Coding to learn Mathematics in 5th grade: Implementation of the ScratchMaths project in Spain

Programar para aprender Matemáticas en 5º de Educación Primaria: implementación del proyecto ScratchMaths en España

Jesús Moreno-León
Programamos. Sevilla, España.
jesus.moreno@programamos.es

Marcos Román-González
Universidad Nacional de Educación a Distancia (UNED). Madrid, Spain.
mroman@edu.uned.es

Ramón García-Perales
Universidad de Castilla-La Mancha. Albacete, Spain.
ramon.garciaperales@uclm.es

Gregorio Robles
Universidad Rey Juan Carlos. Madrid, Spain.
grex@gsyc.urjc.es

Abstract

This article presents an investigation that has measured the causal impact of an intervention carried out within the School of Computational Thinking project framework, launched by the Spanish Ministry of Education and Vocational Training in the 2018-2019 academic year. Specifically, it studies whether it is possible to improve the development of mathematical competence through programming activities in 5th grade of Primary Education. The research design is based on the lessons learned from the ScratchMaths project developed by the University College London in the United Kingdom. Two groups of non-equivalent students have been used, the experimental group and the control group, without random assignment, with pre-test and post-test measurement on the mathematical competence variable. More than 3,700 students participated in the investigation. The results show that students in the experimental group developed this competence to a greater extent than students in the control group, with a significant and positive impact. Being the intervention effect size d=0.449, it can be stated that the project achieved the intended effect on mathematical competence. The generalization of computational thinking experiences in the curriculum can guarantee the improvement of the quality of the educational processes.

Keywords: computational thinking, programming language, technology, mathematics, basic education, computer-assisted learning.

Resumen

Este artículo presenta una investigación que ha medido el impacto causal de la intervención realizada en el marco del proyecto Escuela de Pensamiento Computacional, que el Ministerio de Educación y Formación Profesional de España inició en el curso académico 2018-2019. En concreto, se estudia si es posible mejorar el desarrollo de la competencia matemática a través de actividades de programación en 5º de Educación Primaria. El diseño de la investigación está basado en las lecciones aprendidas del proyecto ScratchMaths desarrollado por la University College London en Reino Unido. Se han usado dos grupos de estudiantes no equivalentes, grupo experimental y grupo de control, sin asignación aleatoria, con medición pre-test y post-test sobre la variable competencia matemática. Para ello, se ha contado con la participación de más de 3.700 estudiantes. Los resultados muestran que el alumnado del grupo experimental desarrolló en mayor medida esta competencia que el alumnado del grupo de control, apreciándose un impacto significativo y positivo. Con un tamaño del efecto de la intervención d=0,449 puede afirmarse que el proyecto logró el efecto pretendido sobre la competencia matemática. La generalización de experiencias de pensamiento computacional en el currículum podrá garantizar la mejora de la calidad de los procesos educativos.

Palabras clave: pensamiento computacional, lenguaje de programación, tecnología, matemáticas, educación básica, aprendizaje asistido por ordenador.

Introduction

During the 2018-2019 school year, the Spanish Ministry of Education and Professional Training, through the Spanish National Institute of Educational Technologies and Teacher Training, launched the School of Computational Thinking project in Spain. Its objective is to “offer open educational resources, training and technological solutions that support Spanish teachers in incorporating this skill into their teaching practice through programming and robotics activities with the greatest guarantees.” (INTEF, 2019, p. 16).

Based on the definitions of computational thinking proposed by Seymour Papert in his Mindstorms book (Papert, 1980), by Jeannette Wing in her seminal article on Computational Thinking (Wing, 2006), and taking into account the latest research in this field (Moreno-León, Robles, Román-González, & Rodríguez, 2019), within the School of Computational Thinking framework, this skill is understood as “the ability to solve problems and communicate ideas taking advantage of the power of computers” (INTEF, 2019, p. 11).

For the Primary Education level, the School of Computational Thinking trained more than 200 teachers from 18 regions (out of the 19 regions in Spain). Participating educators learnt how to teach the 5th Grade Primary Mathematics curriculum through programming activities with the Scratch language (Maloney, Resnick, Rusk, Silverman, & Eastmond, 2010). In addition, it provided a set of open educational resources[1] that teachers could use in their lessons. These resources are programming activities designed in a way that encourage interaction with different math concepts from the 5th grade curriculum. The objective is that while students develop their computational thinking, they also improve the development of mathematical competence. All this work is based on the ScratchMaths research project (Boylan, Demack, Wolstenholme, Reidy, & Reaney, 2018) -- implemented in the United Kingdom by the University College London with funding from the Education Endowment Foundation--, which shared the lessons learned and the educational resources prepared with the Spanish Ministry of Education and Vocational Training.

1 http://code.intef.es/aprende-matematicas-y-otras-cosas-con-scratch-3-0/

The phase of implementation in the classroom of the School of Computational Thinking, in which more than 3,700 students participated, was studied by an independent research group. This article presents the conclusions of this study, which tried to answer the following question: Is it possible to improve the development of students' mathematical competence through programming activities with the Scratch programming language in 5th grade of Primary Education?

Background

The use of computer programming as a tool at the service of learning is not a new idea. As early as the 1960s, the Logo language was created, designed to offer an environment in which learners could set a problem they want to solve, experiment, try out several solutions, and build on what they know (Watt, 1982). The goal of this language, therefore, was not only to introduce children to the use of computers from an early age, but to also learn about other disciplines and improve their creativity (Papert & Solomon, 1972).

