Palabras clave: pensamiento computacional, problemas, matemáticas, modelado, tecnologías, BlocksCAD, Blockly, secundaria, España, educación, impresión 3D, comparación de grupos, satisfacción.

Revista Española de Pedagogía
year 82, n. 287, January-April 2024, 135-152

Date of reception of the original: 2023-07-10.
Date of approval: 2023-10-13.
Please, cite this article as follows: Magreñán-Ruiz, Á.-A., González-Crespo, R.-A., Jiménez-Hernández, C., & Orcos-Palma, L. (2024). Development of computational thinking through BlocksCAD, Blockly and problem-solving in mathematics [Desarrollo del pensamiento computacional a través de BlocksCAD, Blockly y la resolución de problemas en matemáticas]. *Revista Española de Pedagogía, 82* (287), 135-152. https://doi.org/10.22550/2174-0909.3933

1. Introduction

In a society like the current one, in continuous change, digital literacy acquires its full potential and training in the technological field is essential for future students so they can respond to the challenges that society will face. Moreover, the introduction of educational technology in the Spanish system is clear in recent years (Vargas-Quesada et al., 2023). It is for this reason that in the nineties the term STEM (science, technology, engineering and mathematics) emerged at the NSF (National Science Foundation) in the United States, which encompasses the four areas of knowledge that are worked on in the scientific and technological fields. This model arises from the work of Seymour Papert in the eighties on the development of thinking in childhood, artificial intelligence and computer technologies for education in order to train future professionals to meet the demands of society.

There are many studies that propose working under the STEM model in classrooms (including Andersen, 2014; Orcos & Magreñán, 2018; Robinson, et al. 2014; Schroth & Helfer, 2017; Tofel-Grehl & Callahan, 2017). That is why curricula must evolve towards the inclusion of practices based on the implementation and development of strategies that help to promote critical thinking and talent among students in the scientific-technological field (Miedijensky & Tal, 2016).

Digital literacy has evolved from what Paul Glister (1997) proposed in the late 1990s, the ability to understand and use information from many digital sources, towards computational thinking (from now on, CT). More and more studies based on classroom strategies at all academic levels show the effectiveness of the work of CT in securing achievements in the STEM field.

In the field of 3D modelling and printing, more and more computer programs being developed with increasingly simple interfaces so that they can be used by different age ranges in an intuitive way.

In this paper, a proposal is presented to work on CT in a class of third-year secondary education students through the use of BlocksCAD, a 3D modelling and printing tool. In this work, we worked with two groups of students: one made up of twenty-eight students, who only used BlocksCAD software, and another with thirteen students, who also used Blockly for two hours a week while studying mathematics. BlocksCAD is a tool that is gaining more and more weight in secondary education classrooms due to its ease of use. Its block programming and the fact that it is a very visual program make it a very useful and comprehensive tool for entry-level CT. The proposal that has been worked on consists of seven one-hour sessions that include a pre-test on knowledge of CT, several sessions of directed work with BlocksCAD, a final practical activity in which students had to integrate the acquired knowledge and the completion of a post-test and a satisfaction survey.

A study by Beltrán-Pellicer and Muñoz-Escolano (2021) explored the modelling of shapes such as spheres, cubes or tori in the environment with BlocksCAD, collecting the steps, rotations, translations, etc., carried out and finding two main difficulties: the complexity of the interface for not so simple objects and the ignorance of procedures. As a result of this experience developed for geometry work, the authors considered that the tool could be useful for the future work of CT. It is for this reason that research is needed into the potential of BlocksCAD.

The objectives of this study are to improve the development of CT in a sample of third-year compulsory secondary education students through the use of BlocksCAD and to compare the results obtained when using only said software or when combining its use with Blockly in a Maths Extension classroom.

2. Theoretical framework

This section contains the theoretical framework that supports this article. It begins with a description of CT. Afterwards, its relation to the STEM field and problem-solving is analyzed, as well as its use in the classroom with 3D modelling programs. Finally, the tools used in this study are described.

2.1. Computational thinking (CT)

As Wing (2006) comments, CT "is a fundamental competence for everyone, not just for programmers" (p. 33). Wing defines CT as problem-solving, systems design and an understanding of human behaviour through fundamental computer concepts.

CT does not refer only to the ability to program as it implies thinking at different levels of abstraction, which is why it applies to many contexts of everyday life. It is also based on the STEM model (science, technology, engineering and mathematics), since, when this type of thinking is performed, many other skills are also developed (Dapozo et al., 2017).

Zapata-Ros (2015) emphasises that CT is a specific thought in which

> coding skills are the most visible part of a way of thinking that is valid not only in this area of mental activity, which supports the development and creation of programs and systems [...]. It is a way of thinking about the analysis and relationship of ideas, organization, and logical representation. Those skills are favoured with certain activities and with certain learning environments from the earliest stages. It is about the development of a specific thought: computational thinking. (p. 1)

As Keith et al. (2019) comment, “CT can be thought of as a broad foundation consisting of the heuristics used by computer scientists and as a way to think about the diverse thinking skills associated with computing” (p. 225). As such, it should not only be developed by scientists, but by everyone, since it encourages logical and critical development.

Wing (2008) talks about CT as a type of analytical thinking that has a lot to do with mathematical problem-solving skills. In both, the following skills are promoted (Csizmadia et al., 2015): logical thinking (making decisions to reach the result or product by applying mathematical operators), abstraction (translating a problem into mathematical language), algorithmic thinking (applying a sequence of steps to arrive at a solution through codes) and some pattern recognition (identifying parts, similarities and connections and using them to achieve the fastest solution).

2.2. CT and 3D modelling in the classroom

It was not until the beginning of the 21st century that the need to implement the STEM model in classrooms was seen due to the rapid technological boom and the need for specialists in this area (Sanders, 2009).

Tissenbaum et al. (2019) show that, as students learn about computing, they should have the opportunity to create through it in a way that has a direct impact on their lives and on the community. To do this, they need to have access to platforms and learning environments to make their designs to develop digital empowerment (Freire, 1993; Thomas & Velthouse, 1990).

Tissenbaum et al. (2019) indicate that CT training requires that students should feel responsible for articulating and designing their solutions, rather than working towards predetermined “correct” answers (p. 35). Moreover, students need to feel that their work is authentic in relation to the broader computing and engineering communities, practices and products. Furthermore, a significant number of activities have to be situated in contexts that are authentic and personally relevant. In addition, students should feel that their work has the potential to have an impact on their own lives or their community, and they should feel capable of pursuing new computing opportunities because of their current work.

A systematic study by Ting-Chia et al. (2018) highlights that, on the one hand,

> CT activities are primarily introduced in courses in program design, computer science, biology and robot design. CT is a skill that could be widely applied in the living environment rather than being used exclusively by computer engineers. On the contrary, it is a skill that deserves a positive attitude in daily life. (p. 308)

On the other hand, they emphasise that

> most of the research focuses on project-based learning, problem-based learning, cooperative learning and game-based learning, so, future research should attempt to introduce different learning strategies, including scaffolding learning strategies, storytelling, learning and aesthetic experience, among others, in order to assist learners in multiple ways in terms of subject development or high-level skills training, that is, training in critical thinking and problem-solving skills. (p. 308)

Grover and Pea (2018) discuss CT concepts and practices for classrooms similar to those discussed above. These concepts include logic and logical thinking, algorithms and algorithmic thinking, patterns and their recognition, abstraction and generalisation, evaluation and automation.

In relation to evaluation, models and simulations must be evaluated from the point of view of whether they are correct and suitable for the mission to be achieved, in addition to other aspects such as simplification or speed. Çoban and Korkmaz (2021) show that, when evaluating CT in classrooms, validated and reliable instruments must be designed that allow for the level of achievement of these components or skills to be assessed. Tang et al. (2020), in their systematic study on the evaluation of CT in classrooms, stress that

> high school students, college students, and teachers and professional development programs need more CT assessments; most CT assessments focus on student programming or computer skills; traditional tests and performance assessments are often used to assess CT skills, and surveys are used to measure students' CT dispositions; more reliability and validity evidence should be collected and reported in future studies. (p. 1)

Regarding automation, Wing (2008) comments that computing is the automation of abstraction. Among the processes considered, problem decomposition, computational artifact creation, testing and debugging, iterative refinement and collaboration and creativity are included. The author concludes that CT can be integrated into many subjects and contexts.

