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Developing Computational Thinking Skills in Adolescents With Autism Spectrum Disorder Through Digital Game Programming

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ABSTRACT In the last years, many didactic activities have been proposed to develop Computational Thinking (CT) skills in children and adolescents. Among these activities, the digital game programming stands out as a promising alternative considering that it is related to a familiar and motivating context for students. These initiatives are not specifically aimed at individuals with special needs such as the autism spectrum disorder (ASD). Children and adolescents with ASD usually have some limitations related to communication, cognitive flexibility, and interpersonal relationships. However, it seems natural that the skills potentially developed through game programming activities are especially beneficial for the public with ASD. In this paper, we describe the offering and evaluation of a Game Building Workshop adapted to adolescents with this condition. The guidelines used to define the workshop activities are described. An assessment based on the classroom observation and analysis of produced artifacts indicate that the participants acquired CT skills related to programming at a high level. In addition, the collaborative nature of the activities offered a stimulating and welcoming environment for individuals with ASD.

INDEX TERMS Game design workshop, autism spectrum disorder, neurodiversity.

I. INTRODUCTION

Autism Spectrum Disorder (ASD) is a neurodevelopmental condition mainly characterized by a deficit in social interaction as well as in creative behavior. The organization of daily life activities of people with this condition has also been deeply studied [1]. Global statistics suggest that the prevalence of ASD increases annually in a rate between 10% and 17%. In fact, between the years 2000 and 2010, the prevalence of autism increased by 120%, making it the fastest growing disorder in the world. The actual prevalence of this disorder is 1 in 59, making it more common than infantile cancer, juvenile diabetes, and pediatric AIDS combined [2]. People with ASD present difficulties in the capacity to understand others, communication and language functions, comprehension of symbols and cognitive flexibility [3]. Hence, educational initiatives aimed at this public should include diverse features, such as visual aids, an structured and not saturated environment, among others.

Computational Thinking (CT) is a concept that synthesizes a subset of cognitive abilities that professionals in the field of computing generally develop in their formation process [4]. Abilities associated to CT are applicable to different domains; although this terminology is rather recent, the discussions about problem-solving skills augmented by the use of computational devices has already been reported in the last 30 years [5], [6]. CT definitions have incorporated the concept of a problem resolution process, or of a tool for changing the way in which others disciplines are learned, aside from offering the possibility of comprehending, in a better way, a world permeated with computational devices [7]–[9].

Furthermore, the development of digital games by students has been used as a didactic strategy in different areas for the promotion of CT skills [9]–[13]. This is mainly due to motivational aspects that are intrinsic to the digital games domain. The popularity of visual programming tools such as Scratch, Alice, GameMaker, and Greenfoot, among others, allows that a student develops his or her own games in the process of teaching and learning the fundamentals of programming. Moreover, the construction of their own digital artifacts can help students think in a more independent way, which is one of the main characteristics of Constructionism [14].

Diverse scientific, organizational, and governmental initiatives have surfaced to promote CT [15], [16]. However, after a review of the main bibliographic databases (ACM, IEEE, ScienceDirect), to the best of our knowledge, no initiatives exist so far to involve minority groups, such as those with ASD.

Hence, this article presents an experience in promoting Computational Thinking skills in adolescents with ASD. A Digital Game Programming workshop was designed using Scratch as the programming environment. For the definition of the workshop activities, the principles established in the TEACCH Program (Treatment and Education of Autistic and Communication Related Handicapped Children) were considered and particularized [17]. Furthermore, some guidelines for the activities involving the digital games construction were also defined. The workshop was offered in Curicó, Chile in July 2017, and its results evidenced that it is possible to promote CT skills among this particular public and that the skills acquired are kept in a sustained manner over time.

The paper continues as follows. Section II discusses some relevant works related to Special Education and Technologies. Section III presents the methodology of this research. In Section IV we present the main results of the Game Design Workshop for Adolescents with ASD. Finally, Section V exposes our conclusions and future work.