The scientific community investigated the impact of Logo programming on student learning in different areas, and Mathematics was the subject in which most of the research was carried out. Improvements were found in the classification of geometric figures (Battista & Clements, 1988), geometric thinking (Johnson-Gentile, Clements, & Battista, 1994), working with angles (Clements & Battista, 1989) and improvements in linear measurement (Campbell, 1987). Other investigations, on the contrary, did not find improvements in student learning when using Logo in Mathematics lessons (Hamada, 1986; Olive, 1991).

In recent years, programming languages with block-based editors have become popular. These visual languages are designed to take advantage of all the possibilities of traditional (text-based) languages, but also to learn from their limitations when used in education (Weintrop & Wilensky, 2015). Among these languages Scratch stands out, being the most used in the world with more than 62 million registered users, many of them young people of school age. And with this boom in programming in the educational field, new research is being carried out, aiming to find out more about how programming at an early age affects the learning of other subjects (Fagerlund, Häkkinen, Vesisenaho, & Viiri, 2020; Moreno-León, Robles & Román-González, 2016).

Even though the conclusions of the interventions that have been carried out on the use of Scratch as an educational tool offer a very interesting panorama (Moreno-León & Robles, 2016), some of these works do not follow basic recommendations for the development of research in the educational field (Cohen, Manion, & Morrison, 2007) and most have been done with very small student samples.

For this reason, in 2015 the University College London launched the ScratchMaths project with the fundamental objective of testing whether it is possible to improve the learning of Mathematics through programming with Scratch in 5th and 6th grades of Primary Education (Benton, Hoyles, Kalas, & Noss, 2016). For the design of the project, success stories of works that follow this same approach were taken into account, as well as the limitations that had been previously found (Clements, 1999; Voogt et al., 2015). An intervention was carried out in 110 schools in which more than 5,000 students participated.

The main conclusions of the project were the following (Boylan et al., 2018): i) there is no evidence that the intervention had a positive impact on the academic results in Mathematics; ii) there was an improvement in the development of computational thinking in 5th grade; iii) many schools did not implement the project in its entirety, especially in 6th grade; iv) the participating teachers highlighted the high quality of the teaching materials that were made available to them. The training that the participating teachers received consisted of two and a half days -about 20 hours-, and the final report of the project also highlights that the implementation improved in those schools that offered teachers time to work on the materials.

Taking these results into account, those responsible for the School of Computational Thinking at the Spanish Ministry of Education and Professional Training decided to implement ScratchMaths in Spain, but focusing on 5th grade of Primary Education and extending the training period for participating teachers.

Method

The study was designed as an empirical intervention in which two groups of non-equivalent students have participated, one as the experimental group -which studied the Mathematics curriculum through programming activities with Scratch according to the guidelines of the project- and another as the control group -which continued working on this subject as it had been doing to date, following their textbook for the area, and using other types of activities and resources other than programming with Scratch. The assignment of students to each of the groups was not random, since we worked with entire classes of students already formed by the educational centers. A measurement prior to the intervention was carried out on the variable mathematical competence, the pre-test, and another measurement after the intervention, the post-test, which made it possible to estimate the causal impact of the project.

Sample

The total sample was made up of 3,795 5th grade students, who carried out at least one application of the mathematical competence assessment test. However, as detailed in Table 1, only those students who met the following conditions were considered as valid cases for the study: i) having completed the pre-test and post-test of the instrument; and ii) at least 60 days have elapsed between both tests. According to these two requirements, the final valid sample amounts to 2,178 subjects, with a survival rate of 57.39%.

Regarding the valid sample, Figure 1 shows its distribution by gender, while Figure 2 presents its distribution by Spanish regions, key variables to understand the scope of the research and the characterization of the participating sample. As can be seen, the percentage of boys and girls is very balanced. In addition, there is a geographically distributed sample throughout much of the country, since it is made up of students from all the regions of Spain except Galicia, whose Department of Education declined to participate in the research. The sample is also balanced according to the number of 5th grade units of Primary Education and type of educational centers, public or private ownership and urban or rural environment.

Table 1
Summary of case processing

Group	Total participants	Valid subjects	Survival rate
Experimental	3,629	2,097	57.78%
Control	166	81	48.79%
Total	3,795	2,178	57.39%

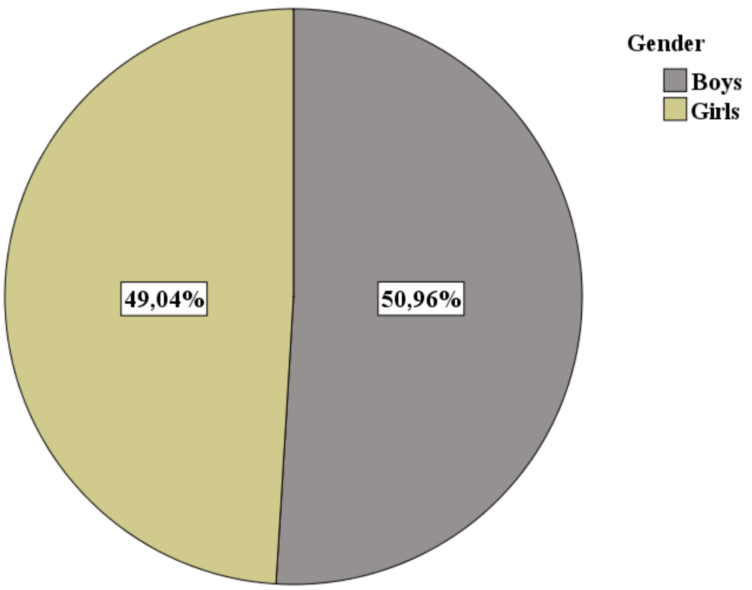

Fig. 1. Distribution by sex of the valid sample.

