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Technologies in mathematical intervention in intellectual disabilities: A scope review

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Abstract
This review aiming to evaluate the evidence for the use of technology in teaching math to individuals with intellectual disability (ID). The study selected articles that met predetermined criteria, including studies that evaluated the effectiveness of technological resources for teaching mathematics to the ID population, published in English or Portuguese from 2000. The search yielded few studies. The selected studies employed various technologies, including computer-based instruction, Touch Math software, iPad apps, and Math Squared software. This review provides preliminary insights into the use of assistive technology in teaching math to individuals with ID, highlighting the need for evidence-based interventions and identifying gaps in the literature. The findings suggest that the use of technology can be effective in teaching math to individuals with ID, but more research is needed to determine the most effective interventions and strategies.

Keywords: Intellectual disability, mathematics, intervention technologies, assistive technologies

1. Introduction
Math is required in many daily life activities including employment, financial skills and daily tasks. Difficulties in learning mathematics resulted in worse outcomes than difficulties in reading [1], since math compromise is associated with higher rate low-paying employment, lower chance of employment promotion, and more time unemployment [2].

Environmental, psychological, and biological features impact on math skills [3] and its development is modular and hierarchical [4]. On a cognitive level, there are at least three systems for manipulating mathematical content. One innate system for manipulating non-symbolic quantities. The other two systems were developed by culture for processing numbers in Arabic format and verbal format [5]. This system interacts with other systems to produce mathematical skills. Studies indicate impairments in numerical processing when compared to peers of the same chronological age in children with mild ID even when working memory impairment is controlled, suggesting direct deficits in mathematical abilities in this population [6]. In addition to direct deficits, intellectual disability impacts on skills that interact with mathematical abilities for their development.

Intellectual disability is a neurodevelopmental disorder characterized by deficits in intellectual functions and deficits on adaptive behaviors with the onset of symptoms in childhood [7] which affects around 3% of population [8]. A population with an intellectual disability (ID) commonly has difficulty in mathematics. Mathematics is a discipline that demands abstraction, logical reasoning, and learning rules and concepts, and these abilities were compromised on ID [9]. Furthermore, studies point to the important role of executive functions in mathematical learning. Results indicate working memory as a predictor of mental calculations and numerical production, and flexibility as a predictor of mathematical problem-solving [10]. The predictive role of Executive Functions is also noted for numerosity [11]. It is known that multiple deficits in executive functions are found in the population with ID, even when compared to pairs of the same mental age [12-16].

The profile of generalized cognitive difficulties in ID makes it essential to develop assistive technologies designed for this population. Assistive technologies are defined as any product that aims to improve or maintain the functionality of a subject, impacting their independence [17]. Although important, the quality of studies investigating teaching technologies in ID is low, making it difficult to recommend practices. However, the evidence suggests educational practices like explicit and systematic instruction with routine use in the teaching environment are beneficial [18] that can be used in the development of assistive technologies.

In education for people with ID, assistive technology is potentially a tool to access and to understand how to teach math to people with intellectual disabilities based on evidence to increase the effectiveness of interventions. So, the aim of this research is: 1. to evaluate the evidence about the use of technologies to teach math for people with intellectual disability; 2. describe assistive technologies investigated in the scientific literature for teaching math for the ID population; 3. describe teaching methodologies and techniques used; 4. characterize interventions protocols and population of researches selected and 5. Discuss gaps in this literature to identify points of attention.

2. Method

2.1 Inclusion criteria

Studies included filled the following criteria: 1. population diagnosed with intellectual disability; 2. group clinical trial or single, series cases design; 3. the studies evaluated the effect of technological resources for teaching mathematics; 4. published from 2000, in English or Portuguese.

2.2 Literature Search Procedures and Screening

Four databases (PubMed, PsycInfo, ERIC and Scopus) were used for search in literature Three descriptors were used on each base: "technology and teaching mathematics and intellectual disability", "technology and mathematics intervention and intellectual disability" and "technology and mathematics learning and intellectual disability". The search on databases was done by two different researchers. We use the Rayyan program to organize and carry out the selection of papers. The paper's selection is detailed in figure 1.