II. RELATED WORK

Approaches related to computing aimed at improving skills in people with ASD have been developed since the 1960s [18]. In 1980, it was proposed to use the LOGO programming language to develop language skills in children that presented specific needs, e.g., children with autism [19]. A few years before, computer-assisted games were proposed to improve communication skills in nonspeaking autistic children [20]. To do this, an exploratory methodology was proposed. The game had a visual screen controlled by a keyboard, on which symbols could appear accompanied by a human voice and other sounds. The study was conducted with 17 children, and 14 of which improved their oral communication skills. The remaining three refused to play with the visualization device. The main advantage evidenced in using this system was that the child became an active agent in the control of an inexhaustible and predictable device, on which the child never felt angry or ignored. Considering the historical context, we believe this improvement was mainly due to two factors: On the one hand, the concrete and systematic manipulation form of computer programs, that coincides with the thought and vision of the world of a subject with ASD; on the other hand, the affinity that people with ASD show by technological elements and tools. For example, there is clear evidence that subjects diagnosed with ASD contributed to the development of the Internet in its current format [21].

Other experiments using LOGO have been performed. One such experiment was conducted with a seven year old child diagnosed with autism possessing stereotypical reading and verbalization. For this case study, a teletypewriter of 16 buttons was used, where each button represented a command (e.g., FORWARD, BACKWARD, LEFT, RIGHT, PENU, PENUP, or HOOT) [22]. The intervention was made of 7 sessions, each one lasting for one hour, during a period of 6 weeks. For analysis, the sessions were recorded, as well as the sequence of buttons pressed by the child. Given the evidence produced by this intervention, we consider that the results are extremely interesting, particularly because the child developed a certain level of autonomy when directing the turtle. In a basic manner, the turtle movements corresponded to the same movements that the child already knew. According to the authors, this emphasizes the constructionist idea that the comprehension of new ideas depends on the ability to relate them to existing ones, and in particular to the mental schemas developed during active exploration. Furthermore, the child also began to verbalize the actions that the turtle had to do, demonstrating his or her understanding of the actions carried out. This was not a short-lived phenomenon: about a year later, the child was transferred out of the autistic unit thanks to a sustained improvement in his or her ability to communicate with others. Another important element of this research work is that the turtle movements were perfectly imitated by the subject of study. Nowadays, imitation is considered fundamental to develop language and communication skills, social skills, executive functions, and theory of mind (ToM). Indeed, the neurobiological basis of these abilities is sustained in the mirror neurons system [23]–[27], whose main function, according to some authors, is imitation [28].

One of the most recent experiments was developed in 2016 by Schmidt and Beck, specifically through a software called "Virtuoso" (according to the authors, the name comes from a word play between "virtual" and "social") whose objective was to motivate the social skills and CT development. The research was developed with a population of children diagnosed with ASD, whose ages ranged between 11 and 14 years [19]. The proposal differs from other systems since not only does it introduce the software for CT acquisition, but also requires the participants to work together with programmable virtual robots, so that they manage to solve the problems to which they were exposed. In this way, social skills development was expected. The program consisted of creating learning materials that would integrate the development of social competence, as well as developing an online space where the participants could work together in the academic content through the use of the Minecraft video game. While the current work is still under development, we believe that it will not only contribute to the CT integration, but

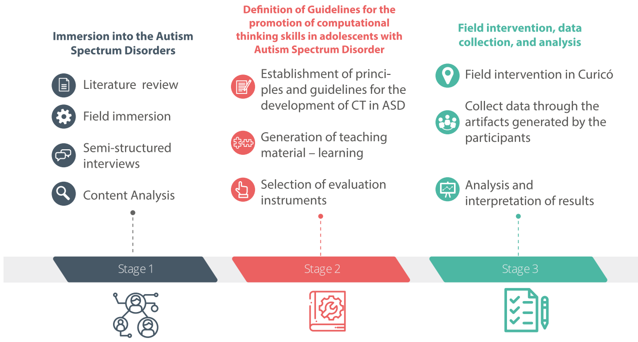

FIGURE 1. Work methodology.

will also initiate a pioneering change in the influence of computational tools for the development of social skills in people with ASD.

III. METHODOLOGY

Numerous initiatives currently exist to promote CT on different educational levels, being the construction of digital games one of the most used methods. However, there is a lack of proposals in the specific domain of people with ASD.

