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Scaffolded programming projects to promote computational thinking

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ABSTRACT
In Uruguay, Plan Ceibal drives the complex task to impulse computational thinking in public schools. The CT framework used by the organization is to introduce computer science from primary and secondary education, with an approach focused on solving problems and coding as a language, and with the intention of taking advantage of the potential of computational thinking. In order to educate users and creators of technology. In 2021 the Computational Thinking program of Plan Ceibal impacted nearly 40 thousand students and teachers, this represents about 30% of the enrollment for K 4 to 6 courses (9 to 11 years old) of the public elementary school. This study explored the impact of the implementation of scaffolded programming projects and final evaluation, in a subset of elementary schools groups. Preliminary results suggest a good adoption of the program and high participation of students and teachers registered through the learning management system (LMS) platform. In addition, the students who had more active participation in the classes had significantly higher performances in the programming tests. Some differences were observed in favor of girls. Results are discussed in relation to the pedagogical characteristics of the program.

KEYWORDS
Computational Thinking, Learning and Teaching, K-12

1. INTRODUCTION
The increase and ease of use of different technological tools in all areas of life has generated the need to integrate them in the classroom in order for students to acquire the necessary skills that allow them to face the difficulties or challenges that arise from this practice (Goyeneche et al., 2021). In response to this new scenario, different countries are developing and implementing educational programs that can meet the technological needs of students, with the intention of reducing the digital divides that some socio-cultural sectors are unable to access technology, ensuring equitable access and critical uses. Within this framework, the concept of Computational Thinking (CT) as a set of competencies for the expression and resolution of problems using the logic of programming and the power of computers is gaining strength, repositioning computer sciences. In Uruguay, the educational innovation center with digital technologies Plan Ceibal, launched in 2017 a pilot program of introduction to computer science with classroom intervention. The Computational Thinking program grows from 50 groups of students at its inception to 1768 groups of students in 2021 (approximately 35 thousand students in primary education) (Koleszar et al., 2021).

Likewise, the program continues to be optional, but classes are held during curricular hours. Teachers who enroll their groups incorporate a remote computational thinking teacher into the classroom work.

The objective of this research is to present the results of the evaluation carried out on the children who have participated in The Drawing Machine project during the implementation of the CT program in 2021.

2. PEDAGOGICAL MODEL
The pedagogical model comprises a set of initiatives and materials to cover different aspects of classroom and teacher work. They are composed of a didactic sequence of learning activities, a training course for teachers, materials and resources for the virtual platform CREA (LMS), and a final evaluation for students.

The didactic sequences of Plan Ceibal's CT program are based on the following aspects: the importance of designing and creating activities that motivate and generate better learning experiences for students (Resnick & Silverman, 2005). In this sense, the sequences combine directed, guided and exploratory activities that give structure to the projects. The teaching of programming is used as the main approach to promote computational thinking (Scherer et al., 2019). Activities are designed with progression: use-modify-create (Lee et al., 2011), with incremental program cycles and inquiry learning methodologies (Furmann, 2016). Projects should be motivating, promote collaborative work, teamwork, and significant play (Resnick, 2014)

The program is organized in three levels (4th, 5th and 6th grade), in which the contents and competencies of computational thinking are covered in an incremental and sequential manner. For each level, several didactic sequences were developed, which in an interdisciplinary way integrate Computational Thinking with other areas of knowledge. The design of these sequences is carried out in collaboration with the Argentinian Sadosky Foundation. The sequences are organized in projects that propose the design and construction of devices or programs with a theme of choice and structure of the contents and practice. The aim is that teachers can make didactic transpositions that allow students to solve problems related to Mathematics, Social or Natural Sciences, Language, etc., or associated to real life situations, through the skills and competences developed by computational thinking.

Each project is presented as a complex challenge to be solved in a period of approximately 6 to 8 weeks, with a dedication of 45 to 60 minutes per week. The teaching approach of the sequences aims at high-level thinking, where a problem or project is presented, and students have the opportunity to explore solutions, to transfer different concepts, to create programs or devices, in a balance of guided activities and peer-to-peer work space. The focus is on practices and concepts rather than tools. The sequences are open in relation to the subject matter so that classroom teachers can link it with the contents of the program they are dealing with; flexible in terms of the complexity of the programming so that teachers can adjust the requirements according to the experience of the group of students and creative in that it places students as designers and creators of stories, video games, simulators, robotic devices, etc.