CT is worked on in the classroom through different software such as Scratch, Lego EV3 and others that are generating a lot of motivation among students (Howland et al., 2019; Resnick et al., 2009; Jocius et al., 2021). However, as Tikva and Tambouris (2021) comment, there is no curricular conceptualisation about CT and, for this reason, many teachers fail when they introduce it in the classroom (Lee et al., 2020). As such, the best way to integrate it is through STEM disciplines, as reflected in many studies based on the construction of models and computational simulations to understand and study scientific phenomena (Hansen et al., 2015; Karaahmetoğlu & Korkmaz, 2018; Sengupta et al., 2013; Wilensky et al., 2014).

Bull et al. (2015) explain that computer design projects that involve physical prototypes such as 3D modelling can provide a basis for improving the learning process in science and mathematics. 3D printers applied to mathematics education constitute a resource that allows for the proposal of activities that involve inquiry learning or learning based on problem-solving (Wang et al., 2019).

As Ford and Minshall (2019) comment, "the emergence of additive manufacturing and 3D printing technologies is introducing industrial skills deficits and opportunities for new teaching practices in a range of subjects and educational settings" (p. 1). In their systematic study, they state that when introducing 3D modelling in classrooms, the following is required: teaching both teachers and students about 3D printing, teaching design skills and creativity, as well as methodologies to promote its development; producing models that facilitate learning and create assistive technologies. As Blikstein (Blikstein et al., 2017) points out, the use of 3D modelling in classrooms also has a positive impact in that it provides opportunities for different learning styles.

A study by Jiang and Li (2021) on the impact of Scratch on CT digital competence in primary education shows its need for integration with other areas such as mathematics to promote a significant development of computational skills through contextualized problems. For its part, the secondary education study by Sen et al. (2021) collects an experience based on the implementation of Lego EV3 software and Tinkercad for 3D modelling. The results show that the use of this type of software and 3D modelling encourages students to carry out effective critical thinking during the development of designs that were original, but, at the same, time realistic. In the same vein, the study by Roscoe et al. (2014) explores the combination of Minecraft and 3D modelling, and there are many studies aimed at describing improvements in creativity (Craddok, 2015; Kostakis et al. 2015), technical drawing (Lütolf, 2013), product design (Chao et al., 2017; Steed & Wevers, 2016), mathematical achievement (Stansell et al., 2015) and, more specifically, in the field of geometry (Corum & Garofalo, 2015; Huleihil, 2017).

2.3. BlocksCAD and Blockly tools

The appliance of technology in the classroom has been a key research topic in recent years (Cox et al., 2022; Prendes-Espinosa & Cartagena, 2021; Wijers et al., 2010). The benefits of its use have been shown, as long as it is planned and the characteristics of both the class and the content to be worked on are considered. Furthermore, students value in a really positive way the use of didactic resources based on technology to improve their teaching-learning process (Medina et al., 2013). Moreover, there are different technology-based methodologies that have shown positive results in mathematics, such as flipped classroom (Orcos et al., 2020; Wei et al., 2020) and gamification (Fuentes-Cabrera et al., 2020; Jiménez et al., 2020; Magreñán et al., 2023), and the use of technology in mathematics classrooms has been studied extensively (Kaufmann et al., 2000; Korenova, 2017; Meadows & Caniglia, 2019; Orcos et al., 2022; Zulnaidi et al., 2020). In this paper, we are interested in the use of two different softwares: BlocksCAD and Blockly.

BlocksCAD is a free block programming tool that eliminates the obstacle that textual syntax can pose in programming (Beltrán-Pellicer et al., 2020), making it very similar to Scratch. As Solomen Menashi, project director of BlocksCAD, explains, its origins lie in the need to create software that is intuitive like Lego but with the power and precision of real modelling software (Berdik, 2017).

As Chytas et al. (2018) say, "however even free block-based parametric tools like BlocksCAD and Beetle Blocks can support the creation of sophisticated projects which include algorithmic concepts to generate complex geometries" (p. 1976). In their study on BlocksCAD, they use the terms "parametric design" as an algorithmic process to build relationships between complex geometries and structures. They conclude that CT is not fostered solely through programming activities and can and should be combined with design and other STEM topics to solve challenging engineering designs.

A study by Beltrán- Pellicer and Muñoz- Escolano (2021) explores the modelling of shapes such as spheres, cubes or tori in the environment with BlocksCAD, collecting the steps, rotations, translations, etc., carried out and obtaining interesting results by improving reflection, spatial capacity, etc.

On the other hand, the use of game-based learning is gaining more and more followers due to the proven benefits of its use in different branches, including mathematics and programming and even in course design (Huang & Hew, 2021). In this sense, serious games have proven to be very valuable tools in programming learning (Frankovic et al., 2018). There are different serious games such as the Blockly Games tool, which has proven to be a good tool to understand block programming since it allows users to work with loops, conditionals or nesting sub-stacks, for example, but they must have a concrete plan (Fraser, 2014). Thanks to certain particularities of this tool, such as having several levels in each game, not requiring registration or being able to use it from any device with an internet connection, it is already beginning to be used in primary education classrooms (Alonso, 2021). In addition, some of the games on this tool have given satisfactory results in terms of the perceptions of students of different ages (De Figueredo et al., 2019).

3. Methodology

In this section, the methodology used in this study is shown, including a description of the group of participants involved in the experience, the activities that the students did during the experience, the information tools used to collect information and the analysis of the collected data.

This work is descriptive, using a descriptive, inferential and interpretive quantitative methodology, since the results obtained by the participants in the required constructions and the types of structures that have been used to make them are analysed. In addition, after the experience, a satisfaction survey was completed by the students to gauge their impressions regarding the use of the program and its capacity for teaching in mathematics classrooms, so the answers given are also presented and analysed.

3.1. Participants

The participants in this experience are from the third year of secondary education in a school located in Spain. The total number is forty-one participants was divided into two groups: one group that was studying the Mathematics Extension subject, made up of thirteen students, and another that was not studying this subject, made up of twenty-eight students. The group of participants was selected from among those who carried out the complete experience and who spent, at least, ten minutes on both the initial and the final test, plus the time to fill in the personal data and examples, to avoid copying or answering at random. The age range of the participants was between 14 and 15 years, as seen in Table 1. The group that worked exclusively with BlocksCAD is called G1, while the group that worked with both tools is called G2. The total number of students is called G.

TABLE 1. Descriptive analysis of the participants in the experience.

Group	Boys	Girls	Total
G1	$n = 12$ Mean of age=14.083	$n = 16$ Mean of age=14.188	$n = 28$ Mean of age=14.050
G2	$n = 9$ Mean of age=14.222	$n = 4$ Mean of age=14.000	$n = 13$ Mean of age=13.933
G	$n = 21$ Mean of age=14.143	$n = 20$ Mean of age=14.150	$n = 41$ Mean of age=14.146

3.2. Experience development

As previously mentioned, this study involves two groups of students who participated in different experiences, but both based on the use of BlocksCAD. Next, they will be described, starting first with the common part of both.

The experience begins with a validated pre-test, which was developed by Román-González et al. (2015) and that can be found in Román (2015). This test, designed to be carried out with students up to the second year of secondary education in Spain (that is to say, the year immediately prior to the one in this study), showed that the participants had a low level of CT. So, this experience was developed to improve it. It is important to remember that this group of students was affected by the Covid-19 pandemic and they could not work on CT due to the lockdowns.

Once the students' level of CT was detected, two well differentiated groups were observed: those with a low level of CT and those with a medium level. Therefore, the decision was made to design these intervention proposals and adapt them to each group to improve their level of CT.

As already mentioned, for the G1 group, the experience was carried out with just BlocksCAD and consisted of five differentiated sessions of one hour each. This group reached the lower level in the pre-test (17.14 out of a possible 28 points). Each of the sessions are shown below.

In the first session, the fundamental idea is for students to become familiar with the BlocksCAD tool and its menu options, including how to save, how to load and ways to create or retrieve creations. This can be seen at the top of Figure 1.

Figure 1. BlocksCAD main interface.

Project Name Sin título

In addition, in this first session, students worked with the first constructions associated with the creation of shapes in 3D and 2D that the program allows and that are shown in Figures 2 and 3.

Figure 2. Simple 3D shapes allowed in BlocksCAD.