Given the complexity of the subject area, a work methodology was established in order to better understand the details about the autism spectrum as a diverse neuro-evolutionary condition. The established work methodology has three stages, described in Figure 1. The main aspects are presented below.

- *Stage 1* – Immersion into the ASD: During this stage, a literature review focused on educational and cognitive development aspects of people with ASD was conducted. In parallel, a field immersion was performed by means of a 6-month participatory observation that was held in two different educational institutions in the region of Valparaíso, Chile. These institutions work directly with children and adolescents with ASD. The field observation results were complemented by five semi-structured interviews with Chilean ASD specialists. A content analysis was conducted to identify the main topics mentioned during the interviews. This analysis was aimed at understanding how ASD specialists apply in their work the recommendations presented in the literature. The results of this stage are presented in Section III-A.
- *Stage 2* – Guidelines definition for the promotion of CT skills in adolescents with ASD: Based on the information obtained during Stage 1, a set of guidelines were established for creating activities based on the construction of digital games for the CT aspects development. These guidelines are presented in Section III-B. Based on the established guidelines, the didactic material for the digital games construction workshop was produced and later validated by ASD specialists.
- *Stage 3* – Field intervention, data collection, and analysis: The workshop was held for the first time in January 2016, with four teenagers, at Valparaiso, Chile [29]. In a second interaction, the workshop took place in Curicó, Chile, in July 2017. In this occasion, seven adolescents were present with the same diagnosis. Based on the proposed workshop activities and the analysis of artifacts produced by the participants, an evaluation rubric for the CT skills promotion was selected. The results are presented in Section IV.

A. STAGE 1: IMMERSION INTO THE AUTISM SPECTRUM DISORDERS

To better understand the current state of research, a bibliographical search was conducted in the ACM, IEEE, and ScienceDirect databases in December 2015. A search string was defined with the parameters "computational thinking" AND (autism OR asperger OR ASD). The search retrieved 22 articles, 11 in the ACM database, 7 in the IEEE, and 4 in ScienceDirect. However, none of the articles effectively presented any information regarding CT with people diagnosed with ASD. This demonstrates the absence of research involving the area that our research is focused on. Furthermore, a bibliographic search was conducted on works that involve the use of technology centered around ASD. The main results are presented in Section II. Simultaneously, a bibliographical search was carried out to find conceptual frameworks for the CT development. The results from this search were already presented in [30]. The field immersion was carried out from November 2015 until December 2016. This immersion was carried out in an educational support institution for children and adolescents with a diagnosis of ASD, in the region of Valparaíso, Chile. Weekly visits to the institution lasting approximately 3 hours each were performed. The visits had both non-participatory and participatory moments. The latter ones were interactions among children and adolescents with ASD in activities designed by the educators and their team. The findings were recorded after each session. In particular, the analysis was focused on the social interaction of children and adolescents with ASD and the organization of the work environment.

The main finding from this activity was the need for a highly structured physical environment, with visual supports and few distractions. This coincides with the study results where children with ASD were exposed to an emotion-learning program, for which the researchers focused on developing and promoting predictable (i.e. structured) environments [31]. According to the authors, this would not only encourage the systematization innate skills of children with ASD, but would also increase the intrinsic motivation and learning ability. This statement is also shared by other authors [32], [33], based on the high capacities that people with ASD have to systematize information, focus their attention, and follow patterns as established rules.

The bibliographical search also found that the activities carried out by the professionals always had limited time for their execution, thus facilitating concentration and the fulfillment of the tasks. According to some authors, this time limitations allows to develop the activities without interruptions, as well as maintain a structured work environment, considering the high skills of this type evidenced in people with ASD [31], [34].

Another important aspect that was identified was that the structure of sessions is usually antecipated to the participants. This is justified by the necessity to stimulate and maintain the structure and systematization of the working environment. For this purpose, visual supports are generally used, and when activities are fulfilled, they is an indication of their completeness [35].