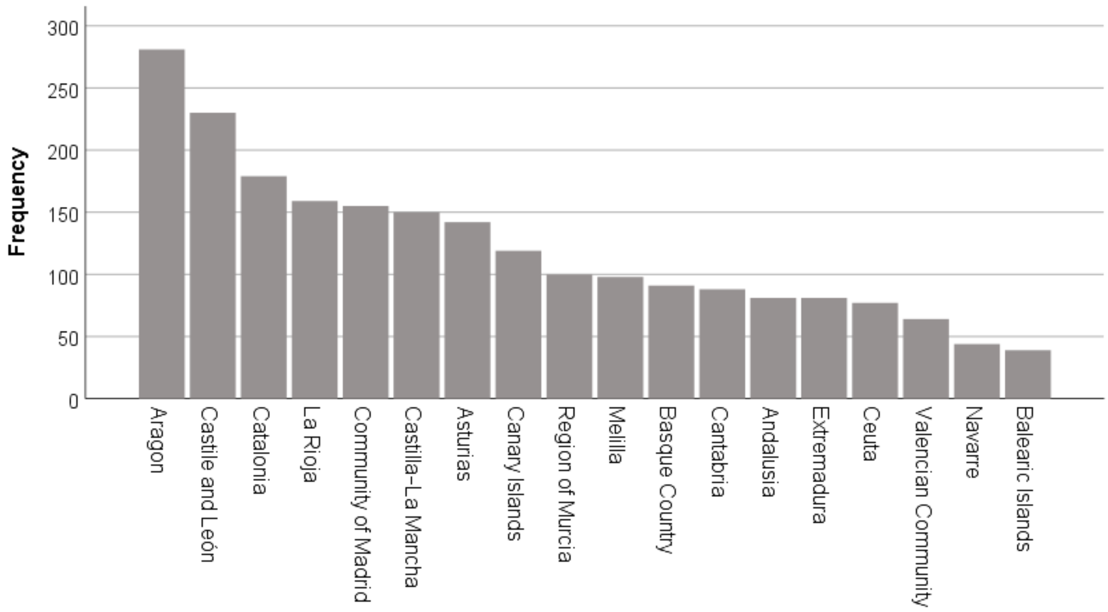

Fig. 2. Distribution by Spanish regions of the valid sample.

Instruments

The acquisition of learning for mathematical competence is characterized by its generalization to the contexts that surround the student, and by its interdisciplinarity in relation to educational achievement for the rest of the areas of the curriculum, aspects that reinforce its transversal and instrumental character. Its integration into the teaching and learning processes allows the cognitive development of students, its approach from education is decisive for well-being and sustainability (Santillán, Cadena, & Cadena, 2019). Specifically, this competence could be defined as "the ability of students to formulate, apply and interpret mathematics in different contexts. It includes reasoning mathematically and using mathematical concepts, procedures, facts and tools to describe, explain and predict phenomena of various kinds" (Spanish Ministry of Education and Professional Training, 2019, p. 17). In this way, its evaluation is key in order to analyze the degree of achievement of the mathematical learning, always taking into consideration its importance for the description, interpretation and prediction of contextual phenomena (Alsina, García, & Torrent, 2019).

In this research, the evaluation of the development of mathematical competence has been carried out using the Battery for the Evaluation of Mathematical Competence, BECOMA (García-Perales, 2014) instrument, which was precisely designed for the 5th year of Primary Education. It is an instrument made up of 30 items distributed among 7 subtests called: *Mathematical interpretation* (5 items), *Mental calculation* (6 items), *Geometric properties* (2 items), *Numerical logical series* (6 items), *Discovering algorithms* (2 items), *Conventional units* (6 items) and *Logical series of figures* (3 items). Each of the items can take a score of 0, 1 or 2 (incorrect, partially correct and correct), with the total score ranging between 0 and 60. The instrument is applied electronically, its application time is 41 minutes, and it contains instructions and examples before the start of each of the subtests.

Regarding its statistical validation, it shows high reliability with Cronbach's Alpha indices between .73 and .90. On the other hand, in terms of their validity (content, criteria and construct), the calculated indices range between .80 and .89 (García-Perales, 2014). There are scientific publications prior to its validation (Jiménez & García-Perales, 2013) and later (García-Perales & Jiménez, 2016; García-Perales, Jiménez, & Palomares, 2020), which offer theoretical and empirical support to this evaluation instrument.

Procedure

Before starting the intervention, participating teachers received a 30-hour online training, over three months, in which they became familiar with the didactic materials that they would later use with their students during the next phase, including instructions and pertinent indications for the application of the test. Only those teachers who passed this training were allowed to continue in the project with their students, which consisted of the pre-test, the implementation in the classroom following the instructions and methodology of the project, and the post-test.

The programming activities developed in the Mathematics classes with the students of the experimental group are based on the curriculum proposed by the ScratchMaths project, which was adapted, updated and translated into Spanish by the Spanish Ministry of Education and Professional Training. These activities are divided into three modules. The first one, “Tiling patterns”, is focused on repeating patterns, such as those found in Islamic art or Gothic stained glass, but also in nature, such as snowflakes. With the activities in this module, students take the first steps in the world of computer programming, become familiar with the Scratch programming environment, and learn to move, rotate and seal objects on the screen; control the flow of programs by repeating instructions; as well as defining their own blocks. The mathematical concepts studied with these activities include: patterns, rotation, angles, coordinates, symmetry, multiplication, translation, transformation, and positive and negative numbers. Figure 3 shows one of the activities, in which the students experiment with the parameters of the “repeat” and “turn” blocks to create different patterns.

