Development of Algorithmic and Mathematical-Logic Competences of Children in Chile with Scratch

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Abstract— Algorithmic competences for the development of organized operations play an important role in the progress of education and learning of the logical and mathematical reasoning for children. In this context, the visual programming language Scratch is a viable tool for that purpose. Precisely, the main objective of this work is to present experiences and results of the use of that programming language with students of the primary school second year in various Chilean educational institutions, that is, in a public school, in a private school and in a private-subsidized school. These schools are in different geographical areas of the Maule region. Thanks to their social and cultural diversity along with their location, the obtained results are of a great relevance to demonstrate empirically that a significant gap does not exist for the development of algorithmic and logical-mathematical competences in children.

Index Terms— *Algorithmic Competences, Mathematical-Logic Competences, Scratch, School, Children*.

1 INTRODUCTION

Algorithmic thinking is essential for the analysis, understanding and solution of computational problems. According to [1], the development of logical thinking is of high relevance for the human being, mainly to analyze and solve problems of his daily life and more if he begins to develop at an early age. In addition, for the mathematical and scientific foundation, algorithmic thinking is essential to face and provide solutions to problems of science and life. Likewise, as observed in [2], the development of algorithmic thinking for both the present and future generations is imperative in today's culture. In addition, as it stands out [3], the use and application of Visual Programming Languages (VPL) today represents one of the most notorious and prevalent computer techniques. This is so, even though, as highlighted [4], there is a large increase in computing devices in schools, but their effective use in the educational process of children has not been decisive. The development of logical and algorithmic reasoning (algorithmic competences) allows not only to analyze problems and deliver solutions in the computational field but in very varied situations of daily life such as in art [5] and the business world [6]. As they stand out [2] [7], algorithmic skills are developed through learning, management, use of syntax, and semantics of programming languages so that developing such skills in young children does not It is a simple task for educators. In this way, educational alternatives are necessary for the development of algorithmic skills in children and students. There currently exist different high-level visual programming languages such as Scratch and Alice [8] [9]. Both programming approaches, Scratch and Alice, allow the elimination of syntax and semantic problems and barriers from traditional programming languages, and, through the use of multimedia objects, to facilitate the understanding and application of essential algorithmic elements such as conditional and repetitive structures. According to [10], one of Scratch's goals is to make programming accessible and motivating for everyone, even when, as they point out [11], the main pseudo-barrier in Scratch It is to understand the semantics of the actions and their classification. The objective of this work is to evaluate the development of algorithmic thinking in second-year students of three primary schools of different realities in Chile. We test if the way to involve technology as didactic means for math classes, along with the development of algorithmic and logical-mathematical skills, present a positive effect in the children's learning process.

This work proposes the development of algorithmic and logical-mathematical competences in second-year basic students of schools of various socioeconomic and geographical sectors of the Maule region, to measure the development of these competencies together with analyzing their impact on academic performance in mathematics. Thus, this work seeks to validate the hypothesis of equivalence in the learning capacity of children in their early years, regardless of geographical location and socioeconomic status. Currently, in Chile, there exist public, private, and private-subsidized education institutions. This work presents experiments in each of these establishment types: Monterilla public school of the city of Teno, private-subsidized Institute Valentín Letelier of Yerbas Buenas, and Conception private school in the town of Talca. In total, five courses participated in the experiment: the second year of the Monterilla School; the second year A, B and C courses of the Colegio Concepción; and the second year of the Valentín Letelier Institute. It is relevant to note that this work is the result of the title work of one of the authors of this work [12].

2 SCRATCH AND COMPETENCES IN CHILDREN

Scratch is a visual programming environment created by MIT whose original focus was the attraction of people to the world

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of programming, thanks to the elimination of syntax rules along with making their semantics closer and higher, since ease of creating visual and interactive routines [2] [13]. Scratch has been occupied in various countries such as Spain, the United States, Mexico, Colombia, Argentina, as a way to introduce programming and to evaluate the effect of promoting learning development and creativity in the stages of children's education. Figure 1 shows the Scratch system that is composed of the following sections: a scenario where the action occurs, an area to select the activities that the main object can perform (in this case Scratch), an area of objects, and a programming area with the set of joined instructions for the main object.