In each videoconference there are initial activities that organize the exchange so that students can tell the remote teacher what they have done between videoconferences; development activities that allow them to advance in the proposal; and closing and reflection activities that are fundamental to recover moments that have been observed during the development and to promote metacognition.

CT program seeks to promote an inclusive educational experience that promotes gender equity. In order to do that, classroom and remote teachers are attentive to constantly denaturalize the bias of computer science and programming as an exclusive male task.

2.1 The Drawing Machine

This paper deals with the results achieved from the project called the drawing machine (TDM), the first project carried out by the students at the beginning of the program, in 2021. This proposal consists of the design and programming in Scratch of a machine capable of drawing from the interaction with the user. Figure 1 summarizes the main elements of the 8 stages of the project.

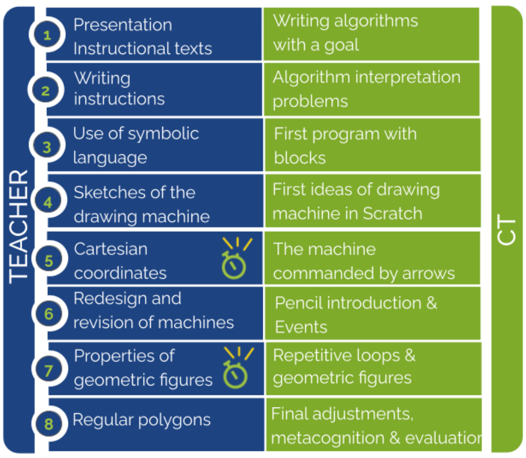

Figure 1. Synthesis of The Drawing Machine sequence

This didactic sequence proposes a series of activities for students to go through computational practices (decompose and plan, abstract and modularize, test and debug, reuse and reinvent) and programming concepts (algorithms, programs, instructions, events and repetitions). Figure 2 illustrates an example of the class guide for the CT remote teacher.

Three moments of the class are highlighted. The introduction or warm-up where the topic is introduced or the previous work is recovered; the development of the central activity with activities that advance in the project; and finally the closing with triggering questions to evaluate the process and final conceptualizations.

CT video conference 4↓ The Drawing Machine in Scratch	Challenge task Draw the machine in Scratch. Create a new object with the Scratch editor that represents the drawing machine.
1. Warm up (15 min) Who was interpreting the code when they made the house that someone else described? And when did they make the drawings with the arrow code? And when was Coty scheduled? The students recover from the work the notions built between all of the algorithms, program and language. It is anticipated that at this stage they will begin to design and program the Drawing Machine using a new block programming language: Scratch. **2. Development** Designing the drawing machine (20/25 min) The challenge is presented and a very brief presentation of Scratch, its workspaces and the drawing editor is presented. Time is set aside for exploration and resolution of the challenge.	Suggestions: **Design:** Students must clearly identify which part of the machine is going to make the drawings. **3. Closure** (10 minutos) Was it easy to adapt the designs? Is the editor similar to another one they have used? What advice would you give to someone drawing an object for the first time in Scratch? Students share their designs, explain what difficulties they encountered and record design tips or tricks in Scratch. They analyze what they have done by comparing it with other drawing experiences on the computer. By way of conclusion, it is highlighted that graphic editors usually have similar logics, iconographies and tools, and the importance of understanding the options offered by the program is pointed
Registration Registration of progress in the CREA forum (LMS)	La Yapa: Home proposals Make a new version of your drawing machine using the tips and techniques we share in the videoconference.

Figure 2. Example of a CT script class

3. METHODS & MATERIAL

An ad hoc questionnaire on concepts and practices worked on in TDM was used for the evaluation. It consists of 13 questions divided as follows: 8 multiple choice, 3 multiple response and 2 true or false. Figure 3 shows item 13 associated with repetitive structures. Internal consistency analysis showed acceptable results.

