Applications With Mathematical Content for Users With Autism

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***Abstract*— Some students with autism may have difficulty acquiring mathematical knowledge. However, the use of technology could help them to understand this knowledge more easily. This study therefore aims to obtain a list of mobile applications with mathematical content that are not only recommendable for users with autism, but can also be used by them in an autonomous manner. To this end, 44 applications were chosen, which were used by 28 students with autism in Primary and Secondary Education. On the one hand, it was found that satisfying the accessibility criteria does not guarantee the suitability of the application for this type of user, since 15.9% of the applications chosen could not be fully used by the trial group with autonomy below 50%. On the other hand, a list is provided of 38 applications with mathematical content, recommended or highly recommended for users with autism, 29 of which can be used by them autonomously.**

***Index Terms*— Computer applications, education, mathematics, technology.**

I. Introduction

THE Autism Spectrum Disorder (ASD) is a neurodevelopmental condition which usually manifests at an early age, and accompanies the individual throughout their life. The main features that define ASD affect two domains, the communicative and behavioural, presenting persistent deficits in communication and social interaction and repetitive or restrictive patterns of behaviour [1]. These features may exhibit considerable variation and, depending on the support or assistance required by the person with autism in their daily life, there are three levels: 3 needs very considerable support, 2 needs considerable support, 1 needs support [1]. People with autism may have deficits in executive functions such as planning and flexibility [2], [3], although they tend to have very good visual memory [4].

This means that some students with autism may have difficulty acquiring mathematical concepts and skills related, for example, with numbers and operations [5], [6], [7], magnitudes and their measurement [8], [9], [10], geometry and spatial orientation [11] and problem solving [6], [12], [13].

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Furthermore, applications (apps) with a clear and structured design have been shown to be the most beneficial software for people with ASD [14]. This is because, having good visual memory, it has been shown that the use of the touch screen leads them to improve their academic performance [15], [16], [17], [18].

The use of educational apps on a touch screen device makes it easier for the user with autism to pay continued attention to the activity, and so offers an active and participative learning. In this way it increases the motivation of the student and improves their autonomy, as the app gives automatic responses about their progress in the activity [16], [19], [20], [21].

There are several studies supporting the findings on the development of skills in mathematics. Liu et al. carried out a meta-analysis where they found 22 studies using a Tablet to teach mathematical content to users with autism and/or intellectual disability, and found a large positive effect on the teaching of numbers and operations, algebra and statistics [22]. Zhang et al. found that the use of three apps with mathematical content (*Splash Math, Motion Math Zoom and Long Multiplication*) was beneficial for eighteen 9-year old students, among whom were four with a diagnosis of autism, emotional disorder, dislexia or learning difficulties. These apps allowed such students to practise content to do with the positional value of digits and arithmetic operations. All the participants achieved higher scores after using the apps, and the initial difference in academic performance between students with and without difficulties was reduced [23]. Similarly, five of the seven students with autism, with ages ranging from 11 to 13, who used the *Matching Game-My First Numbers* app, about counting up to 10, associating number with quantity, and one-to-one correspondence, improved their performance and autonomy in these mathematical areas [24].

The video modeling has returned good results in previous studies, and is considered to be an evidence-based practice [25]. Using an iPad as support for the video modeling, Ledbetter-Cho et al. carried out a study on five students with autism, aged from 6 to 9, working with them on addition, using manipulative material or counting upwards. The participants showed an increase in the number of problems solved correctly, and there was also a decrease in defiant and stereotypical behaviours, although there was no evidence of a functional relationship between the intervention and the reduction in this type of conduct [26]. Four students with developmental disorder, aged from 11 to 13, three of whom had autism, used iPads and computers to carry out reading

activities, counting, or colour and shape recognition. Via these activities, the authors compared the participation of students with both devices, and found no differences between them for three of the four participants, while the fourth had higher participation using the iPad [27].

The effects of using physical materials and their virtual equivalents to improve the academic performance of students with autism have also been compared. Bouck et al. and Bassette et al. performed a number of studies into solving additive problems with base 10 blocks (physical material) and its equivalent, the Base Ten Block application (digital material). Both materials were effective in teaching participants to solve this type of problem; however, better results were obtained using the digital material. Therefore, the authors of these studies agree that the use of digital material could assist the learning of students with autism [28], [29], [30], [31].

In fact, Long et al. have found that virtual manipulatives are an evidence-based practice for students with autism and/or intellectual disability [32].

The combined use of video modeling, virtual manipulatives, and digital maths games (*SplashLearn* and *Math Playground*), through online instruction, has been effective in teaching multiplication, division and subtraction of fractions, or multiplication, addition and equivalence of fractions to two students, 8 and 9 years old, with autism. These findings show the potential of combining digital tools - with each other and/or with other methods - to improve the mathematical skills of students with autism [33].