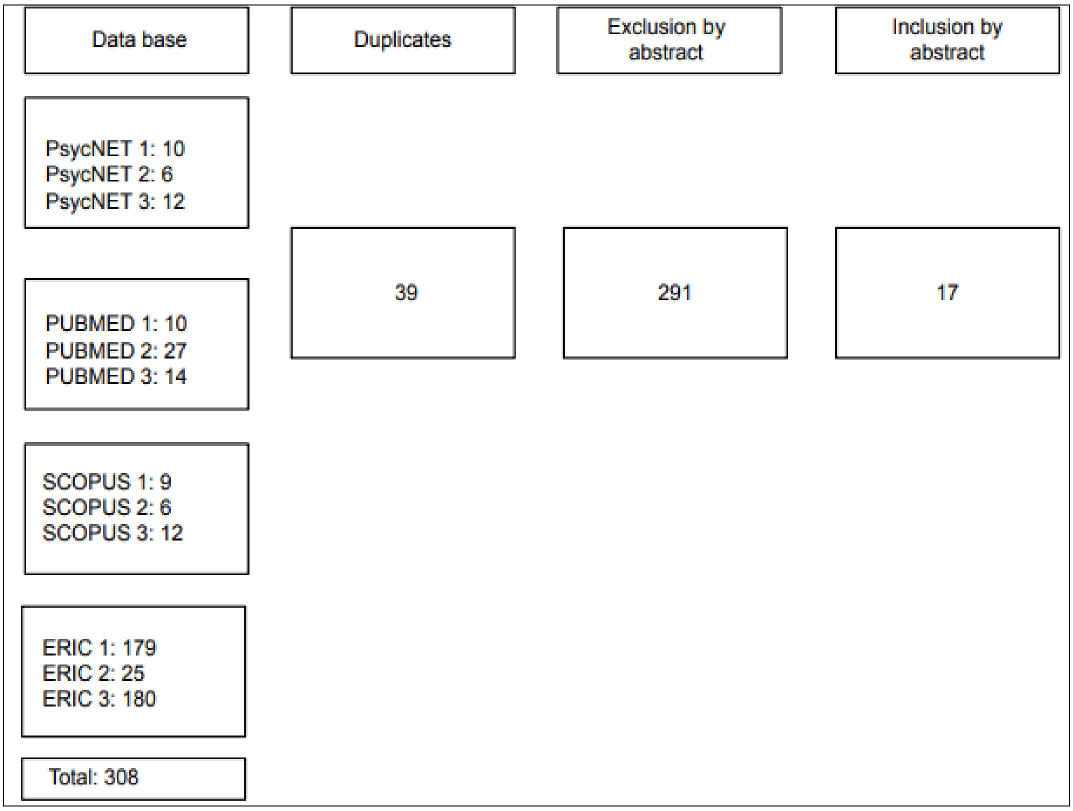

Fig 1: Selection process papers for this review

Search terms: 1= technology and teaching mathematics and intellectual disability/ 2= technology and mathematics intervention and intellectual disability/ 3= technology and mathematics learning and intellectual disability

In the first step 17 papers were selected. In this step papers selected on databases described previously and represented on figure 1. In table 1 are described general information about 17 papers included and papers included on the second step, taken from references of the articles selected in the first step. Of the 17 selected articles, 1 is not found. In the second step 3 papers were selected. In the final, 19 papers were included in this review.

Descriptions data about included papers are represented in table 1.

Table 1: Descriptions data about included papers are represented

Base	Title	Reference	Design	N	Intervention variable	Ages
PsycNET	Teaching a Learning Strategy for Computational Mathematics to Students with Moderate to Profound Intellectual Disabilities Using Video Prompting	Dueker, S. A. (2018) [40]. Teaching a learning strategy for computational mathematics to students with moderate to profound intellectual disabilities using video prompting (Publication No. 11005240) [Doctoral dissertation, Ohio State University]. ProQuest Dissertations and Theses Global.	Multiple Single-case	4	Use of number line for resolution addition and subtraction	15 /17/ 18/20 years