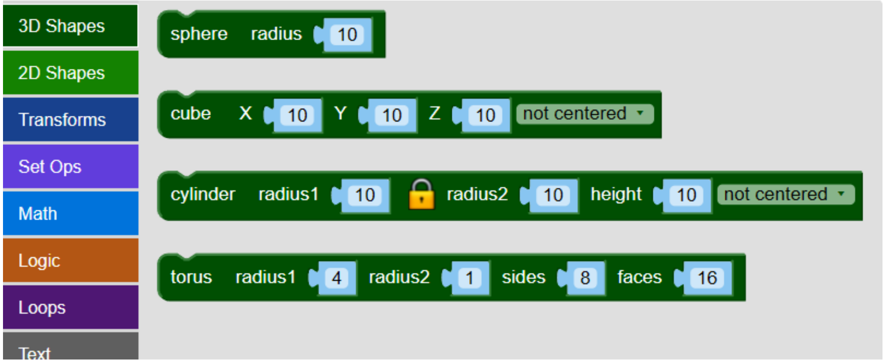


Figure 3. Simple 2D shapes allowed in BlocksCAD.

In the second session of guided work with BlocksCAD, the students had to work with the main options in the "Transforms" menu and those in the set operations menu that are shown in Figure 4.

FIGURE 4. Main operations in the "Transforms" menu in BlocksCAD (left) and operations in the set operations menu (right).

These two sessions were considered the first block of work with BlocksCAD, which was carried out over the course of a week. For the second block, which included three sessions, the participants worked on the different math menus and logic blocks (Figure 5), loops and variables (Figure 6), and, finally, functions (Figure 7). The first two sessions were based on working on all the menus mentioned above except for the functions, that were performed in the third session.

FIGURE 5. "Math" menu operations (left) and "Logic" menu operations (right).

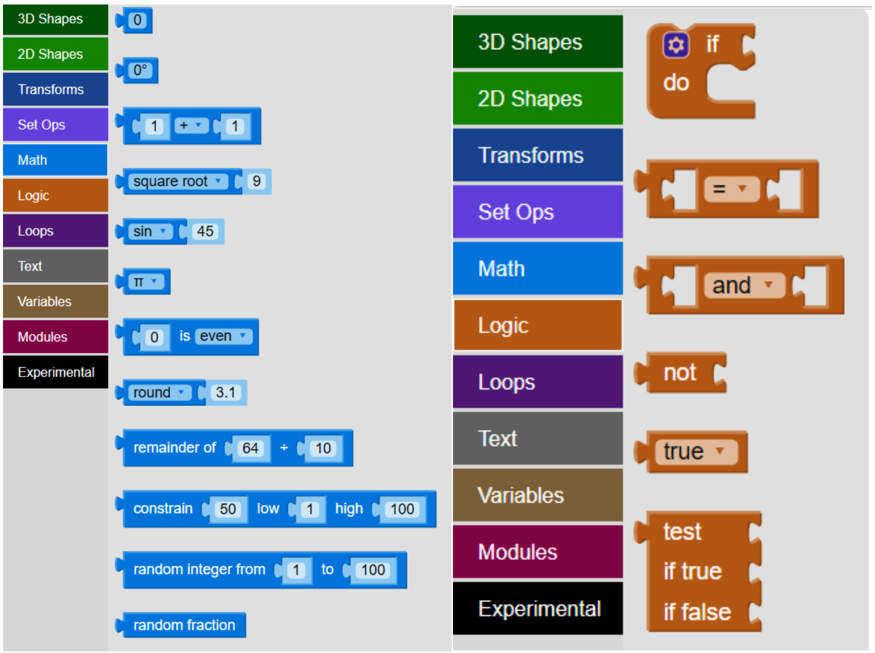


FIGURE 6. "Loops" menu operations (left) and "Variables" menu operations (right).

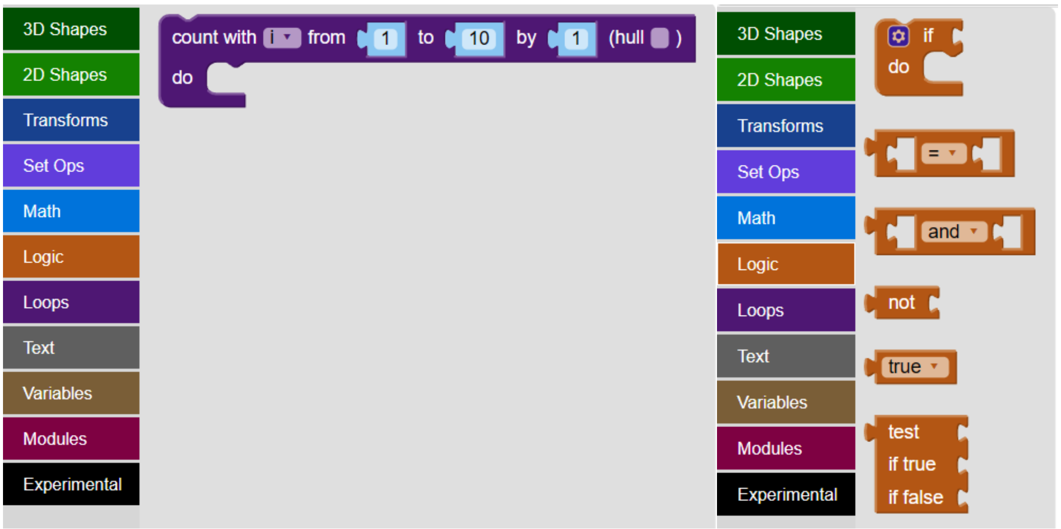
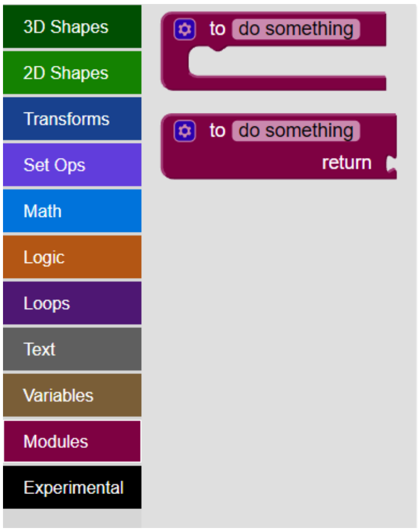


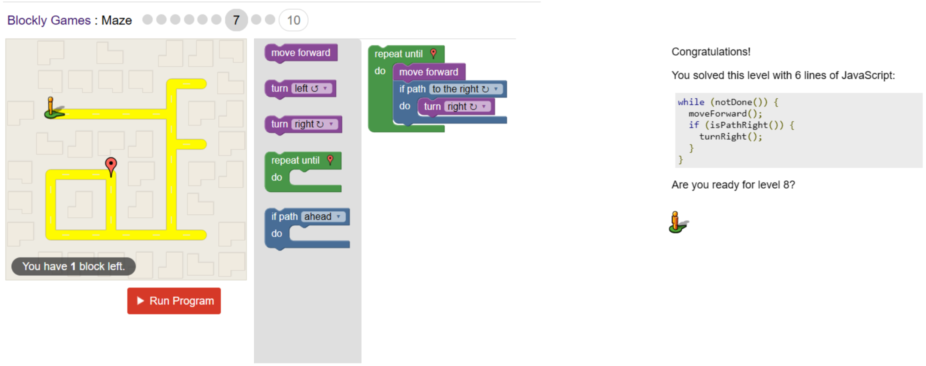
FIGURE 7. "Modules" menu operations that allow you to create in BlocksCAD.



To finish, the third block consisted of two more sessions: the first, where students had to deliver a construction applying BlocksCAD, which required the use of CT; and the second, where they repeated the CT test and completed the satisfaction survey.

In addition, the G2 group, during that time, worked in the Math Extension classroom with Blockly Games, where there are different mazes to be solved by means of sequence blocks, similar to BlocksCAD. In addition, they identified the steps to take in some mathematics' algorithms, such as solving an equation of second degree or the division algorithm. An example of a screen in Blockly can be seen in Figure 8.

FIGURE 8. Example of one of the Blockly Games, with the final solution.



Congratulations!

You solved this level with 6 lines of JavaScript:

```
while (notDone()) {
  moveForward();
  if (isPathRight()) {
    turnRight();
  }
}
```

Are you ready for level 8?