Despite what is stated above, there is still a lack of studies assessing the effect and usefulness of digital tools adapted to these students, especially in developing countries [34]. For this reason, several authors have designed their own digital environments and have tested them with students with autism to verify their effectiveness. Some of these, focused on mathematical content, are:

1. *Touchscreen-assistive Learning Numeracy App* (TaLNA). For working with basic arithmetic [35].
2. *Play and Learn Number* (PLaN). Focuses on arithmetic and arithmetical calculations [36].
3. *123 Autism*. For working on basic mathematical skills, such as correspondences, pairings, identification of numbers and quantities, and numerical sequence, among others. [37].
4. Project@Mathematics. For working on numbers, addition and subtraction, association of number and quantity, shapes and two- and three-dimensional figures, money and its uses [38].
5. *Learning Environment on Mathematics for Autistic Children* (LEMA). For working on mathematical content from deductive and inductive reasoning with plane figures (2D) and geometric bodies (3D). [11], [39], [40].
6. A website with games for users with autism about the use and management of money [41].
7. Application that teaches students with autism to manage money and make purchases [42].
8. Application for counting in 5's, 10's, etc. using coins (5, 10, 20, 50 and 100 Rwandan francs) [43].
9. *ArrasTE-A* digital game for early childhood education students with autism, to identify and match geometric shapes, colours, sizes and animals [44].
10. *€UReka* game to teach the use and handling of coins and notes to adolescents with autism [45].

Given that the number of educational apps is constantly increasing, authors such as Britto and Pizzolato [46] and Gallardo-Montes et al. [47] have designed accessibility guidelines with which to verify that apps are appropriate for users with autism.

Brito and Pizzolato [46, p. 6] consider ten categories with various item: (G1) interface with visual and textual vocabulary; (G2) customization; (G3) engagement; (G4) redundant/multiple representation; (G5) multimedia; (G6) feedback; (G7) affordance; (G8) navigability; (G9) system status; and (G10) interaction with the touch screen. These guidelines were used to evaluate 18 apps (in Portuguese or English) designed for users with autism, among which are the following 7 apps with mathematical content on numbers, quantities and logical sequences, ordered from the highest score to the lowest: *BitsBoard, Step by Step Pair by Numbers/ Step by Step Create a Series, Shop & Math, HearBuilder Sequencing, Camp Discovery, Montessori Preschool* [48]. Among the characteristics shared by the evaluated apps, the following may be highlighted: simple interface, clear instructions, without distracting stimuli and with simple textual and visual language, in addition to expressly stimulating some specific difficulty of users with autism [48]. *BitsBoard* is the application with mathematical content that obtained the highest score, satisfying 68% of the items and ranking third of the 18 evaluated, behind the applications *Super StoryMaker* (79%) and *Social Stories* (77%) [48].

Gallardo-Montes et al. [47, p.10-11] considers three evaluation dimensions, subdivided into various indicators, with sub-indicators in each of them to verify the suitability of applications for users with autism. These dimensions are: (D1) design/form (availability, ergonomics, usability, popularity and accessibility); (D2) content (audio quality; quality of narration, content, notifications, help and tutorials, safety) and (D3) pedagogical (interactivity, adaptation to pace and learning, monitoring/assessment); [47, p.10-11]. There are a total of 46 sub-indicators, so the maximum score that can be obtained is 46 points. The authors consider an application to be highly recommended if it scores 37 points or more; recommended if it obtains between 23 and 36 points; and not recommended if it obtains 22 points or less [47].

These dimensions were used by the authors to evaluate 88 apps for users with autism with instrumental content (oral language, reading, writing and mathematics), among which are 21 with mathematical content in one of the following subareas: numbers, counting, operations, place value of digits and problem-solving. The conclusion was that all the applications except two are highly recommended or recommended for users with autism, but only one of the applications, *Smile and Learn* (39 points), covers these subareas, so there is a lack of quality applications with mathematical content, since only 23.86% of the instrumental content of the apps

corresponds to mathematics [49]. Likewise, this system of indicators was used to evaluate 155 apps, expanding the previous search to applications without instrumental content. Only 14 apps were found to be highly recommended, and the area of emotions was found to be underrepresented [50].

Recently, other authors have developed tools to evaluate educational mobile applications for people with autism [51]. The authors establish 36 indicators grouped into six categories: personal information, technical and descriptive characteristics, pedagogical characteristics in relation to autism, general pedagogical characteristics, characteristics for educational inclusion and accessibility, and professional satisfaction [51]. The pedagogical characteristics can be seen to acquire importance in this instrument, coinciding with the assessments of Gallardo-Montes et al. [50] who suggest expanding the indicators of the pedagogical dimension of their evaluation instrument in the future, which only corresponds to 13% of the total score.

For the use of applications adapted to users with autism in the classroom to be a reality, it is essential to train teachers and future teachers in the use of these technologies, providing them with quality applications and the necessary preparation to know how and when to use them. However, research related to the training of teachers of students with autism shows that, although they consider that applications are beneficial to reinforce concepts- used as a complement to traditional methods- they do not use them as much as one would expect [52]. A lack of training is also evident, for example, in a study in which 20 Early Childhood and Primary Education centres participated, 65.8% of the teachers in the specific classrooms expressed ignorance of applications for students with autism [53]. The lack of specific courses in continuing training and teacher training programs is one of the difficulties that teachers encounter when using these technologies in the classroom; in addition to the lack of resources in their centres, the unsuitablility of the available software (which does not fit the curriculum of students with autism), and the difficulties that students with autism themselves have due to their poor performance, to the fact that they have problems that limit the use they can make of technology, they quickly forget what they have learned with technological devices and the damage that devices suffer due to misuse [54].

That a user with an intellectual disability can use the technology autonomously without a facilitator is essential, for example, in an emergency situation in which he or she must ask for help [55]. Therefore, it is desirable that users with autism can use applications adapted for them autonomously, understanding the latter as the ability to function independently. Some authors have evaluated this degree of autonomy with students with autism and intellectual disability, observing whether the number of steps performed with help decreased until they were able to perform the whole task independently [56]. Self-monitoring of these steps has also been effective in developing the self-determination skills of people with extensive support needs [57].