Within the immersion process, five semi-structured interviews were also carried out with ASD specialists in Chile. The objective of this activity was to understand what methodologies or approaches are used in their day-to-day work with children and adolescents. The interviews are organized around the following questions: (1) How do you organize work environments and what elements do you use in your daily activities? (2) What strategies or methodological references do you use for your work with ASD? and (3) what is the potential and limitations involved in working with children and adolescents with ASD? After the thematic analysis of the responses, the importance of generating a constructivist environment for the teaching-learning of individuals with ASD was identified, in contrast to the dominant behavioral environment of past years. In the answers it is also highlighted the need for a "real understanding" of ASD to proportion a "natural progression" of learning, seeking the development of "true independence".

B. STAGE 2: DEFINITION OF GUIDELINES FOR THE PROMOTION OF COMPUTATIONAL THINKING SKILLS IN ADOLESCENTS WITH AUTISM SPECTRUM DISORDER

The proposed guidelines are associated with two aspects. The first one is orienting the definition of activities suited to individuals with ASD and based on building digital artifacts. The second one is related to the characteristics of the specific domain of digital games and constructionist activities.

For the first aspect, the principles defined in TEACCH were particularized. This particularization was supported by the information provided by professionals working with adolescents and children with ASD. The four TEACCH particularized guidelines for the activities creation are presented below.

- D1 - *Understand the culture of autism.* To deeply understand the difficulties and potential of ASD people, a weekly accompaniment was made during 6 months in a communication center in the region of Valparaíso, Chile. The accompaniment had the format of a participant observation. It was hoped to generate a workshop according to the needs of people with ASD.
- D2 - *Structure the physical environment.* Visual noise in the environment can distract and confuse adolescents with ASD [36]. In this way, the computer lab must have a physical organization with clearly separate areas for each activity (e.g. computers, memberships storage section, collation). The logical organization of the workshop files must also be taken into account. The file folders, for instance, must be organized according to the sessions and, in turn, subdivided into folders for each activity that compose the session.
- D3 - *Use visual supports to make the daily sequence of activities predictable and comprehensible.* It is advisable that the structure of the activities is presented in a clear way from the beginning of the workshop in order to avoid unexpected events throughout the process that could generate participants anxiety. To do this, we recommend the use of an organized presentation format (e.g. tables or conceptual maps) to present to the participants the overall structure of the workshop and each of the sessions to be performed.
- D4 - *Use visual support to make the individual tasks understandable.* For each activity, information about its content and how it will be developed must be presented. Again, this recommendation is designed to reduce the potential for stress caused by uncertainty about how the activity will continue. This aspect is of paramount importance due to the deficit in the executive function presented by individuals with that condition [37], [38].

Regarding the creation of digital games construction activities, four guidelines were incorporated and validated by the authors in previous work [39], [40]:

- D5 - *The construction of games must motivate the development of all the workshop activities.* This guideline is based on the principle of game fluency [41], which argues that the process of design and construction of artifacts in the cultural context of digital games can promote a process of reflection and learning for students.
- D6 - *The activities must progressively lead to the construction of the mechanics of a complete game.* Previous works discussing the development and conduction of practical activities with the aim of developing CT skills mentioned the Use–Modify–Create paradigm [42]. Initially, students interact with previously built programs to understand their behaviour. Students are then invited to introduce changes in their features and appearance. Finally, as students gain more confidence, they begin to create their own games, applying the knowledge acquired in previous stages. This strategy is not applied in a linear way. A student can act as the creator of a stage in the learning process and next, in other stage, re-act as a "user" to understand a new concept. However, the activities structure and the knowledge and skills to be employed induce the student to act each time as "creator" throughout the workshop. The strategy still has an impact on maintaining an appropriate challenge level.
- D7 - *The activities must progressively demand that new concepts be explored by the students and, at the same time, request that the student use previously explored concepts as well.* The aim of introducing new concepts gradually into the activities (through the

use-modify-create scheme) is to introduce, continuously, new challenges that induce the student to seek new knowledge. New challenges should be proposed at the same time concepts already explored are demanded, in order to put students in a position to explore self-employment in game building [43]. In the same way, the teacher is expected to be able to act as a facilitator when students present specific difficulties related, for example, to a particular concept. In these cases, the planned sequence of activities is expected to keep students in the zone of proximal development [44], thus allowing for progress in the activities.