Source: https://blockly.games/maze?lang=en&level=7&skin=0

3.3. Information collection tools

To obtain information to analyse whether the use of these tools has been effective in improving CT, different information tools have been used, which are listed below:

- The CT assessment test designed by Román-González et al. (2015) has been used as the pre-test. This test consists of twenty-eight questions with a single valid answer, and it has a maximum completion time of forty-five minutes. The questions link the use of conditionals, loops and functions, among other aspects.
- To measure the performance of the students in the first two blocks, they had to deliver exercises 1 and 2 shown below.
- In addition, to measure the degree of understanding of the commands, students had to deliver a final task shown below.
- On the other hand, the post-test used was the same as the pre-test, since the answers were not provided to the students.
- Finally, to find out the students' impressions of the experience, a satisfaction survey was completed, which is shown below and is an adaptation of the one used by San Cristobal et al. (2017).

Exercise 1. Perform the following tasks:

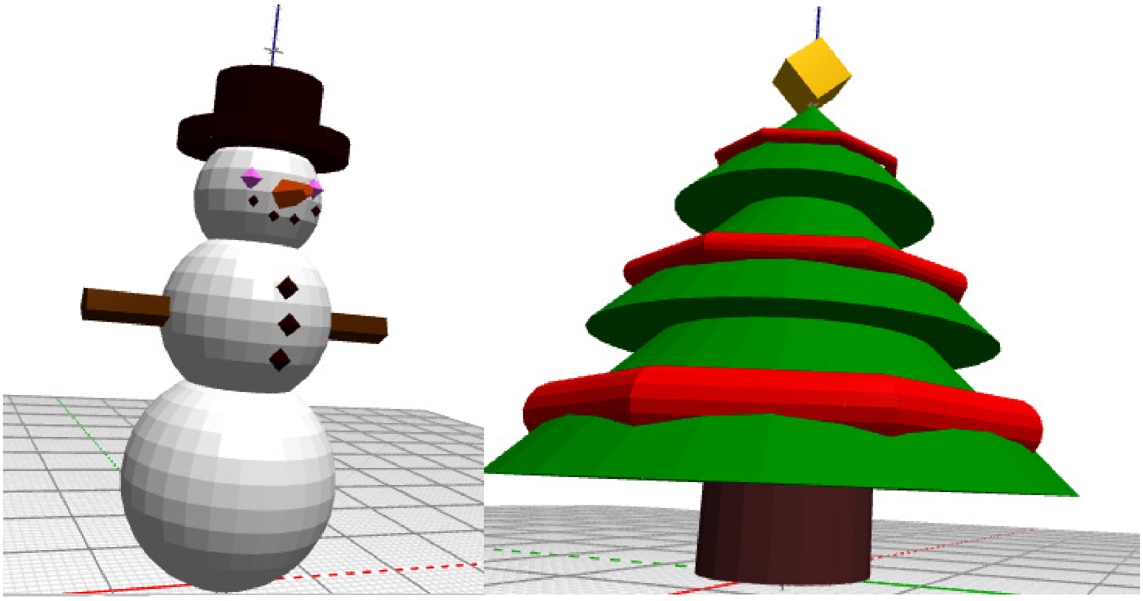
- Build a sphere with radius 5 and paint it yellow.
- Draw a cube with dimensions 10 × 8 × 3.
- Draw a cylinder.
- Draw a cone and a truncated cone.
- Build a pile of three coloured spheres of radius 10 that touch at one point.
- Build a stack of three cylinders with heights 10 and radius 10, 8 and 6.
- Draw a cone, on top of a truncated cone and on top of a sphere, each one of a different colour and touching at a single point.
- Build a white ring like the one in the image.
- Build three ice creams like the ones in the image, but with different flavours.
- Build a yo-yo.

Exercise 2. Perform the following tasks:

- Try to paint ten cubes that alternate between green and red.
- Now, instead of cubes, paint spheres that do not intersect (touch at one point).
- Now build it with cubes that are floating (that is, the *z* coordinate is greater than 0).
- Make a flag in two colours.
- Now make the flag fill the entire screen.
- Try to build a chess board with cubes (remember it is an 8 × 8 board and that, when the sum of the row
- and the column is even, it is coloured and, when it is odd, it is white).
- Build two trees, one like the one in the example and the other with a black treetop.
- Fill in the axis by interspersing green treetops and black treetops.
- Make the design of a castle with four towers.
- Now design the "brick" function and build a wall of bricks of different colours.

Final task. Create the following models (Figure 9)

Figure 9. Some of the models created by the students.



Satisfaction survey

Part 1 questions:

- Q1: Did you already know about the program?

  ○ Yes

  ○ No

- Q2: Would you like to do more classes like this?

  ○ Yes

  ○ No

Questions with answers 1 to 10:

- Q3: How much did you like the experience?

- Q4: Has the program made learning more enjoyable?

- Q5: I liked this class more than a "traditional" class.

- Q6: I think the learning is more active and experience-based.

- Q7: I have more possibilities to work at my own pace.

- Q8: I have fun while learning.

- Q9: How capable do you think you are of making a 3D model?

Likert-type questions:

- Q10: How much did you learn/remember in class?

  ○ Nothing
  ○ Little
  ○ Enough
  ○ A lot

Open-ended questions:

- Q11: Do you have any other comments?

3.4. Data analysis

Firstly, to detect the level of each group and to carry out the intervention more appropriately, a descriptive analysis of the students' scores in the pre-test was performed. Secondly, to observe if the improvement seen in both groups is significant, Student's *t* tests were performed for groups related to the global group and the G1 group. Then, the non-parametric test Wilcoxon W was performed to obtain the difference between the pre-test and the post-test. Moreover, the size effect was also computed to compare the results obtained in both groups. Afterwards, a descriptive analysis of the survey responses was performed, also showing some links between some of the answers. Finally, a descriptive study was done of the marks obtained in both deliverables; of the possible correlations between the marks for both pieces of work, the final exam and the results of the post-test; and of the difference in scores obtained.

4. Results and discussion

The results obtained by the total group (G), both in the pre-test and in the post-test, as well as in the BlocksCAD exam, are presented in this section and then studied separately. Finally, he results of the satisfaction survey are analysed.

4.1. Total group results

Table 2 shows the results obtained by the students belonging to the total group (G), in the different deliverables for the tasks.

TABLE 2. Descriptive analysis of the results obtained by the participants in the experience in the different tasks.

Statistics	Task 1	Task 2	Final task
Mean	7.649	8.988	8.207
Median	7.100	9.000	8.000
Mode	6.700	10.000	8.000

Therefore, it is observed that the results related to the use of iterations, functions, variables and conditionals are quite positive, especially in task 2. In addition, in the final task, the average grade is higher than 8, which is an indicator that they have understood what they have worked on.

Regarding the pre-test and post-test results shown in Table 3, it can be deduced that there is a mean difference of 2.366, higher in the post-test.

In light of the results in Table 3, the Student's *t* test for comparison of means for related groups was performed. The results of which are shown in Table 4.

It is observed that, in general, in the total group, the post-test mean is 2.366 points higher than the pre-test mean, which is a significant difference. In addition, two different definitions were used to calculate the effect size obtained in the experience in the total group. The first, used by Morris (2008) and Morris & DeShon (2002), was defined by the difference of means between the post-test and the pre-test divided by the standard deviation of the marks in the pre-test (D1). The second consisted of dividing the difference of means between pre-test and post-test by the square root of the means of the variations (D2). The results are shown in Table 5, where it is observed that the effect size of the results obtained is medium in size.

TABLE 3. Average of the results obtained in the pre-test and the post-test.

Group	Pre-test mean	Post-test mean
G	18.34	20.71

TABLE 4. Results of the Student's *t* test for related groups.

Group	Par	Mean difference	Value of *t*	Sig. (bilateral)
G	Pre-test - Post-test	-2.366	-4.295	0.000

TABLE 5. Effect sizes obtained from experience.

Group	Variance pre-test	Variance post-test	D1	D2
G	18.680	24.962	0.547	0.506

Consequently, considering the whole group of students, who used one or both of the aforementioned tools, it can be observed that the average of correct answers obtained in the test improves significantly. Moreover, according to the effect size, the results obtained regarding the acquisition of CT in the sample improved in general. These results allow for the use of these tools to be considered in schools in order to work on CT in mathematics classes with students in the third year of compulsory secondary education.

4.2. Results of each group separately

In this section, the same statistics for each group separately as for the entire group are shown. Table 6 shows the results obtained by the students who worked only with BlocksCAD (G1) and by those who combined it with Blockly (G2).

TABLE 6. Descriptive analysis of the results obtained by the participants in the experience in the different tasks.