Fig. 3. One of the activities carried out by the students of the experimental group. Source: INTEF, available with a free license at http://code.intef.es/aprende-matematicas-y-otras-cosas-con-scratch-3-0/

Module 2, “Beetle geometry”, is centered in the development of programs in which the characters make use of the instructions in the Scratch extension “pencil” to draw different figures and landscapes on the screen. This module also incorporates activities that allow students to learn to debug projects with errors and to predict the result of the execution of different types of programs. Some of the mathematical concepts covered in this module are: perimeter, Roman numerals, regular and irregular polygons, and random numbers.

Finally, the “Interacting sprites” module includes activities designed to show how to use conditional instructions and send and receive messages to synchronize the behavior of the characters in a project, making them interact and react to different events, so that the students learn to create different types of interactive narratives. These activities help to deal with mathematical concepts such as factors, rotation, reflection or ordinality.

This phase of implementation in the classroom took place over three months, with an estimated dedication of 40 hours. The following sections describe the analysis performed on the pre- and post-tests and the results obtained.

Data analysis

Prior to the analysis of the results achieved with BECOMA, the internal consistency of the measurements made was assessed by calculating the reliability using Cronbach's Alpha statistic. Afterwards, the descriptive statistics of the data obtained for both moments of the investigation is presented. Finally, in order to assess the existence of statistically significant differences between groups, experimental and control, and thus know the impact of intervention, an analysis of covariance was carried out and the size of the effect of the measurements was calculated. The research team has been in charge of reviewing the data obtained at each moment of the research. All the statistical treatment has been carried out using the SPSS program (version 26.0).

Results

Reliability of measurements

Table 2 presents the reliability of the BECOMA battery, which amounts to $\alpha = 0.83$. This value is considered 'good' as it is an instrument specifically designed for 5th grade (García-Perales, 2014).

Table 2

Summary of the reliability (as internal consistency) of the BECOMA battery

No. of items	Valid sample size	Cronbach's alpha		Average reliability
		Pre-test	Post-test	
30	2,178	0.814	0.837	0.83

Descriptive results

Table 3 presents a summary of the descriptive statistics in relation to the score obtained by all the students considered as a valid sample in the BECOMA battery in the two measurements.

Table 3

Summary of descriptive statistics related to the total score in the BECOMA battery

Statistics		Pre-test	Post-test
N	Valid	2,178	2,178
	Missing	0	0
Mean		36.08	38.79
Median		36.00	39.00
Mode		35	41
Standard deviation		9.273	9.591
Variance		85.982	91.980

DOI: http://dx.doi.org/10.6018/red.485441

Skewness		-.032	-.092
Kurtosis		-.296	-.539
Minimum		3	11
Maximum		59	60
Percentiles	10	24.00	26.00
	20	28.00	30.00
	25	30.00	32.00
	30	31.00	33.00
	40	33.00	36.00
	50	36.00	39.00
	60	39.00	41.40
	70	41.00	44.00
	75	43.00	46.00
	80	44.00	47.00
	90	48.00	52.00

Figure 4 is a box plot that presents the total scores of the entire valid sample in BECOMA, which can be used to compare the distribution of scores before and after the intervention. In the pre-test, the mean score is 36.08 (SD = 9.273), while in the post-test it is 38.79 (SD = 9.591). The median between moments also varies, from 36.00 to 39.00. With these first results and their graphic visualization, the existence of impact of the introduction of the programming can be glimpsed, which justifies continuing with the analysis of the data in order to study the possible existence of statistical differentiation between the experimental and the control groups.

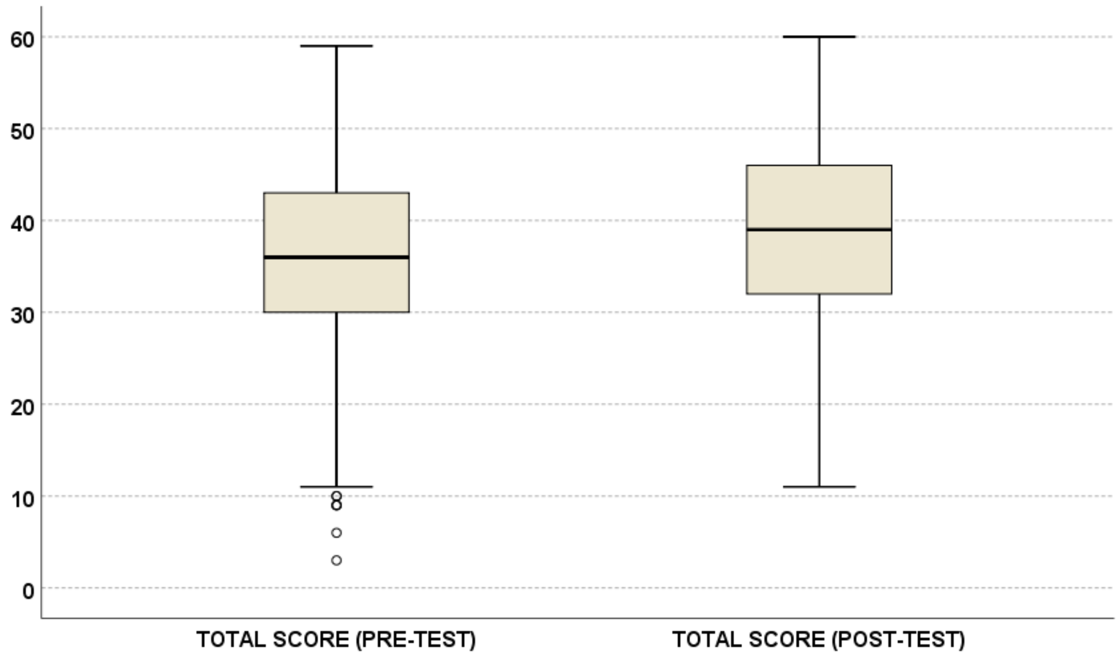

Fig. 4. Box plots on the total score in the BECOMA battery for the whole valid sample (pre-test vs. post-test).