- D8 - *The game mechanics, despite being simple, should bring reference to the universe of "real" games to make them meaningful to students.* Aligned with a constructionist proposal, in which the construction of digital artifacts by students demands them to apply in a reasonably autonomous manner, the activities of the workshop follow the problem-based learning (PBL) approach. According to some authors, problem-based learning is a student-centered strategy, where students works collaboratively in solving a problem and the teacher figures as a reference for support and the knowledge construction is gradual and empirical [45]. In this way, in each workshop activity, students receive instructions on the objectives proposed for the game; besides that, an example of the proposed game being executed is presented and from there work is started. The teacher acts as a facilitator by observing the work and intervening as students request greater support.

For the development of the construction activities of digital games, we used Scratch 2.0 (see Figure 2). This application is an environment of visual programming that allows to develop interactive projects such as games and animations.

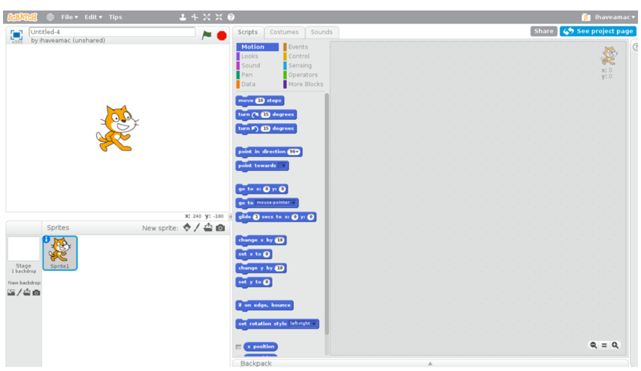

FIGURE 2. Scratch Programming Interface.

This platform was chosen against other alternatives due to the simplicity and highly structured organization of its interface, as well as the use of drag-and-drop style blocks. On the other hand, previous results indicate that the Scratch environment can potentiate the exploration of features and creativity in the generation of digital artifacts [39], [40].

C. STAGE 3: FIELD INTERVENTION, DATA COLLECTION, AND ANALYSISs

In this iteration of the digital game workshop, the study group was about 300 kilometers away from the researchers' workplace. The workshop was structured in 5 sessions, during July 2017, which correspond to the period of Winter holidays of the participants.

The study was approved by the Research Department part of the Vice-rectorate of Research and Graduate Studies at Pontificia Universidad Católica de Valparaíso - Chile. Code: 039.440/201 - *Framework for the Measurement of Computational Thinking Skills in Adolescents with Autism Spectrum Disorders*. Also, in agreement to the recommendations, in terms of investigation ethics defined by the World Health Organization (WHO), the parents had to sign an informed consent on qualitative studies, and the adolescents had to also sign an informed assent [46].

A daily session of 3 hours each was carried out. In each session, there was a 15 minutes break period, in which the teenagers' parents served snacks and refreshments. This activity had 3 foci. The first focus was that participants could talk with their parents, if so wanted, about what they were learning. The second focus was to afford the possibility of taking a break within the activity in a structured way. Finally, the third focus was to encourage the exchange of the activity results among the participants. Regarding the sessions structure, the presence of the parents was essential to maintain a known environment, which helped to control the anxiety caused by the unknown environment—in this case, related to the present people. The tranquility that the parents' presence promotes allows to maintain the attentional focus in the execution of the activities—in this case the construction of digital games—and in the activities that their peers developed. Indirectly, it was sought to stimulate socialization and communication interaction skills, through sharing experiences and interests regarding the activity. All of the above helped to maintain the sessions structure throughout the experimentation, in order to facilitate future work through a familiar, structured, and systematized environment.

At each meeting, the teacher proposed that the participants programmed one or more interaction mechanisms related to a digital game (Sprite animation, collision, keyboard and mouse control) involving programming structures (variables, messages, conditional and looping structures). The content of each activity, as well as the estimated number of blocks used to achieve a functional solution, is presented in Table 1.