Group	Statistics	Task 1	Task 2	Final task
G1	Mean	7.268	8.839	7.8393
	Median	7.100	8.500	8.000
	Mode	6.700	8.000	8.000
G2	Mean	8.469	9.308	9.000
	Median	9.600	10.000	9.000
	Mode	10.000	10.000	8.000

Therefore, it is observed that the results related to the use of iterations, functions, variables and conditionals are quite positive, again especially in task 2. In addition, in the final task, the average grade in both groups is 8 or 9, which is an indicator that the students have understood what they were working on.

Regarding the pre-test and post-test results shown in Table 7, it appears there is an improvement in both groups, although these are uneven. In the group that just used BlocksCAD, the improvement is two points, while, in the group that combined the use of BlocksCAD with the use of Blockly Games, the improvement is four points.

TABLE 7. Rank sum of the Wilcoxon test (post-test- pre-test).

Group	Ranks (positive-negative-equal)	Mean Rank (positive-negative)
G1	17-5-6	12.06-9.60
G2	11-1-1	6.95-1.50

In light of the results in Table 7 and considering there are no parametric assumptions, the Wilcoxon *W* test for comparison for related groups was carried out to compare the results and draw conclusions. The results obtained using SPSS are shown in Table 8.

TABLE 8. Results of the Wilcoxon *W*.

Group	Par	Value of *Z*	Sig. (bilateral)
G1	Pre-test - Post-test	-2.564	0.010
G2	Pre-test - Post-test	-2.944	0.003

The results show that there are significant differences in both cases, with a significance level of 0.05. On the other hand, and as previously mentioned, the difference in the group of students who combined the use of BlocksCAD and Blockly Games is greater than in the group who only worked with BlocksCAD, which also improved the results significantly. In addition, as non-parametric statistics have been used, the effect size in the experience for both groups have been obtained throught a matched-pairs rank biserial correlation coefficient, which is considered a measure of effect size for the Wilcoxon signed-rank test (King et al., 2018). The results can be seen in Table 9.

TABLE 9. Effect sizes obtained from the experience.

Group	Variance pre-test	Variance post-test	RBCC
G1	16.423	20.840	0.1000
G2	14.744	3.859	0.6513

Therefore, it is observed that the effect size of the obtained results is much greater in group G2, which indicates that the combined use of both tools in the sample gives better results.

Consequently, considering each group separately, the results show that there is an improvement in both cases, which is greater in the group that worked with the combined tools. This fact can strengthen the argument that the use of these tools can help to improve the acquisition of CT in mathematics classrooms with students in the third year of compulsory secondary education. Finally, in the group who worked with both tools, the effect size is notably greater than the effect size in the group who only worked with BlocksCAD. As such, in the considered sample, it seems that the combined use of both tools gives better results.

4.3. Satisfaction survey results

This section presents the results of the satisfaction survey provided to the students after the completion of the test. Firstly, the response values of questions Q1 and Q2 are shown in Table 10. These results show that there is not a big difference between the two groups regarding the percentage of students who knew about the program and those who would like to do more similar classes using it.

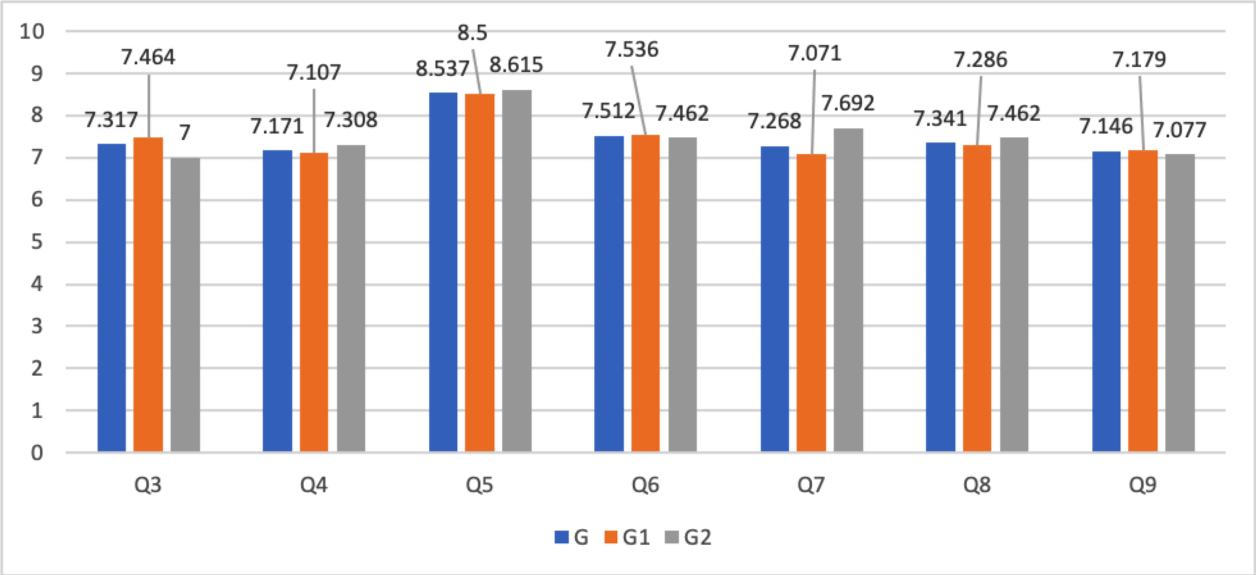
TABLE 10. Answers to questions Q1 and Q2 of the satisfaction survey.

Group	% of positive responses to Q1	% of positive responses to Q2
G	12.2%	80.5%
G1	10.7%	82.1%
G2	15.4%	76.9%

On the other hand, Figure 10 shows the means of the responses to questions Q3-Q9. Once again, these results show how there are no great differences between the two groups and that, in addition, the students' evaluations of the experience are positive.

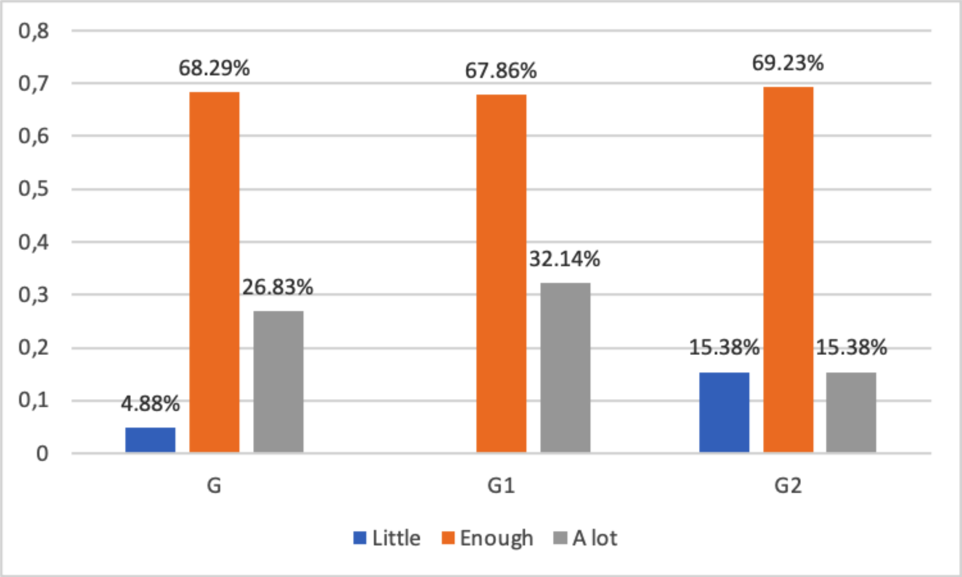
From Figure 10, it can be concluded that, in general, the students liked the experience and that they think the program or programs made their learning more enjoyable. It is also notable that they prefer this type of class to traditional classes, as seen in the responses to Q5, with a result greater than 8.5 in mean. On the other hand, it is clear from the responses to Q6 and Q8 that the learning is more active and that the students had fun while working and learning, an aspect that is really interesting for the teacher community. Furthermore, the responses given by students to Q7 show that they think they have more possibilities to work at their own pace and not be hurried or dependent on the rhythm of the class. Finally, from the responses given to Q9, students think they are now capable of making 3D models, which was one of the objectives of this study.

FIGURE 10. Average responses of students to questions Q3-Q9.



Finally, with respect to question 10, the data for which can be seen in Figure 11, it appears that there is no great difference between the answers given to the question "How much have you learned?". In both groups, the percentage of those who think "little" is low, while the predominant response, by a significant margin, was "enough". Also striking is the fact that, for students who only worked with BlocksCAD, the answer "little" does not appear, so their feeling is that, at least, they have learned "enough".