Impact of the intervention

To measure the impact of the intervention, an Analysis of Covariance (ANCOVA) was performed on the total score of the BECOMA battery in post-test, taking the condition experimental group vs control group as a fixed factor and the total score in the pre-test as a covariate. As can be seen in Table 4, the ANCOVA shows a statistically significant difference (F= 17.758; p = .000), from which it is concluded that the intervention had a significant and positive impact on the development of the mathematical competence of the students who participated in the project.

Table 4

ANCOVA on the total score of the BECOMA (post-test), taking the "Condition" ("Experimental" vs. "Control") as a fixed factor and the total score in the BECOMA battery (pre-test) as a covariate.

Dependent variable: total BECOMA score (post-test)					
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected model	95314.507[a]	2	47657.253	987.892	.000
Intercept	12279.675	1	12279.675	254.547	.000
BECOMA (pre-test)	95197.329	1	95197.329	1973.355	.000
Condition	856.685	1	856.685	**17.758**	**.000**
Error	104924.931	2175	48.241		
Total	3476574.000	2178			
Corrected total	200239.438	2177			

a. R squared= .476 (Adjusted R squared = .476)

Figure 5 is a graphical representation of the error bars with the 95% confidence intervals on the mean of the BECOMA for the control and experimental groups both in the pre-test as in the post-test, and can illustrate the change produced in each of the groups between the measurement before the intervention and the measurement after it.

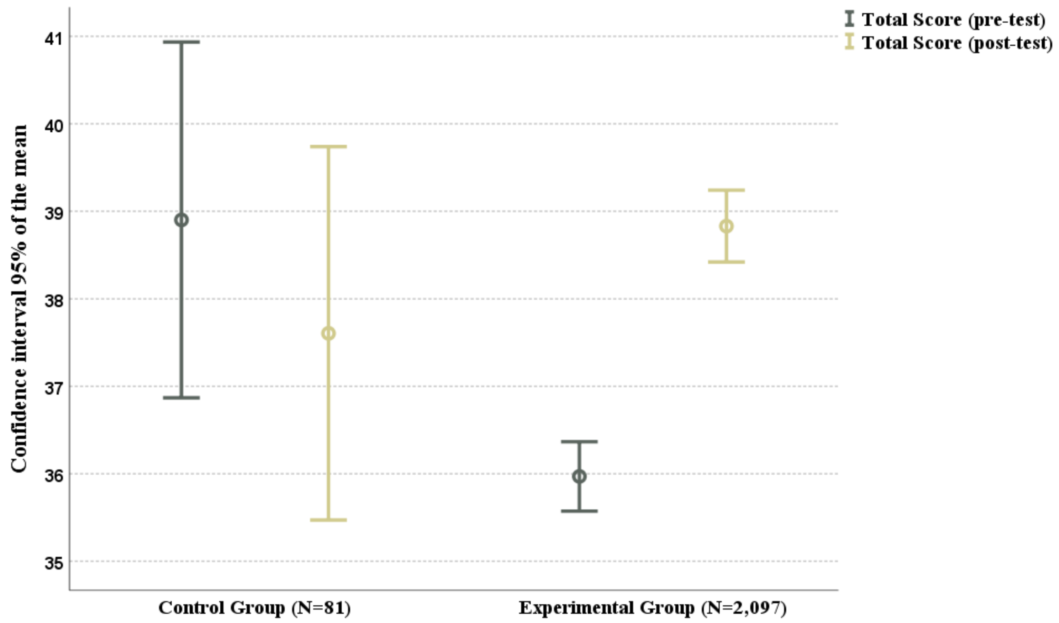

Fig. 5. 95% error bars on the mean of the BECOMA for the Control and Experimental groups in the pre-test and the post-test.

To calculate the magnitude of the impact of the intervention on the mathematical competence, the "effect size" (*d*) (Morris, 2007) has been calculated, as detailed in Table 5. The calculated effect size is *d*=0.449. Although this value indicates a moderate effect (Cohen, 1988), in the context of an educational intervention a value greater than *d*=0.4 indicates that the desired effect has been achieved, according to the influence barometer of Hattie (2009).

Table 5
Calculation of the effect size (d) of the intervention on mathematical competence.

	Control group		Experimental group	
N	81		2,097	
Time	Pre-test	Post-test	Pre-test	Post-test
Mean	38.90	37.60	35.97	38.83
Standard deviation	9.193	9.650	9.261	9.588
Effect size (*d*)	0.449			

Discussion

Since this study is an implementation of the ScratchMaths project, previously conducted in the United Kingdom, it is necessary to discuss the differences in the results between both implementations. What could be the reasons that in the original implementation no evidence of a positive impact on the mathematical competence of the participating students was found, but has been detected in this study?