PsycNET	Building Early Numeracy through Virtual Manipulatives for Students with Intellectual Disability and Autisms	Jimenez, B. A., & Besaw, J. (2020) [44]. Building early numeracy through virtual manipulatives for students with intellectual disability and autism. Education and Training in Autism and Developmental Disabilities, 55(1), 28–44.	not found			
PubMed	Using the virtual-representational instructional sequence to support the acquisition and maintenance of mathematics for students with intellectual disability	Bouck, E. C., Park, J., & Shurr, J. (2019) [45]. Using the virtual-representational instructional sequence to support the acquisition and maintenance of mathematics for students with intellectual disability. International Journal of Developmental Disabilities, 1–12.	Multiple Single-case	4	Calculation (Division and multiplication)	12/13/14/14 years
PubMed	Comparing a number line and audio prompts in supporting price comparison by students with intellectual disability.	Bouck, E. C., Satsangi, R., & Bartlett, W. (2016) [19]. Comparing a number line and audio prompts in supporting price comparison by students with intellectual disability. Research in Developmental Disabilities, 53-54, 342–357.	Multiple Single-case	3	Comparison of magnitudes (commodity values)	18/19/21 years
SCOPUS	Virtual manipulatives as assistive technology to support students with disabilities with mathematics	Bouck, E. C., Park, J., & Stenzel, K. (2020) [23]. Virtual manipulatives as assistive technology to support students with disabilities with mathematics. Preventing School Failure: Alternative Education for Children and Youth, 64(4), 281–289.	Multiple Single-case	3	Calculation (division)	12/13/13 years
SCOPUS	Adding It Up: Comparing Concrete and App-Based Manipulatives to Support Students With Disabilities With Adding Fractions	Bouck, E. C., Shurr, J., Bassette, L., Park, J., & Whorley, A. (2018) [25]. Adding It Up: Comparing Concrete and App-Based Manipulatives to Support Students With Disabilities With Adding Fractions. Journal of Special Education Technology, 33(3), 194–206.	Multiple Single-case	2	Calculation (addition and fraction)	13/13 years
SCOPUS	Using Modified Schema-Based Instruction with Technology-Based Supports to Teach Data Analysis	Root JR, Cox SK, Gonzalez S. Using Modified Schema-Based Instruction with Technology-Based Supports to Teach Data Analysis. Research and Practice for Persons with Severe Disabilities. 2019;44(1):53-68 [27].	Multiple Single-case	2	converting quantity to number and subtract	10/11 years
SCOPUS	Impact of adoption of Information and Communication Technologies (ICTs) in Teaching Mathematics to Intellectually Disabled Children	Sherawat, Joyti & Punia, Poonam. (2022) [29]. Impact of adoption of Information and Communication Technologies (ICTs) in Teaching Mathematics to Intellectually Disabled Children. 14. 41-66.	Group study	100	Number concepts, calculation (addition and subtraction), time and money	10-22 years
REFERENCE	Schema-Based Instruction With Concrete and Virtual Manipulatives to Teach Problem Solving to Students With Autism	Root, J. R., Browder, D. M., Saunders, A. F., & Lo, Y. (2016) [24]. Schema-Based Instruction With Concrete and Virtual Manipulatives to Teach Problem Solving to Students With Autism. Remedial and Special Education, 38(1), 42–52. doi:10.1177/0741932516643592	Multiple Single-case	3	Mathematics problems solve	7/9/11 years
REFERENCE	Acquisition and Generalization of Purchasing Skills Using a Video Enhanced Computer-Based Instructional Program.	Ayres, K. M., & Langone, J. (2002) [46]. Acquisition and Generalization of Purchasing Skills Using a Video Enhanced Computer-Based Instructional Program. Journal of Special Education Technology, 17(4), 15–28. doi:10.1177/016264340201700402	Multiple Single-case	3	Money (purchasing in dollar)	6/7/10 years
REFERENCE	Using Video Prompting to Teach Mathematical Problem Solving of Real-World Video-Simulation Problems	Saunders, A. F., Spooner, F., & Ley Davis, L. (2017) [20]. Using Video Prompting to Teach Mathematical Problem Solving of Real-World Video-Simulation Problems. Remedial and Special Education, 39(1), 53–64. doi:10.1177/0741932517717042	Multiple Single-case	3	Problem solving (subtraction and addiction)	13/13/14 years
ERIC	Self-monitoring of On-task Behaviors Using the MotivAider® by a Middle School Student with a Moderate Intellectual Disability	Boswell, M.A., Knight, V.F., & Spriggs, A.D. (2013) [33]. Self-monitoring of On-task Behaviors Using the MotivAider® by a Middle School Student with a Moderate Intellectual Disability. Rural Special Education Quarterly, 32, 23 - 30.	Multiple Single-case	1	On task behavior in solving subtraction and addition calculations	11 years
ERIC	Video Self-Modeling on an iPad to Teach Functional Math Skills	Burton, C., Anderson, D.H., Prater, M.A., & Dyches, T.T. (2013) [22]. Video Self-Modeling on an iPad to Teach Functional Math Skills to Adolescents With	Multiple Single-case	1	On-task behavior in learning counting and estimation	13 years