Five games were build with increasing complexity levels. In order, the first is called "Bat Collision game", and consist of a simple application to introduce participants to the concept of controlling the sprites movements with the keyboard and detecting the collision between sprites. In the second game, "Magic Number", the computer raffles a random number and the player inputs his or her guesses one at a time. After each guess, the game must inform the player if the guessed number is smaller or greater than the "magic

TABLE 1. Game design workshop activities.

N	Game	Main content	Num. blocks
1	Bat collision game	Simple conditional structures, collision between objects, green flag	25
2	Magic Number	Variable assignment, relational operators (>, <, =), selection structures	22
3	Arkanoid	Repetition structures, sending messages, random mumbers	110
4	Duck Hunt	Clones	77
5	Flappy Bird	Clones, functions	96

number''. The third is a clone of the Arkanoid arcade game developed in 1986. It is based in the Atari Breakouts of the 70's. In this game the player controls a small paddle which allows, if hitted, the bounce of the ball that destroys blocks in the upper part of the screen. In the 4th game, ''Flappy Bird'', the player must dodge obstacles clicking on the mouse repeatedly; each time the user clicks, the bird flies higher. The original game was developed in middle 2013, with more than 50 million downloads in a few months. The last game, ''Duck Hunt'', is a video game developed by Nintendo in 1984. The player must shoot ducks that fly over the screen, winning points and advancing levels while hitting targets. Each time the player successfully hits the ducks, a dog appears and searches the ducks. In Figure 3 we have shown examples of 3 games developed (Arkanoid, Duck Hunt, and Flappy Bird).

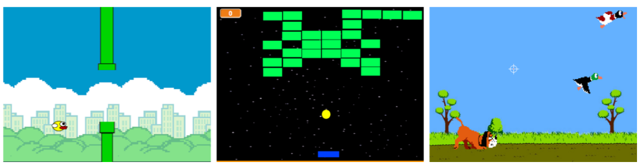

FIGURE 3. Examples of possible games implementations.

Before the construction, a pre-test established the competence level of CT-related skills in the participants. For this purpose, the CT Test was used [47]. The test is composed of 28 questions independent of previous knowledge of a programming language. Each item addresses one or more of the 7 following computational concepts: Basic directions (4 items), ''repeat'' (4 items), ''repeat until'' (4 items), ''if'' (4 items), ''if/else'' (4 items), ''while'' (4 items), and simple functions (4 items). According to the authors, this concepts are aligned with CSTA standards for science education [48].

The correlation of this tests with cognitive abilities was already evaluated [49]. This abilities have a close relationship with those altered in people with ASD, for instance, the dexterity of information systematization, automation of elements and/or concepts related, and performing abstract analysis of any given information. These skills are all related to Executive Functions, one of the superior cognitive skills more affected in people with ASD [50].

This test was digitally sent two weeks earlier to the respective tutors, in order to be shared with adolescents assisting to the workshop. In the same instrument, the adolescents are inquired about their game preferences (categories), previous experiences with programming, and daily hours using the computer. At the end of the workshop, the same test was applied to determine if there is any difference in developed skills.

IV. RESULTS

The workshop for promoting computational thinking through the construction of digital games was conducted on July 2017 in a School of Curicó, Chile.

Seven adolescents diagnosed with Asperger's syndrome (equivalent to ASD Level 1 in the [1]) participated in the workshop. The participants were between 11 and 15 years old (AVG = 12.86 years, SD = 1.6 years). All participants were male and had a high interest in digital games, playing daily more than 5 hours on average. Also, it was identified that their preferred game genres were RPG (role-playing game) and shooter. An important aspect to evidence is that the some participants did not know each other and, moreover, did not possess knowledge of programming of digital games.

After the workshop offering, the code created by the participants in all sessions was analyzed in order to determine the development of skills associated with CT. To determine this, the educational rubric defined in [51] was used, implemented through Hairball in the Dr. Scratch platform. The rubric is presented in Table 2.

According to the authors, the score is obtained by the sum of the proceeds in each of the rows, which represent the criteria to evaluate. A project in which the obtained total score is lower than 8 points is considered to demonstrate an acquisition of CT skills in ''Basic'' levels [51]. A project that obtains between 8 and 14 points is evaluated as ''Developing'' (Dev), and those that obtain more than 14 points are evaluated as ''Proficient'' (Pro). An analysis of the artifacts produced in the five sessions was performed, with the objective of determining the mobilization of skills associated with CT. In Table 3 the scores obtained in the sessions are presented, as well as the metric of dispersion.