FIGURE 11. Average responses of students to question Q10.



On the other hand, some of the answers given by the students in the open-ended question stand out since they appear repeated on several occasions. Based on these responses, it is clear that the students liked the experience, a fact that has been verified by the responsible teacher:

- “I really liked this activity because I found it very fun and interesting, it has further developed my creativity.”

- “I liked being able to work with the instructions to be able to create more complex models later.”

- “I liked being able to work with the instructions to later create more complex models.”

On the other hand, there were other answers that were not so positive but that should also be taken into account. For example:

- “I liked it although some models took me a while to make.”

- “I need more time to do what is asked in class.”

Finally, it also highlights that the students claimed to print their own creations in order to have them at home.

5. Conclusions

The experience that has been described, and that lasted for seven sessions, combines different skills that students have to acquire. These include mathematical skill, which encompasses CT, a key interest in this paper due to its importance in our society, together with technological skill. On the other hand, by involving different subjects which combine all the previous skills, such as mathematics or information and communication technologies (which are highly interrelated), the STEM field is worked on, as has already been presented by authors such as Lee et al. (2020) or Robinson et al. (2014); even the STEAM field is worked on, adding the artistic aspect that allows 3D modelling.

By way of conclusion, it was found that the work with BlocksCAD helped with the acquisition of CT in the group of students in the sample. This conclusion was already intuited in works by authors such as Beltrán-Pellicer et al. (2020) or Beltrán-Pellicer and Muñoz-Escolano (2021), who show how this tool can be introduced in mathematics classrooms. The results obtained in this study exposes that, in the sample used, in general, the students improved their CT capacity.

Moreover, it was proven that the combined use of BlocksCAD and Blockly Games, as well as the work of mathematical algorithms from a Blockly perspective, helped the acquisition of CT, even reaching very large effect sizes. This indicates that not only can the acquisition of CT be worked on with BlocksCAD but that, in combination with other tools, its effect can be multiplied. Using Blockly Games, which is essentially a game where students work through a series of steps to find the solution to a problem, allows them to develop CT, as already mentioned by Roscoe et al. (2014).

Furthermore, from the responses to the satisfaction survey, it can be seen that students liked the experience and that it helped them in different ways, as they felt the learning process was more enjoyable and more active, and they had fun during the experience. They also felt they could work at their own pace, which was a really important aspect for them, and that they were now able to make 3D model, which was one of the main objectives of the study. Finally, they expressed that they really prefer this kind of class to traditional ones.

Considering all the answers and the results obtained by the students, the objectives of this study have been achieved. These aims were to improve the development of computational thinking in a sample of third-year secondary school students through the use of BlocksCAD and to compare the results obtained when using only said software or when combining its use with Blockly in a maths extension classroom. Furthermore, although it was not an objective of the study as such, good satisfaction results have been obtained from the experience. This is a very positive aspect that, together with the rest of the objectives, supports the idea that, with good planning, the use of both tools can help in the development of CT.

In terms of future work, it is felt it would be even more beneficial to choose to print some of the pieces designed in the classroom. This could be seen as an incentive for students, and even more so in light of the Covid-19 pandemic, which is having a negative effect on student motivation, an aspect that is corroborated by the work of Lütolf (2013) and Kostakis et al. (2015).

Acknowledgements

This study is part of the project “Adquisición de competencia matemática a través de tecnologías en diferentes etapas”, funded by the 2022-2023 Teaching Innovation Projects at La Rioja University.

References

Alonso, R. (2021). *Blockly games y su influencia en el desarrollo del pensamiento computacional para los estudiantes de quinto año de la U.E. Carlos María de la Condamine [Blockly games and their influence on the development of computational thinking for fifth year students at U. E. Carlos María de la Condamine]* [Master’s thesis]. Repositorio Digital UNACH, Universidad Nocional de Chimborazo. http://dspace.unach.edu.ec/handle/51000/8310

Andersen, L. (2014). Visual-spatial ability: Important in STEM, ignored in gifted education. *Roeper Review*, *36* (2), 114-121. https://doi.org/10.1080/02783193.2014.884198

Beltrán-Pellicer, P., Rodríguez-Jaso, C., & Muñoz-Escolano, J. M. (2020). Introduciendo BlocksCAD como recurso didáctico en matemáticas [Introducing BlocksCAD as a teaching resource in mathematics]. *Suma, 93,* 39-48. https://bit.ly/3Ah2aka

Beltrán- Pellicer, P., & Muñoz-Escolano, J. M. (2021). Una experiencia formativa con BlocksCAD con futuros docentes de matemáticas en secundaria [A training experience using BlocksCAD with future high school teachers of mathematics]. *Didacticae*, (10), 71-90. https://doi.org/10.1344/did.2021.10.71-90

Berdik, C. (2017). Kids code their own 3D creations with new blocks-based design program. *Tech Directions; Ann Arbor*, *76* (9), 23-24.

Blikstein, P., Harel, I., Machover, T., y Upitis, R. (2017, 26 de enero). Rethinking school [video]. *Thinking about Thinking about Seymour*. MIT Media Lab, Cambridge, Massachusetts, EE. UU. https://www.media.mit.edu/videos/seymour-2017-01-26/

Bull, G., Haj-Hariri, H., Atkins, R., & Moran, P. (2015). An educational framework for digital manufacturing in schools. *3D Printing and Additive Manufacturing*, *2* (2), 42-49. https://doi.org/10.1089/3dp.2015.0009

Chao, J., Po, H. Chang, Y., & Yao, L. (2017). The study of 3D printing project course for indigenous senior high school students in Taiwan. In T. H. Meen, S. D. Prior, & A. D. Kin-Tak (Eds.), *Proceedings of the IEEE International Conference on Advanced Materials for Science and Engineering (IEEE-ICAMSE 2016), Tainan, Taiwan, 12-13 November 2016* (pp. 68-70). Institute of Electrical and Electronics Engineers. https://doi.org/10.1109/ICAMSE.2016.7840234

Chytas, C., Diethelm I., & Tsilingiris, A. (2018). Learning programming through design: An analysis of parametric design projects in digital fabrication labs and an online makerspace. In *Proceedings of 2018 IEEE Global Engineering Education Conference (EDUCON2018)* (pp. 1978-1987). Institute of Electrical and Electronics Engineers. https://doi.org/10.1109/EDUCON.2018.8363478

Çoban, E., & Korkmaz, Ö. (2021). An alternative approach for measuring computational thinking: Performance-based platform. *Thinking Skills and Creativity, 42,* 100929. https://doi.org/10.1016/j.tsc.2021.100929

Corum, K., & Garofalo, J. (2015). Using digital fabrication to support student learning. *3D Printing and Additive Manufacturing*, *2* (2), 50-55. https://doi.org/10.1089/3dp.2015.0008

Cox, F. T., González, D., Magreñán, Á. A., & Orcos, L. (2022). Enseñanza de estadística descriptiva mediante el uso de simuladores y laboratorios virtuales en la etapa universitaria [Teaching of descriptive statistics using simulators and virtual laboratories at university level]. *Bordón: Revista de pedagogía*, *74* (4), 103-123. https://doi.org/10.13042/BORDON.2022.94121

Craddock, I. L. (2015). Makers on the move: A mobile makerspace at a comprehensive public high school. *Library Hi Tech*, *33* (4), 497-504. https://doi.org/10.1108/LHT-05-2015-0056

Csizmadia, A., Curzon, P., Dorling, M., Humphreys, Simon, Ng, T., Selby, C., & Woollard, J. (2015). *Computational thinking. A guide for teachers*. Computing at School. https://eprints.soton.ac.uk/424545/

Dapozo, G. N., Greiner, C. L., Petris, R. H., Espíndola, M. C., & Company, A. M. (2017). Promoción del pensamiento computacional para favorecer la formación de recursos humanos en disciplinas STEM [Promoting computational thinking to foster human resource development in STEM disciplines]. In *WICC 2017. XIX Workshop de Investigadores en Ciencias de la Computación* (pp. 737-742). Instituto Tecnológico de Buenos Aires.