	to Adolescents With Autism and Intellectual Disability.	Autism and Intellectual Disability. Focus on Autism and Other Developmental Disabilities, 28, 67 - 77.				
ERIC	Using a Simultaneous Prompting Procedure with an iPad to Teach the Pythagorean Theorem to Adolescents with Moderate Intellectual Disability	Creech-Galloway, C., Collins, B.C., Knight, V.F., & Bausch, M.E. (2013) [21]. Using a Simultaneous Prompting Procedure with an iPad to Teach the Pythagorean Theorem to Adolescents with Moderate Intellectual Disability. Research and Practice for Persons with Severe Disabilities, 38, 222 - 232.	Multiple Single-case	4	Performance in solving problems with Pythagorean theorem	15-17 years
ERIC	Effectiveness of Video Prompting Delivered via Augmented Reality for Teaching Transition-Related Math Skills to Adults With Intellectual Disabilities.	Kellems, R.O., Cacciatore, G., Hansen, B.D., Sabey, C.V., Bussey, H.C., & Morris, J.R. (2020) [32]. Effectiveness of Video Prompting Delivered via Augmented Reality for Teaching Transition-Related Math Skills to Adults With Intellectual Disabilities. Journal of Special Education Technology, 36, 258 - 270.	Multiple Single-case	3	Performance in vocational math skills	21-21-24 years
ERIC	The Effect of an Augmented Input Intervention on Subtraction Word-Problem Solving for Children with Intellectual Disabilities: A Preliminary Study	Naude, T., Dada, S., & Bornman, J. (2020) [30]. The Effect of an Augmented Input Intervention on Subtraction Word-Problem Solving for Children with Intellectual Disabilities: A Preliminary Study. International Journal of Disability, Development and Education, 1–22. doi:10.1080/1034912x.2020.1840530	Multiple Single-case	7	Performance in subtraction calculates	9-11 years
ERIC	Algebraic Problem Solving for Middle School Students with Autism and Intellectual Disability.	Root, J.R., & Browder, D.M. (2017) [26]. Algebraic Problem Solving for Middle School Students with Autism and Intellectual Disability. Exceptionality, 27, 118 - 132.	Multiple Single-case	3	Number of independent steps of the task and complete solution of the mathematical problem	12-14 years
ERIC	Teacher implemented modified schema-based instruction with middle-grades students with autism and intellectual disability.	Root, J., Cox, S., & McConomy, A. (2022) [28]. Teacher implemented modified schema-based instruction with middle-grades students with autism and intellectual disability. Research And Practice For Persons With Severe Disabilities.	Multiple Single-case	3	Number of independent steps of the task of the word problem math (multiplication)	12-13 years
ERIC	Not all created equally: Exploring calculator use by students with mild intellectual disability.	Yakubova, G., & Bouck, E. C. (2014) [31]. Not all created equally: Exploring calculator use by students with mild intellectual disability. Education and Training in Autism and Developmental Disabilities, 49, 111–126.	Multiple Single-case	5	Accuracy and response time in solving subtraction calculus and word mathematical problems	11 years
ERIC	Evaluating performance on a bespoke maths game with children with Down syndrome.	Porter, J. (2022) [34]. Evaluating performance on a bespoke maths game with children with Down syndrome. Journal of Computer Assisted Learning, 38 (5), 1394– 1407. https://doi.org/10.1111/jcal.12685	Multiple Single-case	8	Accuracy in game tasks	9-14 ears