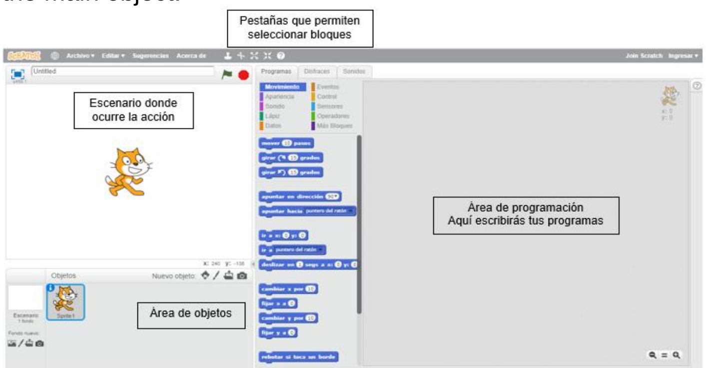

Fig. 1. Desktop of Scratch.

The Scratch system has been a great success in computer club environments [10], where children spend more time working in Scratch than with any other available software application. There exists practical evidence that Scratch manages to foster creativity and the social effect of multimedia among classmates and friends on the web, to share projects, ask for help in completing tasks, among other matters.In a study conducted at Harvard University [14], Scratch was used to introduce beginners to programming before their transition to the Java programming language. In this study, there was a high approval of Scratch by newbies in programming, while the only learners in disagreement were those who already had some programming experience. According to traditional psychology, the term competence refers to the mastery of some knowledge [15]. In the area of education, the Organic Law of Education in Chile introduces the term basic competence in the definition of the curriculum [16]. According to [17], "curriculum means the set of objectives, basic competencies, content, pedagogical methods, and evaluation criteria of each of the teachings." In the teachings of early childhood education, according to [11], "at this educational stage, the foundations for personal and social development are laid out, and learnings are integrated that are at the base of the subsequent development of skills that are considered basic for everything the students." Thus, a basic competence is to understand the child's ability to put into practice in different contexts and situations, both theoretical knowledge and practical skills or knowledge. Thus, the concept of basic competence considers knowing how to be, knowing how to apply or applying, and knowing how to be [17]. According to the work of [18], with VPLs such as Scratch and Alice, programs are built using concrete objects and not just virtual elements or characters on the screen. Besides, as noted [19], Scratch is a suitable LPV for the development of algorithmic skills that are part of the necessary skills and minimum education of today's children.

3 Benefits of Algorithmic Competencies in Children

Algorithmic thinking, or the ability to define the steps to solve a problem, is crucial in courses such as mathematics or science. Students use algorithms all the time without realizing it, especially in math. For example, to solve a massive division problem, girls and boys apply an algorithm to iterate through the digits of the number they are dividing. For each digit of the dividend (the amount to split), students must divide, multiply, and subtract. Thus, algorithmic thinking allows students to decompose problems and conceptualize solutions in terms of discrete steps. Table I [20] describes the characteristics of the cognitive process during the programming process, while Table II [20] indicates the cognitive skills involved in the programming process. The proceedings of the Scratch South conference [20] indicate that the use of Scratch to a greater extent always wants to teach its applicability to more people, especially young people and children. Scratch is a current tool in education in many Latin American countries. For example, in Argentina, at the Rosario Institute for Research in Education Sciences for creating technology for social inclusion, and having experiences with Argentine teachers in primary education to reach teachers first and then students. In addition, in Uruguay, the Scratch Day activity (Scratch Day) is carried out at the University ORT Uruguay - CEIBAL Plan, which is a day dedicated only to Scratch, in order to make it known and Scratch users can present their examples. Currently, in Chile, programming with free projects for the community is introduced with the Young BiblioRedes Program of the Directorate of Libraries, Archives and Museums (DIBAM), of the Ministry of Education, a project that teaches to program online to people from 8 years old, and Scratch is one of the courses [21].

TABLA I

CHARACTERISTICS OF COGNITIVE PROCESSES IN COMPUTER PROGRAMMING IN CHILDREN.