In addition to making a selection of appropriate apps for users with autism, it is necessary to determine whether they are capable of using them autonomously, so that these applications can be used in practice, regardless of whether their design and implementation complies with the guidelines established by the various evaluation instruments.

Therefore, the starting point is the following hypothesis: accessibility guidelines ensure that users with autism can handle applications without help. Which leads to the question: What apps with mathematical content can be used autonomously by students with autism?

II. Methodology

This is an exploratory study carried out in two stages, which is part of a larger study whose purpose is the design and implementation of an educational application for users with autism [58]. In the first stage, a search and selection of apps with mathematical content was carried out, and in the second phase, the usability of the apps was evaluated, by putting into practice the apps selected by students with autism, to measure the degree of autonomy they showed during use. It is therefore a descriptive study, with a cross-sectional design and an observational quantitative method.

A. Participants

The participants in this research belong to several formal and non-formal educational environments in Spain (Primary Education Schools, Compulsory Secondary Education Centres and associations). The selection of participants was carried out according to the following inclusion criteria: (1) having an ASD diagnosis according to the Diagnostic and Statistical Manual of Mental Disorders, revised text 5th edition (DSM-V-TR) [1]; (2) be between 6 and 16 years old; and (3) communicate verbally and/or non-verbally.

Various formal and non-formal educational environments were first contacted in order to find participants for the study who met the inclusion requirements. Subsequently, a face-to-face and individual interview was carried out with each of the families with sons or daughters with autism. It was possible to access information of their diagnosis made by health personnel from public health centres, in order to know the characteristics of the future participants. Then, the information provided by the families was corroborated with the educator who spends the most time with the boy or girl in the formal or non-formal educational environtment, and a sample of twenty-eight students was obtained. Finally, the families, having reached agreement with their son or daughter, agreed to sign the consent to participate in this study. The public centers and the families, together with the agreement of their sons or daughters, signed the informed consents. The information was collected in compliance with the principles of Helsinki Declaration and the standards of good practice in research.

Table I shows the characteristics of the twenty-eight participants, where the intelligence quotient, (IQ) was measured using the Intelligence Scale for Children (WISC-V) [59] or Leiter-3 [60], depending on the characteristics of the student.

B. App Selection Procedure

Apps with mathematical content had to meet the following inclusion criteria: (1) can be used on Android devices; (2) available on the Google Play Store, free or with a free partial version; (3) allows the user to practise some mathematical content related to numbers and operations, magnitudes and their measurements, spatial orientation, geometry or problem

TABLE I
PARTICIPANTS

	Age	Gender	IQ	Language	Comorbidity	Year
1	10.8	M	48	Functional		5th PE
2	10.10	M	55	Functional	LKS	5th PE
3	15.4	M	69	Functional		CBE
4	7.5	M	129	Functional		2nd PE
5	10.11	M	59	Functional	ADHD	5th PE
6	10.8	M	99	Functional	ADHD	5th PE
7	11.4	M	67	Functional		6th PE
8	8.0	M	45	Functional	ADHD	2nd PE
9	7.1	M	62	Functional	ADHD	2nd PE
10	10.8	M	105	Functional		5th PE
11	12.6	M	67	Functional		1st CSE
12	10.10	M	110	Functional	ADHD	5th PE
13	11.9	M		Functional		6th PE
14	7.7	M	91	Functional		2nd PE
15	11.11	M	107	Functional	ADHD	6th PE
16	8.11	F	58	Functional		4th PE
17	11.3	M		Functional		5thPE
18	15.9	M	66	Functional		CBE
19	10.6	M	55	Functional	ADHD	CBE
20	12.1	M	63	Functional		1st CSE
21	12.11	M	47	Functional	ADHD	1st CSE
22	6.9	M	65	No functional language	ADHD	1st PE
23	7.4	M	82	Functional	ADHD	2nd PE
24	11.6	M	50	No language		6th PE
25	10.3	M	58	Functional		5th PE
26	10.2	M		Functional		5th PE
27	11.6	M	62	Functional	ADHD	6th PE
28	7.3	M	48	Functional	ADHD	2nd PE

Notes. Age = years. months, M = male, F = female; LKS = Landau Kleffner Syndrome; ADHD = Attention Deficit Hyperactivity Disorder; PE = Primary Education; CSE = Compulsory Secondary Education; CBE: Compulsory Basic Education
Source: Table adapted from [61, p. 214].