3. Results

3.1 Sample description

The sample of selected articles has 113 subjects in an experimental sample, mostly males (60, 17%) included in single case or case series studies. The ages varied between 6- 24 years old. Only one study used a group study design including a control group in a quasi-experimental study. Three subjects have an etiology of intellectual disability report which was the Down syndrome. About the level of severity, 52, 63% of the studies don’t report, 21, 05% of studies report sample composed by moderate intellectual disability, 15% report sample composed by mild intellectual disability and two studies report mixed sample, one with mild and moderate ID and other with moderate to severe ID.

3.2 Evidence of effects

Even mathematical variables of intervention were heterogenous, and tested teaching and digital methodologies were found. Some studies investigate the use of video prompting (VP) to teach mathematical problem-solving and comparison skills [19-22]. The results appointed in the first study that acquisition and generalization of abilities in two cases of three subjects, with big effect size for number line and video-prompt, in this case with Tau-U major 1. The second study used visual analysis for statistical analysis and the authors suggested a functional relationship between the use of VP with systematic procedures for requesting and correcting errors and students' mathematical problem-solving skills. The results of these studies suggest that video prompting is a possible intervention for promoting the acquisition and maybe generalization of math skills. The third study presented favorable results to the methodology in three out of four participants, including maintenance outcomes after the intervention. The last study evaluated the use of prompts for independent task steps and demonstrated gains during the intervention, which were not maintained in the intervention phase. One study reports no results [40]. This study was the only to try to apply strategy to individuals with severe intellectual disability and they concluded, none of participants acquired the target skill, what was to learn to

use the number line through video prompt.
Virtual manipulatives are also examined in two studies [23-24]. Results suggest that as expected virtual manipulatives can be an effective assistive technology in teaching mathematics to students with intellectual deficiency. Concrete manipulatives were compared with app-based manipulatives [25] and both types were effective in promoting the acquisition of fraction addition skills.
Schema-based instruction is examined in four studies [24, 26, 27, 28]. All of studies suggest that this instructional approach, particularly when used in conjunction with technology-based supports, can help in teaching data analysis and problem-solving skills. Furthermore, results suggest a reduction in response time in subtraction and support in identifying mathematical vocabulary. The device used to deliver the technology was the iPad.
The impact of Information and Communication Technologies (ICTs) to intervention on teaching number concepts, money, hours and addiction and subtraction abilities to intellectually disabled children were examined in one study [29]. The results point t value 2,027 comparing control group and clinical group with significance 0, 05. The results suggest that ICTs can be a valuable tool for promoting the acquisition and generalization of mathematical skills among this population.
Other methodologies tested were visual representation [30], calculator [31], video-based instructional [32], self-monitoring device [33], and digital game [34]. For visual representation, the results indicated that the combination of visual representation and voice command had an impact on mathematical skill acquisition in 4 out of 5 participant subjects. In the evaluation of graphic calculator versus scientific calculator, both showed favorable results in increasing accuracy and reducing response time. The results are also favorable for video-based instruction, in which Tau-U 1 was found, suggesting a large effect size, as well as maintenance of skills after the intervention. Regarding the self-monitoring device, results showed an increase in on-task behaviors. With a heterogeneous result, the evaluation of a digital game for teaching mathematics showed gains in skills in 5 out of 8 participant subjects and generalization results to other contexts in 4 out of 8 participants.