De Figueiredo, M. P. S., De Oliveira, E. G., & Filho, G. A. De A. C. (2019). Intervenção em turmas de jovens e adultos numa escola da rede pública do Recife, multidisciplinaridade e uso da ferramenta Blockly Games: um relato de experiência [Intervention in youth and adult classes in a public school in Recife, multidisciplinarity and the use of the Blockly Games tool: An experience report]. In *Anais do IV Congresso sobre Tecnologias na Educação* (pp. 561-567). SBC. https://doi.org/10.5753/ctrle.2019.8932

Ford, S., & Minshall, T. (2019). Where and how 3D printing is used in teaching and education. *Additive Manufacturing, 25,* 131-150. https://doi.org/10.1016/j.addma.2018.10.028

Frankovic, I., Hoic-Bozic, N., & Prskalo, L. N. (2018). Serious games for learning programming concepts. In *Proceedings 2012 IEEE International Conference on Systems, Man, and Cybernetics (SMC)* (p. 354). Institute of Electrical and Electronics Engineers. https://doi.org/10.1109/ICSMC.2012.6378001

Fraser, N. (2015). Ten things we've learned from Blockly. In F. Turbak, D. Bau, J. Gray, C. Kelleher, & J. Sheldon (Eds.), *2015 IEEE Blocks and Beyond Workshop (Blocks and Beyond)* (pp. 49-50). Institute of Electrical and Electronics Engineers. https://doi.org/10.1109/BLOCKS.2015.7369000

Freire, P. (1993). *Pedagogy of the oppressed.* Continuum

Fuentes-Cabrera, A., Parra-González, M. E., López-Belmonte, J., & Segura-Robles, A. (2020). Learning mathematics with emerging methodologies - The escape room as a case study. *Mathematics*, *8* (9), 1586, 1-14. https://doi.org/10.3390/math8091586

Glister, P. (1997). *Digital literacy*. Wiley.

Grover, S., & Pea, R. D. (2018). Computational thinking: A competency whose time has come. In S. Sentance, E. Barendsen, & C. Schulte (Eds.), *Computer science education: Perspectives on teaching and learning in schools* (pp. 19-38). Bloomsbury Academic.

Hansen, A. K., Iveland, A., Dwyer, H. Harlow D. B., & Franklin, D. (2015). Programming science digital stories: Computer science and engineering design in the science classroom. *Science and Children*, *53* (3), 60-64.

Howland, K., Good, J., Robertson, J., & Manches, A. (2019). Special issue on computing thinking and coding in childhood. *International journal of child-computer interaction*, *19*, 93-95. https://doi.org/10.1016/j.ijcci.2018.11.001

Huang, B., & Hew, K. F. (2021). Using gamification to design courses. *Educational Technology & Society*, *24* (1), 44-63.

Huleihil, H. (2017). 3D printing technology as innovative tool for math and geometry teaching applications. *IOP Conference Series: Materials Science and Engineering*, *164*, 012023. http://doi.org/10.1088/1757-899X/164/1/012023

Jiang, B. & Li, Z. (2021). Effect of Scratch on computational thinking skills of Chinese primary school students. *Journal of Computers in Education*, *8*, 505-525. https://doi.org/10.1007/s40692-021-00190-z

Jiménez, C., Arís, N., Ruiz, Á. A. M., & Orcos, L. (2020). Digital escape room, using Genial.Ly and a breakout to learn algebra at secondary education level in Spain. *Education Sciences*, *10* (10), 1-14. https://doi.org/10.3390/EDUCSCI10100271

Jocius, R., O'Byrne, W. I., Albert, J., Joshi, D., Robinson, R., & Andrews, A. (2021). Infusing computational thinking into STEM teaching. *Educational Technology & Society*, *24* (4), 166-179.

Karaahmetoğlu, K., & Korkmaz, Ö. (2019). The effect of project-based arduino educational robot applications on students' computational thinking skills and their perception of basic STEM skill levels. *Participatory Educational Research (PER)*, *6* (2). http://dx.doi.org/10.17275/per.19.8.6.2

Kaufmann, H., Schmalstieg, D., & Wagner, M. (2000). Construct3D: A virtual reality application for mathematics and geometry education. *Education and Information Technologies*, *5*, 263-276. https://doi.org/10.1023/A:1012049406877

Keith, K., Sullivan, F., & Pham, D. (2019). Roles, collaboration, and the development of computational thinking in a robotics learning environment. In S. C. Kong, & H. Abelson (Eds.), *Computational thinking education* (pp. 223-245). Springer. https://doi.org/10.1007/978-981-13-6528-7_13

Korenova, L. (2017). GeoGebra in teaching of primary school mathematics. *International Journal for Technology in Mathematics Education*, *24* (3), 155-160.

Kostakis, V., Niaros, V., & Giotitsas, C. (2015). Open source 3D printing as a means of learning: An educational experiment in two high schools in Greece. *Telematics and Informatics*, *32* (1), 118-128. https://doi.org/10.1016/j.tele.2014.05.001

Lee, I., Grover, S., Martin, F., Pillai, S., & Malyn-Smith, J. (2020). Computational thinking from a disciplinary perspective: Integrating computational thinking in K-12 science, technology, engineering and mathematics education. *Journal of Science Education and Technology*, *29* (1), https://doi.org/10.1007/s10956-019-09803-w

Lütolf, G. (2013). Using 3D printers at school: the experience of 3drucken.ch. In E. Canessa, C. Fonda, M. Zennaro (Eds.), *Low-cost 3D printing for science, education and sustainable development* (pp. 149-158). The Abdus Salam International Centre for Theoretical Physics (ICTP).

Magreñán, Á. A., Jiménez, C., Orcos, L., & Roca, S. (2022). Teaching calculus in the first year of an engineering degree using a digital escape room in an online scenario. *Computer Applications in Engineering Education*. https://doi.org/10.1002/CAE.22568

Meadows, M. L., & Caniglia, J. C. (2019). Using PhET simulations in the mathematics classroom. *The Mathematics Teacher*, *112* (5), 386-389. https://doi.org/10.5951/mathteacher.112.5.0386

Medina, L., Jaquez, J., Noguez, J., & García, R. M. (2013). Newton Gymlab: gimnasio-laboratorio virtual de física y matemática [Newton Gymlab: virtual physics and mathematics gymnasium-laboratory]. Instituto Tecnológico y Estudios Superiores de Monterrey. http://hdl.handle.net/11285/621356

Miedijensky, S., & Tal, T. (2016). Reflection and assessment for learning in science enrichment courses for the gifted. *Studies in Educational Evaluation*, *50*, 1-13. https://doi.org/10.1016/j.stueduc.2016.05.001

Morris, S. B. (2008). Estimating effect sizes from pretest-posttest-control group designs. *Organizational Research Methods*, *11* (2), 364-386. https://doi.org/10.1177/1094428106291059

Morris, S. B., & DeShon, R. P. (2002). Combining effect size estimates in meta-analysis with repeated measures and independent-groups designs. *Psychological methods*, *7* (1), 105-125. https://doi.org/10.1037/1082-989x.7.1.105

Orcos, L., & Magreñán, Á. A. (2018). The hologram as a teaching medium for the acquisition of STEM contents. *International Journal of Learning Technology*, *13* (2), 163-177. https://doi.org/10.1504/IJLT.2018.092097

Orcos, L., Cordero, A., Jordán, C., Magreñán, Á. A., Sanabria, E., & Torregrosa, J. R. (2020). Reverse teaching as a methodological strategy for mathematics learning in higher education. En Á. A. Magreñán (Ed.), *Didactics of mathematics: New trends and experiences* (pp. 153-180). Nova Science Publishers.

Orcos, L., Jiménez, C., & Magreñán, Á. A. (2022). Itinerarios de aprendizaje para trabajar la probabilidad matemática en futuros maestros en un escenario *online* con Deck.Toys [Learning itineraries to work mathematic probability with future teachers in an online scenario with Deck.Toys tool]. *RIED: Revista Iberoamericana de Educación a Distancia*, *25* (2), 195-218. https://doi.org/10.5944/ried.25.2.31748

Prendes-Espinosa, M. P., & Cartagena, F. C. (2021). Tecnologías avanzadas para afrontar el reto de la innovación educativa [Advanced technologies to face the challenge of educational innovation]. *RIED, Revista Iberoamericana de Educación a Distancia*, *24* (1), 35-53. https://doi.org/10.5944/ried.24.1.28415

Resnick, M., Maloney, J., Monroy-Hernández, A., Rusk, N. Eastmond, E., Brennan, K., Millner, A., Rosenbaum, E., Silver, J., Silverman, B., & Kafai, Y. (2009). Scratch: Programming for all. *Communications of the ACM, 52* (11), 60. https://doi.org/10.1145/1592761.1592779

Robinson, A., Dailey, D., Hughes, G., & Cotabish, A. (2014). The effects of a science-focused STEM intervention on gifted elementary students' science knowledge and skills. *Journal of Advanced Academics, 25* (3), 189-213. https://doi.org/10.1177/1932202X14533799

Román, M. (2015). *Test de pensamiento computacional [Computational thinking test]*. Retrieved on January 15, 2024 from http://goo.gl/IYEKMB

Román-González, M., Pérez-González, J. C., & Jiménez-Fernández, C. (2015, October 14-16). *Test de pensamiento computacional: diseño y psicometría general [Computational thinking test: design & general psychometry]* [conference paper]. III Congreso Internacional sobre Aprendizaje, Innovación y Competitividad (CINAIC 2015), Madrid, España.