In the first place, it must be taken into consideration that the implementation carried out in Spain took place after the British one (Boylan et al., 2018; Noss, Hoyles, Saunders, Clark-Wilson, Benton & Kalas, 2020), which allowed us to know what had worked and where there was room for improvement. This is an example of why it is valuable that negative results are also published, as in recent times these have been disappearing from the scientific literature (Fanelli, 2012). Our work is thus a *modified replication*, which aims to find scientific evidence of positive effects through slightly different procedures (Hayes, Young, Matchett, McCaffrey, & Cochran, 2020).

In this regard, the original ScratchMaths project was conducted over two academic years, and improvement in mathematical proficiency was measured at the end of the second year. But the results report explains that, especially during the second year, many schools did not implement the project correctly, probably due to the pressure that 6th grade students suffer with the SATs (Boylan et al., 2018). That is why in the Spanish implementation it was decided to limit the study to a school level, 5th year of Primary Education. Therefore, improvement in mathematical competence was measured with a test specifically developed for this educational grade.

On the other hand, the original report also shows that the implementation improved in those schools where teachers had time to work on the proposed teaching materials, and that this occurred more clearly with teachers who had less previous familiarity with Scratch (Boylan et al., 2018). That is why for the Spanish implementation, it was decided to expand the training received by participating teachers, going from 2 and a half days -around 20 hours- to a 30-hour course developed over three months.

The results achieved, therefore, are in line with previous research on the use of programming with Scratch as an educational resource (Briceño, Duarte, & Fernández, 2019; Durango-Warnes & Ravelo-Méndez, 2020), which detect differences in student learning outcomes based on teachers' programming knowledge and experience (Meerbaum-Salant, Armoni, & Ben-Ari, 2013; Moreno-León & Robles, 2015). In this sense, teacher training on knowledge, methodologies, tools and strategies that favor computer science education with their students is essential (Malott, 2020; Sierra-Rodríguez & García-Peñalvo, 2015).

Limitations

There are several limitations in this study that have to be considered. On the one hand, the difference in the number of students who are part of the experimental group and the control group is large, since after the adjustments and checks carried out the number of valid subjects in the control group was limited to 81. Consequently, in future implementations of the study, it would be advisable to have a larger control group. In this line, it should also be noted the low survival rate of the sample between moments of the research for both groups of students, derived from the demanding conditions established for an adequate development of the research according to the proposed objectives.

On the other hand, although the large number of students participating in the experimental group -who belonged to 200 schools spread over 18 regions- is one of the strengths of the work, it also had a negative consequence, as it prevented researchers from personally visiting the classrooms to supervise the performance of the tests. Although written information was sent to the participating schools in different communications with precise explanations that guided the procedure step by step, the truth is that there is no certainty that teachers and students have respected all the instructions. For example, it could be that in some classrooms students have been allowed to take the tests for a longer time than in others. However, both those responsible for the project in the Spanish Ministry of Education and Vocational Training and the researchers themselves carried out telematic monitoring to solve all the doubts that arose during the project and tried to make the implementation as uniform as possible.

Finally, there is no precise information on the number of activities of the proposed curriculum that each teacher carried out with their students. In the satisfaction surveys that the Spanish Ministry of Education and Vocational Training sent to the participating teachers, they asked about this, and the responses offered a heterogeneous panorama. Thus, taking into account that the activities were divided into three modules, the surveys indicate that around 50% of the schools stayed in module 1, close to the other half reached module 2, and very few schools reached the third module. However, not knowing how many specific activities of each module had been developed in each center, it was decided not to take this factor into consideration, even though it is clear that it can have an impact on student learning.

In sum, it seems obvious that in future interventions it would be desirable for researchers to have greater control over the performance of the tests in the classrooms, as well as over the degree of implementation of the activities of the proposed learning itinerary.

Conclusions

The results obtained indicate that it is possible to improve the development of students' mathematical competence through computer programming activities with the Scratch language in the 5th year of Primary Education. The students of the experimental group, who worked on Mathematics programming with Scratch, improved the development of their mathematical competence to a greater degree than the students of the control group, who worked on this competence by making use of common resources in this area that are not related to computer programming.

In a context in which computational thinking is considered a fundamental skill for life in the 21st century (Li et al., 2020; Mohaghegh & McCauley, 2016; Bocconi et al., 2016), and steps are being taken throughout Europe to incorporate this ability to the curricula of Primary Education (Bocconi, Chioccariello, Dettori, Ferrari & Engelhardt, 2016), the results of this work offer evidence of the effectiveness of developing computational thinking through computer programming activities as an educational tool at the service of learning Mathematics. This approach in which programming and computational thinking become educational resources and are integrated into existing subjects, is being implemented in various European countries (Bocconi, Chioccariello & Earp, 2018) and Spanish regions (INTEF, 2018). These are fundamental learning contents to take into consideration in the digital escalation that is taking place in educational centers (Van Dijk, 2020).

Likewise, it is considered appropriate to highlight that these results may be of great interest to the international educational community in view of the next test of the Program for International Student Assessment of the Organization for Economic Cooperation and Development, which in 2021 will focus on the evaluation of mathematical competence as the main subject and will also measure the computational thinking of the students. Thus, the framework for the test explains that "students must have and be able to demonstrate computational thinking skills while applying mathematics as part of their problem-solving practice" (Organization for Economic Cooperation and Development, 2018, p 5), an approach that we consider to be a perfect fit with the intervention presented in this work.