TABLE II
MATHEMATICS APPS SELECTED

App	Block 1	2	3	4	App Section	Score
1. Mathematics with Grin II 6,7,8	x	x	x	x	Operations, multiplication; money; geometry, figure series, 2D figures, 3D figures; problems	38
2. Mathematics with Grin I 4,5,6	x	x	x	x	Trace, write; operations; money: coins, geometry, figure series; problems	37
3. Writing 123- Spanish	x					33
4. Adventures in Pre-school- 1	x				Level 1, numbers; level 2 numbers	33
5. Mathematical games for children	x				Counting, games for addition; games for subtraction	33
6. Lucas Logic Series			x		Less than 5, plane figures	33
7. Learn to write numbers	x				From 1 to 10	32
8. Pre-school Adventures- 2	x				Level 1, numbers	32
9. iSecuencias Lite		x				32
10. Multiplication table games	x				Game play	31
11. Baby Panda: comparisons		x			big-small; a lot-a little; long-short	30
12. Mathematics: Multiplication	x				Practice, automatic choice	30
13. Mathematics: Division	x				Practice, automatic choice	30
14. Learn the Hours in Spanish		x			Hours; quarters: minutes; mix	30
15. Colours and shapes			x		Figures: ????	29
16. Baby Panda's Number Friends	x				0-10; 10-20	29
17. The game of opposites		x	x		Choose the right one	29
18. Express yourself: for children free		x			Easy	29
19. Addition and subtraction for girls 3-5	x				Biretta, +/-20	29
20. Fractions Lite	x				Practice, addition, subtraction	29
21. Tiggly Addventure	x				Apple; gift	28
22. Learn to count money		x			Coins; notes	28
23. LudiTab Spatial Orientation			x		LudiTab	27
24. Numbers 0-100 game for children	x				Numbers 1, 2, 3, 4 …	26
25. Count things	x				1-10	26
26. Challenge more or less	x	x		x	Level 1, addition and subtraction, more or less; level 2, addition and subtraction, problems	26
27. Learn the time through play		x				26
28. Geometry 2nd Primary			x			26
29. Pocoyó Geometric shapes			x		My world; make shapes	26
30. Units of Mass 5th Primary		x			Explore	26
31. Multiplication table	x				Biretta joining	25
32. Multiplication table	x				Play now	25
33. Changing units with Miss Athenea		x			Practice	25
34. Mathematics 6 years		x	x		Coins; weight and capacity; Geometry, plane figures	25
35. Mathematics 7 years		x	x	x	Length, weight and capacity; clocks; geometry, geometric bodies; addition and subtraction problems	25
36. Mathematics 8 years	x	x	x		Division, exact. inexact; measures of length, multiples and submultiples; measures of capacity and mass, multiples and submultiples; time and money, water clock, digital clock, work out the price; geometric bodies, polyhedra	25
37. Mathematics 9 years	x	x	x	x	Division, exact. inexact; measures of length, multiples and submultiples; measures of capacity and mass, multiples and submultiples; time and money, water clock, digital clock, work out the price; geometric bodies, polyhedra	25
38. Mathematics 10 years	x	x			Decimal numbers, addition and subtraction with decimal numbers; sexagesimal systems, years, half-years, quarters and months, lustra, decades, centuries and millenia	25
39. Mathematics 11 years	x				Decimal numbers and operations, addition and subtraction with decimal numbers	25
40. Mathematics 12 years	x				Decimal numbers and operations, addition and subtraction with decimal numbers	25
41. Oppositeland		x				24
42. Learning games: numbers	x				Rolling balls	24
43. Number, counting for children	x					24
44. Test fractions	x					23

Notes. 1 = numbers and operations; 2 = magnitudes and their measurement; 3 = geometry and spatial orientation; 4 = problems.
Source: Table adapted from [61, p. 226-227].

solving; (4) can be used by students with autism in educational settings; (5) returns a score equal to or greater than 23 points in the evaluation rubric of Gallardo-Montes et al. [47]; and (6) is available in Spanish.

Firstly, a search was carried out for work on apps for people with autism, apps with mathematical content and apps with mathematical content for people with autism, using these search engines: Google Scholar, ERIC, World Wide Science and Dialnet. Subsequently, the participants' educators were contacted to provide the apps they use with students with autism to work on mathematical content. Having contacted ten Schools of Primary Education, one Compulsory Secondary Education institute, and five associations in Spain that have people with autism among their students, together with the aforementioned search, a total of fifty-eight apps with mathematical content was obtained.

Of these fifty-eight apps with mathematical content, fourteen were excluded because, at the time of the search, they were apps for the IOS operating system: These were: (1) *1st Operations*; (2) *Eddie Eur*; (3) *Pickerpics*; (4) *Pickerplay*; (5) *Sequences for Kids*; (6) *Complete the series 1*; (7) *Complete the series 2*; (8) *Complete the series 3*; (9) *123 Zoo write*; (10) *Opposites 1*; (11) *Opposites 2*, (12) *opposites free*; (13) *Lazoo squiggles*; and (14) *Tonyhands towers*. Finally, Google Play Store was used to download the apps and they were evaluated using the indicators of Gallardo-Montes et al. [47, p.10-11].

C. Setting and Materials

The research was carried out in the formal (schools and institutes) and non-formal (associations) educational environments attended by the participants. It was undertaken in a classroom free of distractions and interruptions and, depending on the place where the study was carried out, it could be done inside or outside of school hours.

Each participant individually attended a 45-minute session and used a Samsung Galaxy Tab A10.1 with a case and screen protector to work on mathematical content with different apps.

Table II gives the names of the selected apps, the content that the participants worked on with each of them and the score they obtained in the Gallardo-Montes et al.

rubric. [47, p.10-11]. The selected apps are ordered from highest to lowest score and were tested by the authors to verify that they met the (5) inclusion criterion, and subsequently by the participants of this study.

Likewise, an observation scale with two values was used. Where 0 = the student does not need help to use the app with mathematical content, and 1 = the student does need help to use the app with mathematical content. This served to check the autonomy of the students when using each of the apps and to decide whether it was necessary for any of them to also be evaluated with the Britto and Pizzolato rubric [46].

D. Dependent and Independent Variable

The dependent variable was the percentage of autonomy shown by the participants while using the apps, while the independent variable was the score obtained by the apps in each item of the Gallardo-Montes et al. rubric. [47].

E. Procedure

With the forty-four apps downloaded on the Tablet, each of the participants was asked to test those apps with mathematical content appropriate to their level, according to the information obtained in the interviews carried out with families and educators. To do this, each student attended a 45-minute session, in which they were able to use each app for approximately 10 minutes.