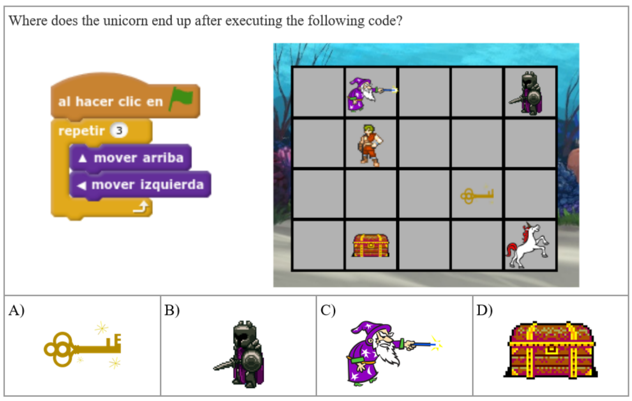

Figure 3. Evaluation task example

This evaluation was carried out through CREA (LMS) used on a daily basis, and in a classroom context. From this platform, data were obtained to identify the children, such as: date of birth, gender, school grade, socio-cultural level (five quintiles), area (urban/rural) and region of the country (department). Data on the use of the CREA platform on

Computational Thinking materials were also considered, specifically, number of entries, readings, homework submissions and forum comments. Four groups of use frequency were created by quartiles, taking into account these data: low use, medium low, medium high, and high use, in order to compare differences in performance.

4. RESULTS

4.1 Participants

Of the universe of students participating in the CT Ceibal program, a total of 3773 students participated in this evaluation, with a mean age of 133 months and a standard deviation of 11.70 months, at the time of the evaluation, from grades 4, 5 and 6 of elementary school. About gender, 50.1% are girls and 49.9% boys. Of the schools, 96% are urban, 3.7% are rural and 0.3% belong to another country, so there is no categorization (urban/rural).

Of the total number of children, 26.2% attend 4th grade, 32.5% attend 5th grade, 35.5% attend 6th grade and 5.8% attend multilevel shared classrooms.

Taking into account the sociocultural level to which the schools belong 576 children attend schools of low sociocultural level, 716 attend schools of medium-low, 585 attend schools of medium level, 728 attend schools of medium-high, 1155 attend schools of high sociocultural level (see Figure 1), 11 students are from a Uruguayan managed school but in Paraguay so it does not have socio cultural categorization and 2 students have missing data.

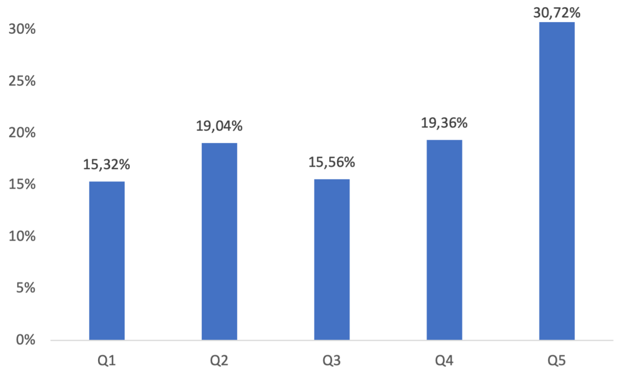

Figure 4. Students distribution by sociocultural quintile.

4.2 Descriptives and findings

This section shows the results: first presenting a descriptive analysis of the scores and then the results of the comparison of means by gender (t-test), sociocultural level, grade, and frequency of use of CREA (ANOVAs).

The mean score obtained in the assessment was 6.88 (SD = 2.81), with scores across the entire possible range of points (0 to 13) (see Figure 5).

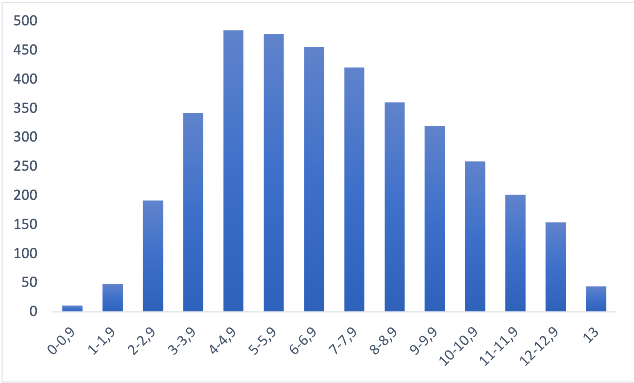

Figure 5. Distribution of students total scores

Table 1 shows statistically significant differences in the scores in favor of the female gender.