Characteristic	Description
Formulate	Formulate the problem for the use of computers and tools for your solution.
Collect	data Gather the necessary information.
Analyze and organize data	Find meaning in the data, find patterns, relationships, generate information, organize it, and obtain conclusions.
Represent data Design	data representation strategies through abstractions such as models and simulations (tables, graphs, diagrams, drawings, maps, etc.).
Decompose problem	Divide the task or problem into smaller parts and easier to solve.
Developed parts represent reusable parts.	Automate Solve the problem through an orderly sequence of steps (implementation of an algorithm).
Abstract	Build through the union of smaller parts the solution to a bigger problem, reducing complexity by developing the main solution.
Generalize	Generalize and transfer the process implemented in solving the problem to a greater number of problems.

TABLA II
COGNITIVE SKILLS IN COMPUTER PROGRAMMING.

Skill	Description
Confidence	Confidence in managing complexity.
Persistence	Being persistent at work and finding solutions.
Tolerance	Ability to tolerate and resolve ambiguous situations.
Solve problems	To deal with the probl em, especially complex and unstructured problems.
Communication	Communicate and work with others (teamwork below).

TABLA IV
QUESTIONS OF 1ST SESSION OF WORK – SCHOOL CONCEPCIÓN.

#	Question	Yes	No
1	Have you used a computer before?	71	2
2	Do you have a computer in your home?	67	6
3	Do you have internet access in your home?	61	12
4	Do you like math?	66	7
5	Do you know what programming is?	18	55
6	Would you like to learn math using technology?	69	4
7	Have you heard of Scratch?	31	42

4 EXPERIMENTS AND RESULTS

The various experiments carried out in the schools (schools), were three sessions in each establishment, in different academic schedules, which are described below.

First session: It begins with a survey, in which it is intended to evaluate the use of student technologies, and then give way to an introduction on Scratch, where it will be taught how it works, the important parts and the essentials for students begin to focus on the tool, and can use it without problems. Tables III, IV and V show the questions and answers og those questions in the schools.

TABLA III
QUESTIONS OF 1ST SESSION OF WORK – SCHOOL MONTERILLA.

#	Question	Yes	No
1	Have you used a computer before?	14	0
2	Do you have a computer in your home?	6	8
3	Do you have internet access in your home?	3	11
4	Do you like math?	13	1
5	Do you know what programming is?	5	9
6	Would you like to learn math using technology?	14	0
7	Have you heard of Scratch?	0	14

TABLA V
QUESTIONS OF 1ST SESSION OF WORK – SCHOOL V. LETELIER.

#	Question	Yes	No
1	Have you used a computer before?	16	0
2	Do you have a computer in your home?	12	4
3	Do you have internet access in your home?	12	4
4	Do you like math?	15	1
5	Do you know what programming is?	3	13
6	Would you like to learn math using technology?	16	0
7	Have you heard of Scratch?	0	16

Second session: In the second session, they ask at the beginning of the previous meeting: Did they use Scratch again after the first visit? Is the first session clear? Do they feel prepared to continue using Scratch? Then, we proceed with a review of the topics discussed in the first session to clarify basic concepts and the management of Scratch to ensure the successful development of this session. Then you are asked to create a small example of using Scratch (the steps will be asked and indicated for the Scratch cat to walk five steps and then say Hello), and thus validate the progress and provide feedback when necessary.

Fig. 2. Scratch simulator of mathematical exercises.

Besides, in the second session, an example Scratch application is used as a test of basic mathematical operations in the second year of primary school in Chile. Thus, students are the users to validate the learning and development of mathematical logic to solve basic problems of math operations that require feedback. That feedback is essential to motivate them to continue trying to achieve a correct response when an answer was incorrect (essay and error), where you get more points when fewer mistakes are made. That is, to analyze the advantages of using software against written tests, given immediate feedback, whether the answer is correct or not. Figure 2 shows the environment of the developed application.
The questions in the mathematical test with Scratch are ten sums, five sums, and 5 five subtractions, where the sums have random numbers between 1 and 99, and the first number of each subtraction will be one at random between 25 and 50 and the second number between 1 and 25 to avoid negative subtractions). Table VI shows the results obtained in each school according to the minimum, maximum and average number of attempts, as well as the time required for resolution. Each school source is numbered as follows: 1 for a class of the Monterilla schook; 2, 3 and 4 for classes of the Concepción school; and 5 for a class of the Valentín Letelier school. It should be noted that the test activity consists of two parts: the experiment with Scratch in the second session, and a written test of the same mathematical content and with the same amount of questions, but this time without the help exposed by the software. The written test is part of the beginning of the next session.