III. Results

Of the 44 selected applications, only two are highly recommended for users with autism according to the rubric of Gallardo-Montes et al. [47], *Mathematics with Grin I 4,5,6*; *first numbers* and *Mathematics with Grin II 6,7,8*, as seen in Table II.

Regarding mathematical content, as seen in Table II, most applications focus on numbers and operations, followed by magnitudes and their measurement, and only a small number of applications contain arithmetic problems. When all the applications meet selection criterion (4), it is evident that students with autism have more difficulties in numerical content, since a greater number of applications are used to practice these contents.

When scoring applications with the Gallardo-Montes et al. rubric [47] it was observed that none of the 44 applications allows making changes to the size of the text or images (D1) or adding custom images or pictograms (D3). However, some of the apps do contain the option to choose an avatar from several options (*Mathematics with Grin I 4,5,6; first numbers; Mathematics with Grin II 6,7,8; The game of opposites; Switching units with Miss Athenea*).

When carrying out the initial evaluation of the applications, some indicators of the Gallardo-Montes et al. rubric were examined in detail. Reference [47] that we consider essential for users with autism, finding that the applications verify the following characteristics (Table III): 86.36% have a clear aesthetic (D1-A2), 38.64% have activities that are solved by clicking and dragging (D1-A5), 81.82% are structured in categories (D2-B3), 36.36% have instructions/indications (D2-B5), 38.64% have optional distractors (D3-C1) and 45.45% offer

TABLE III
App Characteristics

App	D1-A2	D1-A5	D2-B3	D2-B5	D3-C1	D3-C3	Positive feedback
1. Mathematics with Grin II 6,7,8	x	x	x	x	x	x	Oral, sound, visual
2. Mathematics with Grin I 4,5,6	x	x	x	x	x	x	Oral, sound, visual
3. Writing 123- Spanish	x	x		x			Sound
4. Adventures in Pre-school-1	x	x	x		x		Oral, sound, visual
5. Mathematical games for children	x	x	x	x			Oral, sound, visual
6. Lucas Logic Series	x	x	x		x		Oral, sound
7. Learn to write numbers	x						Oral, sound, visual
8. Pre-school Adventures- 2	x	x	x		x		Oral, sound, visual
9. iSecuencias Lite	x	x	x	x	x		Oral, sound
10. Multiplication table games	x		x		x	x	Sound, visual
11. Baby Panda: comparisons	x		x	x			Oral, visual
12. Mathematics: Multiplication	x		x	x	x	x	Visual
13. Mathematics: Division	x		x	x	x	x	Visual
14. Learn the Hours in Spanish	x	x	x	x	x	x	Oral, sound
15. Colours and shapes	x		x		x	x	Oral, visual
16. Baby Panda's Number Friends	x		x				Oral, sound, visual
17. The game of opposites	x		x		x		
18. Express yourself: for children free	x	x	x	x	x		Sound, visual
19. Addition and subtraction for girls 3-5	x		x				Visual
20. Fractions Lite	x		x	x		x	Oral, sound
21. Tiggly Addventure				x	x		Visual
22. Learn to count money		x		x		x	Oral, sound, visual
23. LudiTab Spatial Orientation		x	x				Sound
24. Numbers 0-100 game for children		x	x				
25. Count things	x		x			x	Visual
26. Challenge more or less	x	x	x	x		x	Sound, visual
27. Learn the time through play	x					x	Oral, sound, visual
28. Geometry 2nd Primary	x						Oral, sound, visual
29. Pocoyó Geometric shapes	x	x	x		x		Sound
30. Units of Mass 5th Primary	x	x	x	x	x		Visual
31. Multiplication table	x		x			x	Sound
32. Multiplication table	x		x				Visual, sound
33. Changing units with Miss Athenea	x		x	x			Visual
34. Mathematics 6 years	x		x			x	Visual
35. Mathematics 7 years	x		x			x	Visual
36. Mathematics 8 years	x		x			x	Visual
37. Mathematics 9 years	x		x			x	Visual
38. Mathematics 10 years	x		x			x	Visual
39. Mathematics 11 years	x		x			x	Visual
40. Mathematics 12 years	x		x			x	Visual
41. Oppositeland	x						Sound, visual
42. Learning games: numbers		x	x		x		Sound
43. Number, counting for children		x	x				Oral, sound, visual
44. Test fractions	x						Visual, sound

Source: Created by the authors.

reports on successes and/or errors (D3-C3). Furthermore, positive reinforcement is transmitted to the user through an oral (38.64%), audio (54.54%) and visual (75%) message.

Table IV shows the mathematical content worked on, the students who used each app, the response of each app when the user succeeds or fails, and the percentage of autonomy obtained by the users regarding each app. The applications appear ordered from highest to lowest percentage of autonomy, taking as a reference for this sorting the lowest value obtained by the application in any of the sections.

The percentage of autonomy of each section of the app tested was obtained through this operation: sum of the scores obtained by the students between the number of students and multiplying this result by 100. A scale was used to assess the degree of autonomy shown by the participants during the use of each app: independently/without help (75-100%), needs notable help (50-74%), needs severe help (25-49%), presents a total dependence (0 -24%).