Roscoe, J. F., Fearn, S., & Posey, E. (2014). Teaching computational thinking by playing games and building robots. In *Proceedings of 2014 International Conference on Interactive Technologies and Games iTAG 2014* (pp. 9-12). The Institute of Electrical and Electronics Engineers. https://doi.ieeecomputersociety.org/10.1109/iTAG.2014.15

San Cristóbal, M. S., Martín, D., Asencio, E. N., & Figueroa, J. T. (2017). Flipped classroom y didáctica de las matemáticas en la formación *online* de maestros de educación infantil [Flipped classroom and mathematics didactics in online education of early childhood teachers]. *Revista Electrónica Interuniversitaria de Formación del Profesorado*, *20* (3), 1-14.

Sanders, M. (2009). STEM, STEM education, STEMmania. *The Technology Teacher.* https://www.teachmeteamwork.com/files/sanders.istem.ed.ttt.istem.ed.def.pdf

Schroth, S. T., & Helfer, J. A. (2017). Gifted & green: Sustainability/environmental science investigations that promote gifted children's learning. *Gifted Child Today, 40* (1), 14-28. https://doi.org/10.1177/1076217516675903.

Sen, C., Ay, Z. S., & Kiray, S. A. (2021). Computational thinking skills of gifted and talented students in integrated STEM activities based on the engineering design process: The case of robotics and 3D robot modelling. *Thinking Skills and Creativity, 42,* 100931. https://doi.org/10.1016/j.tsc.2021.100931

Sengupta, P., Kinnebrew, J. S. Basu, S., Biswas G., & Clark, D. (2013). Integrating computational thinking with K-12 science education using agent- based computation: A theoretical framework. *Education and Information Technologies, 18* (2), 351-380. https://doi.org/10.1007/s10639-012-9240-x

Stansell, A., & Tyler-Wood, T. (2016). Digital fabrication for STEM projects: A middle school example. In J. M. Spector, C. Tsai, D. G. Sampson, Kinshuk, R. Huang, N. Chen, & P. Resta (Eds.), *Proceedings of the IEEE 16th International Conference on Advanced Learning Technologies* (pp. 483-485). The Institute of Electrical and Electronics Engineers. https://doi.org/10.1109/ICALT.2016.44

Steed, M., & Wevers, M. (2016). 3D printing & the design process: A pilot project between university student teachers and grade four students. In *Proceedings of EdMedia 2016 - World Conference on Educational Media and Technology* (pp. 354-359). Association for the Advancement of Computing in Education.

Tang, X., Yin, Y., Hadad, R., & Zhai, X. (2020). Assessing computational thinking: A systematic review of empirical studies. *Computers & Education*, *148*, 103798. https://doi.org/10.1016/j.compedu.2019.103798

Thomas, K. W., & Velthouse, B. A. (1990). Cognitive elements of empowerment: An "interpretive" model of intrinsic task motivation. *Academy of Management Review*, *15* (4), 666-681. https://psycnet.apa.org/doi/10.2307/258687

Tikva, C., & Tambouris, E. (2021). Mapping computational thinking through programming in K-12 education: A conceptual model based on a systematic literature review. *Computers and Education*, *162*, 104083. https://doi.org/10.1016/j.compedu.2020.104083

Ting-Chia H., Shao-Chen C., & Yu-Ting H. (2018). How to learn and how to teach computational thinking: Suggestions based on a review of the literature. *Computers & Education*, *126*, 296-310. https://doi.org/10.1016/j.compedu.2018.07.004

Tissenbaum, M., Sheldon, J., & Abelson, H. (2019). From computational thinking to computational action. Envisioning computing education that both teaches and empowers. *Communications of the ACM, 62* (3), 34-36. https://doi.org/10.1145/3265747

Tofel-Grehl, C., & Callahan, C. M. (2017). STEM high schools teachers' belief regarding STEM student giftedness. *Gifted Child Quarterly*, *61* (1), 40-51. https://doi.org/10.1177/0016986216673712

Vargas-Quesada, B., Zarco, C., & Cordón, O. (2023). Mapping the situation of educational technologies in the Spanish university system using social network analysis and visualization. *International Journal of Interactive Multimedia and Artificial Intelligence*, *8* (2), 190-201. https://doi.org/10.9781/ijimai.2021.09.004

Wang, T. H., Lim, K. Y., Lavonen, J., & Clark-Wilson, A. (2019). Maker-centred science and mathematics education: Lenses, scales and contexts. *International Journal of Science and Mathematics Education*, *17* (1), 1-11. https://doi.org/10.1007/s10763-019-09999-8

Wei, X., Cheng, I. L., Chen, N. S., & Yang, X., Liu, Y., Dong, Y., Zhai, X., & Kinshuk. (2020). Effect of the flipped classroom on the mathematics performance of middle school students. *Educational Technology Research and Development*, *68*, 1461-1484. https://doi.org/10.1007/s11423-020-09752-x

Wijers, M., Jonker, V., & Drijvers, P. (2010). MobileMath: Exploring mathematics outside the classroom. *ZDM, The International Journal on Mathematics Education*, *42* (7), 789-799. https://doi.org/10.1007/s11858-010-0276-3

Wilensky, U., Brady C. E., & Horn, M. S. (2014). Fostering computational literacy in science classrooms. *Communications of the ACM*, *57* (8), 24-28. https://doi.org/10.1145/2633031

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

Wing, J. M. (2008). Computational thinking and thinking about computing. *Philosophical Transactions of the Royal Society of London A: Mathematical, Physical and Engineering Sciences*, *366* (1881), 3717–3725. https://doi.org/10.1098/rsta.2008.0118

Zapata-Ros, M. (2015). Pensamiento computacional: una nueva alfabetización digital [Computational thinking: A new digital literacy]. *RED-Revista de Educación a Distancia*, *46* (4). https://doi.org/10.6018/red/46/4

Zulnaidi, H., Oktavika, E., & Hidayat, R. (2020). Effect of use of GeoGebra on achievement of high school mathematics students. *Education and Information Technologies*, *25*, 51-72.

Authors' biographies

Ángel-Alberto Magreñán-Ruiz. He has a doctorate (*cum laude* and special award) in Mathematics, a certificate in teaching, a licentiate degree in Mathematics and a technical engineering degree in Business Computing from Universidad de La Rioja. He is currently an Associate Professor in the Mathematics Teaching Area of the Mathematics and Computing Department at Universidad de La Rioja.

https://orcid.org/0000-0002-6991-5706

Rubén-Arístides González-Crespo. He is a doctor of Engineering in Computer Engineering and has a degree in Engineering in Industrial Organisation from Universidad Pontificia de Salamanca. He also holds a master's in Project Management and Administration and a master's in Web Engineering from the same university, as well as a diploma in International Studies from Sociedad de Estudios Internacionales. He is a Professor at Universidad Internacional de La Rioja.

https://orcid.org/0000-0001-5541-6319

Cristina Jiménez-Hernández. She has a degree in Mathematics from Universidad del País Vasco. She is currently studying for a PhD at Universidad Politécnica de Valencia while working in a secondary school in Spain.

https://orcid.org/0000-0002-0189-4910

Lara Orcos-Palma. She has a doctorate (*cum laude* and special award) from Universidad Politécnica de Valencia. She holds a licentiate degree in Chemistry from Universidad de La Rioja and a licentiate degree in Biochemistry from Universidad de Salamanca. In addition, she studied a master's in Teacher Training at Universidad de La Rioja and a master's in Chemical Science and Technology with Spain's Universidad Nacional de Educación a Distancia (UNED). She is currently an Associate Professor in the Mathematics Teaching Area of the Mathematics and Computing Department at Universidad de La Rioja.

https://orcid.org/0000-0001-8138-551X