Received: June, 28, 2021
Accepted: November, 03, 2021
Published: November 30, 2021

Moreno-León, J., Román-González, M., García-Perales, R., & Robles, G. (2021). Coding to learn Mathematics in 5th grade: implementation of the ScratchMaths project in Spain. *RED. Revista Educación a Distancia, 21(68).* http://dx.doi.org/10.6018/red.485441

Funding

This work has received public funding within the framework of the collaboration signed between the National Institute of Educational Technologies and Teacher Training (INTEF) of the Ministry of Education and Professional Training, and the National University of Distance Education (UNED), through Teacher Marcos Román, for the concept "Research and report on the results obtained by the students of the School of Computational Thinking (Primary and ESO levels)". Furthermore, this work has been funded by the Regional Government of Madrid (eMadrid P2018 / TCS4307, co-funded by the European Structural Funds -FSE- and FEDER).

References

Alsina, A., García, M., & Torrent, E. (2019). The assessment of mathematical competence from school and for school. *UNION. Ibero-American Journal of Mathematical Education*, *55,* 85-108.

Battista, MT, & Clements, DH (1988). A case for a Logo-based elementary school geometry curriculum. *Arithmetic Teacher*, *36*(3), 11-17. https://doi.org/10.5951/AT.36.3.0011

Benton, L., Hoyles, C., Kalas, I., & Noss, R. (2016). Building mathematical knowledge with programming: insights from the ScratchMaths project. In *Constructionism in Action 2016: Conference Proceedings* (pp. 26-33). Suksapattana Foundation: Thung Khru, Thailand.

Bocconi, S., Chioccariello, A., Dettori, G., Ferrari, A., & Engelhardt, K. (2016). *Developing computational thinking in compulsory education-Implications for policy and practice* (No. JRC104188). Joint Research Centre (Seville site).

Bocconi, S., Chioccariello, A., Dettori, G., Ferrari, A., Engelhardt, K., Kampylis, P., & Punie, Y. (2016). Exploring the field of computational thinking as a 21st century skill. *Proceedings of the EDULEARN16*, *16*, 4725-4733.

Bocconi, S., Chioccariello, A., & Earp, J. (2018). The Nordic approach to introducing Computational Thinking and programming in compulsory education. *Report prepared for the Nordic@ BETT2018 Steering Group*.

Boylan, M., Demack, S., Wolstenholme, C., Reidy, J., & Reaney, S. (2018). *ScratchMaths: evaluation report and executive summary*. Education Endowment Foundation.

Briceño, OL, Duarte, JE, & Fernández, FH (2019). Diseño didáctico para el desarrollo de destrezas básicas de programación por medio del programa Scratch a estudiantes del grado quinto del Colegio Seminario Diocesano de Duitama. *Revista Colombiana de Tecnologías de Avanzada*, *2*(34), 180-190. https://doi.org/10.24054/16927257.v34.n34.2019.4006

Campbell, PF (1987). Measuring distance: Children's use of number and unit. *Final report submitted to the National Institute of Mental Health Under the ADAMHA Small Grant Award Program. Grant No. MSMA, 1*, R03.

Clements, DH (1999). The future of educational computing research: *T*he case of computer programming. *Information Technology in Childhood Education Annual, 1*, 147-179.

Clements, DH, & Battista, MT (1989). Learning of geometric concepts in a Logo environment. *Journal for Research in Mathematics Education, 20*(5), 450-467. https://doi.org/10.2307/749420

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences (2nd edition)*. Hillsdale, NJ: Erlbaum.

Cohen, L., Manion, L., & Morrison, K. (2007). *Research methods in education*. New York: Routledge.

Comisión Europea (2018). *Comunicación de la Comisión al Parlamento Europeo, al Consejo, al Comité Económico y Social Europeo y al Comité de las Regiones sobre el Plan de Acción de Educación Digital*. Bruselas: Comisión Europea.

Durango-Warnes, C., & Ravelo-Méndez, RE (2020). Beneficios del programa Scratch para potenciar el aprendizaje significativo de las Matemáticas en tercero de Primaria. *Trilogía Ciencia Tecnología Sociedad*, *12*(23), 163-186. https://doi.org/10.22430/21457778.1524

Fanelli, D. (2012). Negative results are disappearing from most disciplines and countries. *Scientometrics*, *90*(3), 891-904.

Fagerlund, J., Häkkinen, P., Vesisenaho, M., & Viiri, J. (2020). Computational thinking in programming with Scratch in primary schools: A systematic review. *Comput Appl Eng Educ.*, *2020*, 1-17. https://doi.org/10.1002/cae.22255

García-Perales, R. (2014). *Diseño y validación de un instrumento de evaluación de la competencia matemática: rendimiento matemático de los alumnos más capaces* [Tesis Doctoral]. Madrid: UNED.

García-Perales, R., & Jiménez, C. (2016). Diagnóstico de la competencia matemática de los alumnos más capaces. *Revista de Investigación Educativa*, *34*(1), 205-219. https://doi.org/10.6018/rie.34.1.218521

García-Perales, R., Jiménez, C., & Palomares, A. (2020). Seguimiento de un grupo de alumnos y alumnas con alta capacidad matemática. *Revista de Investigación Educativa*, *38*(2), 415-434. doi: http://dx.doi.org/10.6018/rie.366541

Hamada, RM (1986) *The relationship between learning Logo and proficiency in mathematics*. (Tesis Doctoral, Columbia University).

Hattie, J. (2009). *Visible learning*. New York: Routledge.

Hayes, JR, Young, RE, Matchett, ML, McCaffrey, M., & Cochran, C. (Eds.). (2020). *Reading empirical research studies: The rhetoric of research*. New York: Routledge.

Instituto Nacional de Tecnologías Educativas y de Formación del Profesorado, INTEF (2018). *Programación, robótica y pensamiento computacional en el aula - Situación en España y propuesta normativa*. Madrid: Ministerio de Educación y Formación Profesional.