TABLE IV
PERCENTAGE OF AUTONOMY IN USING THE APPS

App	Content	Students	%
3. Writing 123- Spanish	Writing numbers	1, 5, 8, 22, 23, 26	100
9. iSecuencias Lite	Time sequences	9, 27	100
10. Multiplication table games	Multiplication table	11, 18, 20	100
12. Mathematics: Multiplication	Multiplication	15, 20	100
13. Mathematics: Division	Division	15	100
14. Learn the Hours in Spanish	Time	2, 3, 4, 6, 7, 10, 16, 17, 25	100
19. Addition and subtraction (+/- 20)	Addition and subtraction with carrying	3, 11, 17, 20	100
20. Fractions Lite	Addition and subtraction with fractions	18, 20	100
27. Learn the time through play	Time	2, 3, 4, 6, 7, 10, 16, 17, 25	100
31. Multiplication table	Multiplication table	11, 18, 20	100
32. Multiplication table	Multiplication table	11, 18, 20	100
38. Mathematics 10 years	Addition and subtraction with decimals	3, 17, 20	100
	Time	6, 10, 12, 13, 15, 16	100
39. Mathematics 11 years	Addition and subtraction with decimals	3, 17, 20	100
40. Mathematics 12 years	Addition and subtraction with decimals	3, 17, 20	100
44. Test fractions	Addition and subtraction with fractions	18, 20	100
11. Baby Panda: comparisons	Measuring units	3, 5, 8, 9, 19, 21*, 22, 23, 24, 25, 27, 28	92.67
41. Oppositeland	Measuring units	3, 5, 8, 9, 19, 21*, 22, 23, 24, 26, 27, 28	92.67
35. Mathematics 7 years	Measuring units	6, 10, 12, 13	100
	Time	6, 10, 12, 13, 15, 16	100
	Problems	3, 4, 6, 10, 12, 13, 14, 15*, 16, 17, 20	90.90
15. Colours and shapes	Plane figures	6, 7, 8, 11, 14, 15, 16, 18*, 19, 26, 28	90.90
28. Geometry 2nd Primary	Geometric bodies	6, 10, 11, 12, 13, 14, 15, 16, 20, 21*	90
29. Pocoyó Geometric shapes	Plane figures	6, 7, 8, 11, 14, 16, 18*, 19, 28, 26	90
22. Learn to count money	Money	2, 3, 6, 7, 14, 25, 27*	85.71
6. Lucas Logic Series	Series with plane figures	8, 9, 21*, 22, 24, 27	83.33
4. Adventures in Pre-school- 1	Pairs of numbers	5, 21*, 22, 23, 24	80
8. Pre-school Adventures- 2	Pairs of numbers	5, 21*, 22, 23, 24	80
16. Baby Panda's Number Friends	Addition and subtraction with carrying	3, 11, 17	100
	Addition and subtraction with carrying	3, 7, 14, 20, 26*	80
17. The game of opposites	Units of measurement and spatial concepts	3, 5, 8, 9, 19, 21*, 22, 23, 24*, 26*, 27, 28	75
30. Units of Mass 5th Primary	Measuring units	6*, 10, 12, 13	75
33. Changing units with Miss Athenea	Measuring units	6*, 10, 12, 13	75
1. Mathematics with Grin II 6,7,8	Multiplication	15, 20	100
	Money	2, 3, 7, 14, 17, 25, 26, 27	100
	Problems	3, 4, 6, 7, 11, 12, 13, 15*, 16, 17, 20	100
	Geometric series	8, 9, 21*, 22, 24, 27	83.33
	Geometric bodies	6, 7, 8*, 9*, 11, 13, 14, 15, 16, 21*, 22*, 23	66.67
5. Mathematical games for children: addition and subtraction	Addition and subtraction with carrying	3, 7, 14, 20, 26	100
	Associating number with quantity	1, 5, 8, 9, 19*, 21*, 22, 23, 26*, 27, 28*	63.64
25. Count things	Associating number with quantity	1, 5, 8*, 9, 19*, 21*, 22, 23, 26, 27, 28*	63.64
34. Mathematics 6 years	Measuring units	6, 10, 12, 14	100
	Plane figures	6, 10, 12, 13, 14, 15, 16	100
	Money	2*, 3, 7, 14*, 17 25, 27*	62.5
36. Mathematics 8 years	Division	15	100
	Measuring units	6, 10, 12, 13	100
	Time	6, 10, 12, 13, 15, 16	100
	Geometric bodies	6, 10, 11, 12, 13, 14, 15, 16, 20, 21*, 22*	81.81
	Money	2*, 3, 7, 14*, 17, 20, 24, 27*	62.5
37. Mathematics 9 years	Measuring units	6, 10, 12, 13	100
	Time	6, 10, 12, 13, 15, 16	100
	Problems	3, 4, 6, 10, 12, 13,14 15*, 16, 17, 20	90.90
	Geometric bodies	6, 10, 11, 12, 13, 14, 15, 16, 20, 21*, 22*	81.81
	Money	2*, 3, 7, 14*, 17 25, 27*	62.5
7. Numbers in Spanish and how to write them	Writing numbers	1*, 5, 8*, 22*, 23, 26	50
26. Challenge more or less	Addition and subtraction with carrying	3, 7, 14, 20, 26	100
	Addition and subtraction with carrying	3, 11, 17, 20	100
	Problems	3, 4, 6, 7, 11, 12, 13, 15, 16, 17, 20	100
	More-less	527-529].	50
2. Mathematics with Grin I 4,5,6	Addition and subtraction with carrying	3, 7, 14, 20, 26	100
	Money	2, 3, 7, 14, 17, 25, 36, 27	100
	Problems	3, 4, 6, 7, 11, 12, 13, 15, 16, 17, 20	100
	Geometric series	8, 9, 21*, 22, 24, 27	83.33
	Plane figures	6, 7, 10, 11, 12, 13, 14, 15, 16, 18*, 19*, 28	83.33
	Writing numbers	1, 5*, 8*, 22*, 23, 26*	33.33