The analysis of the artifacts produced by the participants reveal that more advanced programming structures were used by them through time. According to the structure of the rubric, this is an evidence that the participants progressively acquired more advanced CT skills. One possible explanation for this is the structure of the workshop, as the sequence of activities demanded that students recalled CT concepts that they were previously exposed to and, at the same time, explored new concepts (principle D3 in Section III-C). Moreover, the new concepts needed were always intrinsically related to new game mechanisms (principle D1 in Section III-C).

To illustrate the relationship between this hypothesis and the structure of the workshop we will consider the *Synchronization* criterion of the rubric. In the diagram of Figure 4

TABLE 2. Rubric for CT acquisition.

CT Concept	Basic (1 point)	Developing (2 points)	Proficiency (3 points)
Abstraction and Problem decomposition	More than one script and more than one sprite	Definition of blocks	Use of clones
Parallelism	Two scripts on green flag	Two scripts on "key pressed" events, two scripts on "sprite clicked" events on the same sprite	Two scripts on "when I receive message" events, creation of clones, two scripts "when %s is > %s", two scripts on "when backdrop changes to"
Logical Thinking	If	If else	Logical Operations
Synchronization	Wait	Broadcast, when I receive message, stop all, stop program, stop programs sprite	Wait until, when backdrop changes to, broadcast and wait
Flow control	Sequence of blocks	Repeat, forever	Repeat until
User interactivity	Green flag	Key pressed, sprite clicked, ask and wait, mouse blocks	When %s is > %s, video, audio
Data representation	Modifiers of Sprites properties	Operations on variables	Operations on lists

TABLE 3. Results of CT skills acquisition.

CT Skill	S1	S2	S3	S4	S5
Abstraction and Problem decomposition	1.00	0.57	1.00	3.00	3.00
Parallelism	0.67	0.71	1.29	3.00	3.00
Logical Thinking	0.83	1.00	1.00	2.00	1.86
Synchronization	1.00	2.14	2.14	2.00	2.43
Flow control	2.00	2.00	2.00	2.29	2.00
User interactivity	2.00	2.00	1.00	1.43	2.00
Data representation	1.00	2.00	2.00	1.29	2.00
Total	8.50 (Dev)	10.43 (Dev)	10.57 (Dev)	15.00 (Pro)	16.29 (Pro)

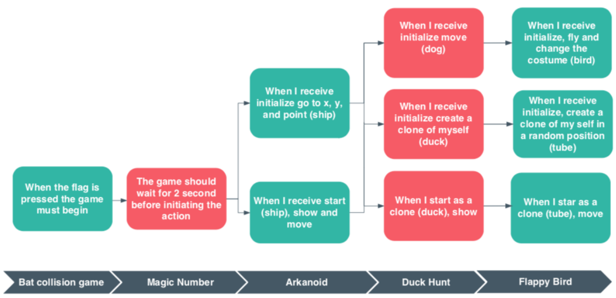

FIGURE 4. Mechanisms of each game that demanded synchronization concept.

the mechanisms of each game that demanded synchronization concepts are shown in sequence. It is possible to identify that participants were exposed to simpler synchronization concepts since session 3 and more complex tasks are demanded in the acquisition of more skills as each session develops.

According to results obtained, the less acquired skill during the workshop, considering the rubric definition, was the one associated with logic thinking. In Table 2, it can be seen that higher development levels in this category are associated to the use of logic operators in the program code. However, when analyzing activities associated to logic thinking, while contemplate the use of these operators (simple or compound) the participants tend to use them in simple way. As this strategy was useful to them, they kept using it. Regarding [30], in this occasion activities were redirected to include the use of clones in activities 4 and 5. For this reason the dimension of parallelism was considerably improved.

An analysis of developed artifacts reveals that the participants were even adding unsolicited functionalities, for instance, extra lives, messages or sounds. These type of extra elements are indications of fluidity in the use of the platform, and therefore, development of competencies associated with CT.