3.3 Educational methodologies
Variability on technologies and methodologies to teach was found between studies. Three methodologies are highlighted: video prompt, schema-based instruction, manipulatives, Self-monitoring, reinforcement, explicit instruction, calculator, and visual representation.
Video prompting refers to an instructional method that involves using video models to teach a specific skill or behavior. The logic behind technique involves transforming a big issue into small parts and teaching one part at a time. The aim is to reduce complexity of target and to model in small parts [35]. Schema-based instruction is a problem-solving strategy consisting in teaching based on predefined schemas. Schemas are predefined mental structures for situations, people, things which save energy in interpretation. Strategies and steps are supported by visual information, diagrams, flowcharts and others [36]. Virtual manipulatives are digital tools designed to help students learn math concepts using visual representations. They are interactive and allow students to manipulate virtual objects to help them understand and solve mathematical problems [23]. Concrete manipulatives are physical objects with the same function and aim of virtual manipulatives [25].
Explicit instruction: this method involves the use of clear, direct, and structured lessons to teach specific skills or concepts to learners. This approach is characterized by systematic, step-by-step instruction that includes frequent checks for understanding and opportunities for practice [37].
Self-monitoring: involves developing the ability in the individual to observe and check for consistency between their behavior and the target behavior. This technique aims to increase self-awareness and self-regulation by encouraging individuals to monitor their own behavior and evaluate whether it aligns with the desired behavior [38].
Reinforcement: use of rewards or punishments to increase or decrease the likelihood of a particular behavior [39].

3.4 Technologies
Regarding the technologies used in the selected works, there is a concentration on computers, tablets, pagers, and calculators. Computers and tablets were predominantly used for video modeling and visual representations, as well as for accessing educational games. Pagers were used for task-oriented behavior training, serving as a resource for self-regulation training. It is noted that these technologies tend to be lower in cost and accessible in domestic or school environments, which impacts their feasibility for practice. Additionally, these technologies do not require specialized training. This suggests the possibility of intervention using tools that are more commonly integrated into the daily lives of individuals with intellectual disabilities and their families.

3.5 Characterization of protocols
The characterization of the intervention protocols was poor and compromised by the preliminary character of the intervention. Most studies were more a proof of concept, and they did not clearly report the intervention format. There is a need of standardization of the protocols to understand how these technologies may help on development of math skills. Duration of the intervention sessions described just four studies and they all presented short sessions, ranging from 10 to 20 minutes. In general, the data are insufficient for a characterization, but we would need an ideal timing, number of sections, standardized measures, and standardized outcomes.

4. Discussion
Ten studies realized between 2002 to 2022 addressed technology-mediated interventions to teach mathematical skills in subjects with intellectual disabilities. Case series and single case design were common, so the results are not possible to generalize. However, the summary of results points directions to future investigations and tendencies about methodologies in use to teaching people with ID. Video-prompt [19-20, 40], virtual manipulatives [23-25] and computer schema-based instruction [24, 27] are used by technologies in the area. About effect, they seem technologies with good reasoning to be tried, there is no possible conclusion about effectiveness [24, 20, 40]. Virtual manipulatives seem to be a good assistive technology in teaching mathematics to students with disabilities [23-24], although the effect is similar with concrete manipulatives [25]. Concrete manipulatives have a moderate to small effect depending on the mathematical skill demanded in the

activity [41]. Computer-schema based instruction presents results favorable to supportive to improve problem-solving skills [24, 27]. Besides the perspectives, the hallmark is the lack of testing and the preliminary effects of the tested strategies.

In educational demanding times, there is a basic need to optimize the mental capital and to have strategies evidence based to teach math to children and adolescents with intellectual deficiency. For now, limitations are the rule. The predominance of case studies reduces the potential for generalizing the results beyond individual effect. A limited number of math abilities were investigated, limiting the practical application in the teaching context. Most math abilities can be classified by numerical processing cognitive model, as symbolic skills [5]. Despite evidence about primary deficits in no symbolic abilities on this population [6]. There is also a gap in the comprehensive assessment of skills that predict and interact with mathematical learning, such as executive functions. None of the studies included in the review assessed this key group in mathematical learning. Great variability in the research sample is observed. The participants varied in terms of their age, disability type, and level of mathematical proficiency, which makes it difficult to draw any conclusions about the effect of the interventions. Intellectual deficiency still a disorder not well characterized for its etiology. Only 13 participants out of 113 had their etiology reported, but literature suggests that different etiologies of intellectual disability impact differently in cognitive profiles [42-43].

In general, the studies included in this review point to directions regarding digital and teaching methodologies to be investigated for use with this population and highlight the gap in scientific productions regarding mathematics education for the population with intellectual disabilities.

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