Instituto Nacional de Tecnologías Educativas y de Formación del Profesorado, INTEF (2019). *La Escuela de pensamiento computacional y su impacto en el aprendizaje. Curso escolar 2018-2019*. Madrid: Ministerio de Educación y Formación Profesional.

Jiménez, C., & García-Perales, R. (2013). Los alumnos más capaces en España. Normativa e incidencia en el diagnóstico y la educación. *Revista Española de Orientación y Psicopedagogía, 24*(1), 7-24. https://doi.org/10.5944/reop.vol.24.num.1.2013.11267

Johnson-Gentile, K., Clements, DH, & Battista, MT (1994). Effects of computer and noncomputer environments on students' conceptualizations of geometric motions. *Journal of Educational Computing Research, 11*(2), 121-140. https://doi.org/10.2190/49EE-8PXL-YY8C-A923

Li, Y., Schoenfeld, AH, diSessa, AA, Graesser, AC, Benson, LC, English, LD, Duschl, RA (2020). Computational Thinking Is More about Thinking than Computing. *Journal for STEM Education Research, 3,* 1-18. https://doi.org/10.1007/s41979-020-00030-2

Maloney, J., Resnick, M., Rusk, N., Silverman, B., & Eastmond, E. (2010). The scratch programming language and environment. *ACM Transactions on Computing Education (TOCE), 10*(4), 1-15. http://doi.acm.org/10.1145/1868358.1868363

Malott, C. (2020). The Sublation of Digital Education. *Postdigital Science and Education, 2,* 365-379. https://doi.org/10.1007/s42438-019-00083-6

Meerbaum-Salant, O., Armoni, M., & Ben-Ari, M. (2013). Learning computer science concepts with scratch. *Computer Science Education, 23*(3), 239-264. https://doi.org/10.1145/1839594.1839607

Ministerio de Educación y Formación Profesional (2019). *PISA 2018 Programa para la Evaluación Internacional de los Estudiantes. Informe español*. Madrid: Ministerio de y Formación Profesional.

Mohaghegh, DM, & McCauley, M. (2016). Computational thinking: The skill set of the 21st century. *International Journal of Computer Science and Information Technologies, 7*(3), 1524-1530.

Moreno-León, J., & Robles, G. (2015). Computer programming as an educational tool in the English classroom: a preliminary study. In *2015 IEEE Global Engineering Education Conference (EDUCON)* (pp. 961-966). IEEE.

Moreno-León, J., & Robles, G. (2016). Code to learn with Scratch? A systematic literature review. In *2016 IEEE Global Engineering Education Conference (EDUCON)* (pp. 150-156). IEEE.

Moreno-León, J., Robles, G., & Román-González, M. (2016). Code to learn: Where does it belong in the K-12 curriculum. *Journal of Information Technology Education: Research, 15*, 283-303. https://doi.org/10.28945/3521

Moreno-León, J., Robles, G., Román-González, M., & Rodríguez, JD (2019). Not the same: a text network analysis on computational thinking definitions to study its relationship with computer programming. *Revista Interuniversitaria de Investigación en Tecnología Educativa*, *7*, 26-35. https://doi.org/10.6018/riite.397151

Morris, SB (2007). Estimating Effect Sizes from Pretest-Posttest-Control Group Designs. *Organizational Research Methods, 11*(2), 364-386. https://doi.org/10.1177/1094428106291059

Noss, R., Hoyles, C., Saunders, P., Clark-Wilson, A., Benton, L., & Kalas, I. (2020). *Constructionism can work: the story of ScratchMaths*. MIT Press.

Olive, J. (1991). LOGO programming and geometric understanding: An in-depth study. *Journal for Research in Mathematics Education, 22*(2), 90-111. https://doi.org/10.5951/jresematheduc.22.2.0090

Organisation for Economic Co-operation and Development (2018). *PISA 2021 Mathematics Framework (Draft)*. Recuperado de https://cutt.ly/lhYve27

Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas*. Basic Books, Inc.

Papert, S., & Solomon, C. (1972). Twenty Things to Do with a Computer. *Educational Technology, 12*(4), 9-18. Recuperado de https://eric.ed.gov/?id=EJ062142

Santillán, JP, Cadena, VC, & Cadena, M. (2019). Educación Steam: entrada a la sociedad del conocimiento. *Ciencia Digital*, *3*(34), 212-227. doi: https://doi.org/10.33262/cienciadigital.v3i3.4.847

Sierra-Rodríguez, JL, & García-Peñalvo, FJ (2015). Informática Educativa y Educación en Informática. *Education in the Knowledge Society (EKS)*, *16*(4), 25-31. doi: http://dx.doi.org/10.14201/eks20151642531

Watt, M. (1982). What is Logo? *Creative Computing, 8*(10), 112-29.

Weintrop, D., & Wilensky, U. (2015). To block or not to block, that is the question: Students' perceptions of blocks-based programming. *Proceedings of the 14th International Conference on Interaction Design and Children* (pp 199-208). Medford, MA, USA: ACM. http://dx.doi.org/10.1145/2771839.2771860

Wing, JM (2006). Computational thinking. *Communications of the ACM*, *49*(3), 33-35.

Van Dijk, J. (2020). *The Digital Divide*. Cambrigde, UK: Polity Press.

Voogt, J., Fisser, P., Good, J., Mishra, P., & Yadav, A. (2015). Computational thinking in compulsory education: Towards an agenda for research and practice. *Education and Information Technologies, 20*(4), 715-728. https://doi.org/10.1007/s10639-015-9412-6