Another important aspect is related to the collaboration scheme defined during the workshop, that facilitated the communication between participants. We believe that this strategy was relevant in the offered workshop, due to the fact that the participants, upon working in a highly motivating activity, were confident in interacting with their peers, given that their interests were similar. For this reason, in a secondary manner, social interaction was steadily promoted. It is important to point out that this trait is a condition decreased in people with ASD.

As mentioned in Section III-C, a pre and post test of 28 questions was conducted. A box-plot of the results is presented in Figure 5.

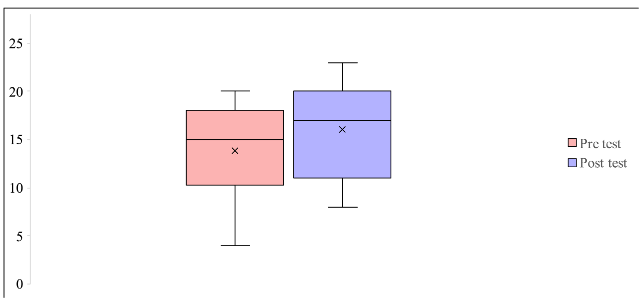

FIGURE 5. Results of the Pre - Post test.

In quantitative terms, there is a positive difference in pre and post median of 2 points, being 15 on first and 17 in second. Average in pre test was 13.9 and in post test 16.0. It is also important to mention that the minimum score also changed, being twice as large in the post test. Although the number of participants was low, this is compensated by the type of population in which the initiative is addressed, setting a precedent for other types of interventions. Finally, although the instrument used did not have curricular adaptations to people with ASD, it has already been validated in groups without disabilities.

V. CONCLUSIONS

Computational Thinking represents a set of skills related to Computer Science that should be developed by everyone and gradually is becoming a crucial skill for the XXI century, due to the potential benefits that comes with developing these skills, in addition to aiding the understanding of other scientific areas.

The number of people diagnosed with Autism Spectrum Disorder continues to grow, which reminds us of the need to understand both of limitations and skills of people with this condition. Computational tools, and specifically, CT, become fundamental, given that this public tends to learn and handle such tools with ease. However, after a bibliographical review, no such initiatives that search to promote computational thinking skills in people with ASD were found.

In this article, the development and evaluation of a workshop involving digital game creation using the Scratch environment was presented. This workshop sought to promote computational thinking skills. Its development was rooted in principles based in the understanding the culture of autism, as well as in guidelines for the definition of activities that involve building digital artifacts.

To carry out this initiative, it was required to attend communication centers on a regular basis. In this way, we understood the difficulties and strengths of people with ASD. Furthermore, the selection of Scratch as a tool for the workshop was beneficial, showing a low learning curve. We believe that this was mainly due to its highly structured interface and its type of drag and drop interaction. It is important to understand that this interface could be so successful because it was considered one of the greatest skills that we find in people diagnosed with ASD: the ability to organize, systematize and process information.

For the evaluation of the workshop results, a rubric proposed by [51] was considered, as well as an analysis of artifacts produced by the participants. The obtained results, considering that the participants did not have prior knowledge in programming, are encouraging. On one hand, the workshop permitted the promotion of skills associated with computational thinking, such as abstraction and logical thinking, obtaining sustainable results over time. This was evidenced in the application of a pre and post test given for the participants. On the other hand, during the workshop, communication and collaboration between peers were promoted, as well as social skills that people with ASD have not acquired, or, they have not developed. This last result is very significant, not only for researchers but also for people with ASD, since, according to the results of the present study, these can be developed and improved through digital games programs that encourage the development of computational thinking.

A set of pedagogical skills oriented towards working with people with ASD was particularized, along with defining a set of guidelines for the construction of didactic activities. This will allow the creation of new activities to promote Computational Thinking in minority groups, such as those with ASD.

As future works, it is hoped to particularize rubrics for measuring CT, according to educational levels, taking as a reference that proposed by the CSTA, as well as the generation of new automated assessment tools associated with the non-verbal behavior of people with ASD. On the other hand, as future work we also hope to replicate this type of initiatives with people with other types of disabilities.

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