TABLE IV
(Continued.) PERCENTAGE OF AUTONOMY IN USING THE APPS

21. Tiggly Addventure	Associating number with quantity	1*, 5*, 8*, 9, 19, 21*, 22*, 23*, 26, 27*, 28*	27.27
23. LudiTab Spatial orientation section "LudiTab"	Spatial concepts	3*, 5*, 8*, 9, 19*, 21*, 22*, 23*, 24	22.22
42. Learning games: numbers section rolling balls"	Pairs of numbers	5*, 21*, 22*, 23*, 24	20
43. Number, counting for children section "I need"	Associating number with quantity	1*, 5*, 8*, 9, 19*, 21*, 22*, 23, 26*, 27*, 28*	18.18
18. Express yourself: for children free section "easy"	Time sequences		0
24. Numbers 0-100 game for children	Writing numbers	1*, 5*, 8*, 22*, 23*, 26*	0

Notes. * = needed help using the app.
Source: Table adapted from [61, p. 527-529].

The results show that, although a large proportion of the applications were not specific for students with autism, 29 of them (65.9%) could be used autonomously (75-100%) by the study participants (15 of them reaching 100%), using them effortlessly and with a high degree of motivation. These participants seemed happy using these apps and even asked to continue using them. Eight apps achieved the next degree of autonomy (50-74%), the participants used them with effort, requested help to count the images that appeared on the screen, and some participants needed paper and pencil to perform operations on units of measurement. Even so, they showed low anxiety and a medium degree of entertainment and motivation.

Seven applications returned a percentage below 50% autonomy. With the two apps between 25% and 49% autonomy, the participants needed very significant help and made a lot of effort to use them. A medium level of anxiety and low motivation was observed, as participants left the application and asked for help due to difficulties in fine motor skills and hand-eye coordination. Five of the apps obtained an almost zero degree of autonomy because the participants were barely able to operate them, even with great effort. They showed a lot of anxiety and no motivation because they did not understand what was being asked of them; frustration led some of them to throw away the Tablet and others to try to leave the classroom or get under the table.

The applications that are specific for certain users are: *Oppositeland*, which is specifically for people with Down Syndrome; *iSequencesLite* for children with autism or other needs; and *More and Less Challenges*, created for children with special educational needs.

Regarding the contents worked on, once the selection shown in Table IV has been made, it is seen that the 15 applications with the best scores work on arithmetic operations or contents related to time, and that, in the set of the 29 best placed, the numerical contents are in the majority, followed by the units of measurement.

The seven apps that obtained a percentage equal to or less than 50% are: (1) *Mathematics with Grin I 4,5,6 first numbers*; (2) *Express yourself: for children free*; (3) *Tiggly Addventure*; (4) *LudiTab Spatial orientation*; (5) *Numbers 0-100 game for children*; (6) *Learning games* (7) *Number, counting for kids*.

To obtain more information about these apps and find out those categories that need to be improved in order to be used autonomously by users with autism, the applications were evaluated following the accessibility guidelines of Britto and Pizzolato [46]. These obtained the percentages shown in Table V.

TABLE V
PERCENTAGE OBTAINED IN EACH CATEGORY BY APPS WITH AUTONOMY LESS THAN 50%

App	%	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10
2.	A	50	0	100	0	33.33	0	66.67	50	0	100
	B	0	0	0	0	33.33	0	0	50	33.33	0
	C	0	100	0	33.33	33.33	100	33.33	0	66.67	0
	N/A	50	0	0	66.67	0	0	0	0	0	0
18.	A	100	0	100	33.33	66.67	0	66.67	50	0	100
	B	0	25	0	33.33	0	100	0	0	33.33	0
	C	0	75	0	33.33	33.33	0	33.33	50	66.67	0
21.	A	50	0	75	0	33.33	0	75	50	0	100
	B	0	0	0	0	0	100	0	0	33.33	0
	C	0	100	25	66.67	66.67	0	25	50	66.67	0
	N/A	50	0	0	33.33	0	0	0	0	0	0
23.	A	50	0	75	0	33.33	0	75	50	0	100
	B	0	0	0	33.33	0	100	0	0	33.33	0
	C	25	100	25	66.67	66.67	0	25	50	66.67	0
	N/A	25	0	0	0	0	0	0	0	0	0
24.	A	50	0	75	0	33.33	0	66.67	50	0	100
	B	0	0	0	0	0	0	0	0	0	0
	C	0	75	25	66.67	66.67	100	33.33	50	100	0
	N/A	50	25	0	33.33	0	0	0	0	0	0
42.	A	50	25	75	0	33.33	0	75	50	0	100
	B	0	0	0	0	0	100	0	0	0	0
	C	0	25	25	75	66.67	0	25	50	100	0
	N/A	50	50	0	25	0	0	0	0	0	0
43.	A	50	0	75	0	33.33	0	66.67	50	0	100
	B	0	25	0	0	0	100	0	0	0	0
	C	25	50	25	100	66.67	0	33.33	50	100	0
	N/A	25	25	0	0	0	0	0	0	0	0

Notes. 2 = Mathematics with Grin I 4,5,6 first numbers section "trace, write". 18 = Express yourself: for children free "easy" section. 21= Tiggly Addventure. 23 = LudiTab Spatial orientation "Luditab" section. 24 = Numbers 0-100 game for children section "numbers 1,2,3,4…". 42 = Learning games: numbers section "rolling balls". 43 = Number, account for children in the "need" section.
Source: Table adapted from [61, p. 242].