TABLA VI
MATHEMATICS EXERCISE RESULTS IN SCRATCH

Sch.	Indicator	Attempts Add	Attempts Sub	Time
1	Min score	7	2	16′ 53″
	Max score	19	25	28′ 51″
	Avg score	13	17	21′ 5″
2	Min score	4	2	6′ 39″
	Max score	12	11	17′ 5″
	Avg score	6	5	11′ 40″
3	Min score	1	2	2′ 40″
	Max score	12	1	19′ 1′
	Avg score	5	3	8′ 45″
4	Min score	3	3	4′ 56″
	Max score	9	13	20′ 31″
	Avg score	7	9	12′ 1′
5	Min score	6	0	22′ 51′
	Max score	14	25	6′ 58″
	Avg score	7	8	13′ 54″

TABLA VII
RESULTS OF EXERCISE WRITTEN TEST OF MATHEMATICS

Sch.	# Students	Correct Answers	Wrong Answers	No Answered
1	14	1	7	6
2	25	5	12	8
3	25	16	8	1
4	23	11	8	4
5	16	5	11	0

Third session: This session begins with the written math test, the same for all students. As with the previous Scratch experiment, there are ten questions divided into five additions and five subtractions, where the most difficult thing for the students was to solve the subtractions with reservations, since, according to comments from teachers, this is the most complex for children. Thus, students will be asked to develop the test and, in the end, raise their hands to write down how long they took to do so. There is a maximum time of 20 minutes. Table VII shows the results of the written test according to the number of students, with the number of tests with correct answers, with some incorrect answers and unfinished tests.
After the written test, the students meet in groups with other classmates (4 students), to imagine a game they would like to create in the context of mathematics, and then work on their development supported by the guides. The objective of the last activity is to foster creativity and teamwork. That permits knowing their motivation to create their games to share their experiences.

4 FINAL DISCUSSION

When comparing the results obtained in each of the schools, the great contribution that technology provides in the development of mathematical exercises, as well as the advantages attainable when facing the problems with software, can be verified, since it allows verifying the veracity of the Real-time responses.
As for the digital divide that was expected at the end of all the sessions and when comparing each of the various schools involved in the research, it is noteworthy to realize that the municipal school of Teno had a greater degree of technology and its students with a high degree of mastery in computers, not so, in the title Valentín Letelier de Yerbas Buenas, since the students did not have an adequate laboratory to be able to develop the activity in the beginning, and not everyone had access in their homes to technology . In Colegio Concepcion, if there were greater aptitudes to solve mathematical problems, as well as in the use of computers, since their laboratory was in better condition and almost all of their students had computers in their homes according to the survey carried out at the beginning of the first session. Although the Monterilla school and the Valentín Letelier

Institute are far from the regional capital, which is Talca, the knowledge and manner of reception of the new skills regarding the Concepción College were much better received due to various factors such as the number of students in the room, the attachment that exists with the head teacher, and the desire to use computers..

5 Conclusions

Scratch in schools: 1) For the familiarity of children with technological elements, the insertion of Scratch permits developing algorithmic and logical-mathematical competences, regardless demographic and social sector of schools. That is, Scratch is lively, fast, and easy access for children. 2) Teachers experience a role change because they participate like students in each of the sessions, which motivates children. That invites us to analyze the reasons for this situation. 3) The option to create visual applications motivated children to occupy Scratch once the sessions were carried out. This validates what [3] proposed, that is, teachers require the continuous use of Scratch with pedagogical purposes for the next few years, and thus enhance mathematical and science learning with the help of technology. 4) Regardless of their social or demographic level, developing mechanisms to capture and maintain the attention of all students, answer questions, carry out different projects, and create and mature ideas during class are of high value in education. For example, each school in this study had different characteristics.

Even if there were differences of knowledge among students in different schools in mathematics, this unevenness did not prevent them from successfully carrying out the exercises both with Scratch and on paper, which allowed the hypothesis of this work to be validated.

With all of the above, without a doubt, Scratch represents an excellent tool for education.

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