Table 1. Mean comparison by gender

	t	df	p
Score	-2.34	3771	.02

From the Analysis of Variance (ANOVA) taking into account the sociocultural quintile of the schools attended by the children (Table 2), it is noted that there are statistically significant differences in the performances obtained. The post-hoc analysis shows that the statistically significant differences are between the groups of low, medium-low and medium socio-cultural levels (Q1, Q2 and Q3) and the groups of medium-high and high socio-cultural levels (Q4 and Q5). Within these two groups of quintiles there are no statistically significant differences.

Table 2. Comparison of means by sociocultural quintile

Variable	df	F	p
Quintile	4	11.07	< .00

Considering the school grade to which the students belong, it is observed that there are significant differences in the scores (Table 3). Considering the post-hoc analysis, it is observed that the differences are between the sixth grade and the rest, while there are no statistically significant differences between the fourth and fifth grades.

Table 3. Means comparison by grade

Variable	df	F	p
Quintile	2	29.43	< .00

Finally, taking into account the use of computational thinking activities on the platform CREA, there are statistically significant differences in the performance between the groups created by the quartiles of frequency use ($F(3, 942)=91.43$; $p<0.001$). The post-hoc analysis yields differences between all the groups, always in favor of the higher use grouping, asi shown in Figure 6. A two-way ANOVA was realized to reject the possible effect of confounding independent variables ($F(24, 23)=.68$; $p=.88$).

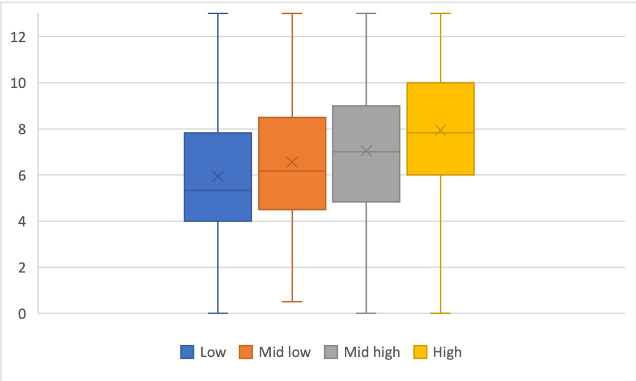

Figure 6. Performance according to frequency of use of CT activities

5. CONCLUSION AND DISCUSSION

Considering the results obtained in this research, it can be concluded that there are effects on the assessment scores:

1. By gender, girls obtain higher scores than boys.
2. By sociocultural level, there are two possible groupings taking into account the scores obtained by sociocultural level, the first being the first three levels (Q1, Q2 and Q3) and the second the two highest levels (Q4 and Q5). Within these groups there are no statistically significant differences, but between groups there are.
3. By grade, although there are differences between the means of all grades, only the difference between the 4th and 6th grades and between the 5th and 6th grades are statistically significant. There are no statistically significant differences between 4th and 5th grades.
4. Frequency of use of the CREA platform. The higher the use of the platform shows higher mean performances in the test, this happens from the lowest level (low level of use) to the highest (high level of use), happening progressively in the rest of the levels.

The statistically significant differences found in favor of women go hand in hand with what has been proposed by some authors who state that at the educational level, in general, women have better performance, (Driessen & van Langen, 2013), in turn, this contradicts other authors who found no statistically significant differences in programming skills by gender (Price & Price-Mohr, 2021). The Analysis of Variance (ANOVA) by sociocultural level provides an expected result, in which children from more favorable sociocultural contexts scored better on the assessment compared to those from less favorable sociocultural contexts (Liu et al., 2020). The results found on the use of CREA and the scores go hand in hand with those found by other authors, in which a relationship is found between the use of LMS and academic performance (Kim, 2017). In this sense, it is a good sign that participation in the program could promote computational thinking and programming skills.

6. FURTHER WORK

In order to obtain more evidence to help us distinguish causal effects of the CT program, it is being planned to conduct new interventions with pre-post experimental design.

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