TABLE VI
OVERALL PERCENTAGE

	A	B	C	N/A	%	Students
18. Express yourself: for children free "easy" section	53.57	14.29	32.14	0	0	2
2. Mathematics with Grin I 4,5,6 section "trace, write"	39.29	10.71	35.71	14.29	33.33	6
42. Learning games: numbers section "rolling balls"	39.28	3.57	39.28	17.86	20	5
23. LudiTab Spatial orientation "Luditab" section	35.71	10.71	50	3.57	22.22	9
43. Number, counting for children "need" section	35.71	7.14	50	7.14	18.18	11
21. Tiggly Addventure sections "apple; gift"	35.71	7.14	46.43	10.71	27.27	11
24. Numbers 0-100 game for children section "numbers 1,2,3,4…"	35.71	0	50	14.29	0	6

Source: Created by the authors.

As seen in Table V, the categories in which the applications obtain high scores in C and N/A are: G2 (customization), G4 (redundant representation), G5 (multimedia) and G9 (system status). In these categories they obtain the highest overall percentages of C and N/A, which are between 66% and 100% in practically all applications. Followed by categories G1 and G8, in which they obtain 50%.

Table VI shows the overall percentage of each section, in addition to the percentage of autonomy resulting from the implementation and the number of participants who tested the application. Considering the scores obtained in the categories of the Britto and Pizzolato rubric [46] and arranging the applications from best to worst, it is observed that none of them reaches 60% A scores, and all except *Express yourself*, obtain 50% or more between C and N/A, the percentage of autonomy being variable.

IV. DISCUSSION

The use of technological devices such as Tablets or iPads motivates students with autism and improves their academic performance in the activities carried out with this support [15], [16], [17], [18], [21], [27].

Specifically in Mathematics, educational applications with mathematical content are proving to be an effective resource for improving the performance and autonomy of students with autism [22], [23], [24], [26], [28], [29], [30].

Taking into account the lack of educational applications with mathematical content adapted for users with autism [48], [49], [50], a search and evaluation of apps in Spanish for the Android operating system that work on mathematical content was carried out. 44 apps were selected that met the requirement of being at least recommended for users with autism, of which only two are highly recommended for users with autism according to the rubric of Gallardo-Montes et al. [47], evidencing a lack of quality applications suitable for this type of users, as stated by other authors [48], [49], [50].

Furthermore, the autonomy shown by users with autism was assessed when using the selected applications, concluding that the rating of recommendable in the Gallardo-Montes et al. rubric [47] does not guarantee that the app is suitable for this type of user, since 15.9% of the apps (7 out of 44) could not be used in their entirety by the test group with an autonomy of at least 50%. When scoring these applications according to the Britto and Pizzolato [46] rubric, all of them obtain less than 60% of A, so it is concluded that none of the applications is recommended for users with autism. These results allow us to partially verify the starting hypothesis, since the combination of both evaluation instruments has been effective in determining the adequacy of the applications.

In the case of the *Express yourself* app, it would be necessary to expand the sample to more reliably determine the percentage of autonomy, since it was only used by two participants. The *Mathematics with Grin I 4,5,6* application obtains good percentages of autonomy in all sections except for "trace, write". This shows a deficiency in the existing rubrics, since they consider the applications in their entirety, without distinguishing between their sections, which often include diverse tasks with variable accessibility.

Although there are applications and/or digital environments with mathematical content, expressly designed for students with autism, many of them are not available for download on the Internet or platforms such as Google Play Store, they lack content in several languages or lack maintenance by the researchers who developed them, being this fact an important limitation for their effective use in educational environments [35], [36], [39], [42].

V. CONCLUSION

On one hand, the present study contributes to the existing literature, providing a final selection of 38 apps (including *Mathematics with Grin I 4,5,6*) in Spanish available on Google Play that work on mathematical content, shown in Table II, which they are recommended or highly recommended for users with autism [47] and can be used by them with an autonomy of at least 50%. Of them, 29 were used autonomously by the participants, showing a high degree of motivation during their use. Furthermore, having considered different selection criteria, none of these apps appear in previous studies [49], [50], so our work expands the existing selection.

On the other hand, to increase the percentage of autonomy in the use of these apps by users with autism, those aspects of the accessibility guidelines [46] and evaluation rubrics [47] in which they obtain the lowest score should be improved, such as customization, representation in various formats, feedback and interaction with the system.

The next step would be to check whether the use of this selection of applications helps users with autism to improve their performance and reduce their difficulties in the mathematical content that can be practiced with the apps.

Finally, it is necessary to implement specific apps for users with autism that meet the aforementioned accessibility guidelines and are available in several languages to improve the inclusion of this kind of students.

In addition to the implementation of new applications, future lines of work include carrying out studies in which the applications are used with students with autism in inclusive environments (which will only be feasible if students can use them autonomously); studies in which a training plan is developed to solve some of the difficulties that teachers have when using these resources in the classroom; and studies in which the opinion of families on the viability of using this type of educational applications in their family environment is considered, taking into account the possible difficulties that users with autism may have and the possible lack of specific training of the users' familiar in teaching and learning Mathematics.

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