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Aspects of knowledge for teaching mathematics to students with Down syndrome: insights from a community of teachers

Aspectos del saber para enseñar Matemática a estudiantes con Síndrome de Down mencionados en una comunidad de profesoras

Aspects des connaissances pour enseigner les mathématiques aux élèves trisomiques élevés dans une communauté d'enseignantes

Aspectos do conhecimento para ensinar Matemática a estudantes com síndrome de Down suscitados em uma comunidade de professoras

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Abstract

This research, presented in the article, aimed to investigate aspects of knowledge necessary for teaching Mathematics to students with Down syndrome elicited within the formative context of a community of teachers. Adopting a qualitative, intervention-research approach, a group of seven teachers specializing in Mathematics education for students with Down syndrome was formed. These educators worked in both special education schools and mainstream schools. The group interacted synchronously and asynchronously, as the training occurred before and after the onset of the COVID-19 pandemic. Data were collected using audio recordings, field diary notes by the researcher, and records of interactions in a WhatsApp group. Analysis of the produced information was guided by three emerging aspects from the data set: a) Down syndrome, potentials, and challenges related to Mathematics; b) knowledge of the concept (number) for teaching and learning in students with Down syndrome; and c) curriculum adaptation and the use of multisensory materials. In conclusion, formative actions based on a

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community of teachers allow for a flexible work plan, leading the teacher to consider the specific difficulties, skills, and motivations of students with Down syndrome in Mathematics education. This approach values the diverse perspectives of teachers and the importance of sharing their knowledge and experiences, addressing the emerging needs of the group, and articulating their interests and practices.
Keywords: Special Education, Inclusive mathematics education, Teacher Education, Down syndrome, Number teaching.

Resumem

La investigación presentada en este artículo tuvo como objetivo investigar aspectos del conocimiento para enseñar Matemática a estudiantes con Síndrome de Down, mencionados en un contexto formativo de una Comunidad de Profesoras. Por lo tanto, se asumió la perspectiva cualitativa del tipo investigación-intervención. Para ello, se constituyó un grupo de siete docentes que enseñan Matemática a alumnos con Síndrome de Down, laborando tanto en escuelas en la modalidad de Educación Especial como en escuelas regulares. El grupo se relacionó de forma sincrónica y asincrónica, considerando que la capacitación se dio antes y después del inicio de la Pandemia de Covid-19. Para la producción de datos se utilizaron grabaciones de audio y apuntes de la investigadora en un diario de campo, así como interacciones que se dieron en un grupo de WhatsApp. Los análisis de la información producida fueron guiados por tres aspectos emergentes del conjunto de datos: a) Síndrome de Down, potencialidades y dificultades relacionadas con las Matemáticas; b) conocimiento del concepto (número) para la enseñanza y aprendizaje de los alumnos con Síndrome de Down (SD); y c) Adaptación curricular y uso de materiales multisensoriales. Como conclusión, se destaca que las acciones formativas basadas en una Comunidad de Docentes permiten un plan de trabajo flexible, llevando el docente a pensar la enseñanza de las Matemáticas considerando las dificultades, habilidades y motivaciones específicas del alumno con SD, valorando las diferentes miradas de los docentes y la importancia de compartir sus saberes y experiencias, atendiendo las necesidades que emergen del grupo, articulando sus intereses y prácticas.

Palabras clave: Educación especial; Educación matemática inclusiva; Formación de profesores; Síndrome de Down, Enseñanza de los números.

Résumé

La recherche présentée dans cet article visait à étudier les aspects de la connaissance pour enseigner les mathématiques aux élèves trisomiques élevés dans un contexte formatif d'une

communauté d'enseignants. En ce sens, la perspective qualitative du type recherche-intervention a été adoptée. À cette fin, un groupe de sept enseignants a été constitué qui enseignent les mathématiques aux élèves trisomiques, travaillant à la fois dans les écoles de la modalité d'éducation spéciale et dans les écoles ordinaires. Le groupe a relaté de manière synchrone et asynchrone, considérant que la formation a eu lieu avant et après le début de la Pandémie provoquée par le Covid-19. Pour la production de données, des enregistrements audio et des notes de chercheur dans un journal de terrain ont été utilisés, ainsi que des interactions qui ont eu lieu dans un groupe WhatsApp. Les analyses des informations produites ont été guidées par trois aspects émergents de l'ensemble de données, à savoir : a) le syndrome de Down, les potentialités et les difficultés liées aux mathématiques; b) Connaissance du concept (nombre) pour l'enseignement et l'apprentissage des élèves trisomiques; c) Adaptation du curriculum et utilisation de matériel multisensoriel. En conclusion, il est souligné que les actions de formation basées sur une Communauté d'Enseignants permettent un plan de travail flexible, amenant l'enseignant à réfléchir à l'enseignement des Mathématiques en tenant compte des difficultés, des compétences et des motivations spécifiques de l'élève avec DS, avec une appréciation des différents points de vue de les élèves, les enseignants et l'importance de partager leurs connaissances et leurs expériences, de répondre aux besoins qui émergent du groupe, d'articuler leurs intérêts et leurs pratiques.

Mots-clés: Éducation spéciale; l'enseignement inclusif des mathématiques; Formation des enseignants; Le syndrome de Down, Enseigner les nombres.

Resumo

A pesquisa apresentada neste artigo teve por objetivo investigar aspectos do conhecimento para ensinar Matemática a estudantes com Síndrome de Down, suscitados em um contexto formativo de uma Comunidade de Professoras. Nesse sentido, foi assumida a perspectiva qualitativa do tipo pesquisa-intervenção. Para tal, foi constituído um grupo de sete professoras que ensinam Matemática para estudantes com Síndrome de Down, atuantes tanto em escola na modalidade de Educação Especial quanto em escola comum. O grupo relacionou-se de maneira síncrona e assíncrona, considerando que a formação ocorreu antes e depois do início da Pandemia causada pela Covid-19. Para a produção dos dados, foram utilizadas gravações em áudio, anotações da pesquisadora em diário de campo e registros de interações em um grupo de *WhatsApp*. As análises das informações produzidas foram orientadas por três aspectos emergentes do conjunto dos dados: a) Síndrome de Down, potencialidades e dificuldades relacionadas à Matemática; b) conhecimento do conceito (número) para o ensino e a aprendizagem de estudantes com

Síndrome de Down (SD); e c) adaptação curricular e o uso de materiais multissensoriais. Como conclusão, destaca-se que ações formativas pautadas em uma Comunidade de Professores possibilitam um plano de trabalho flexível, conduzindo o professor a pensar o ensino de Matemática considerando as dificuldades, habilidades e motivações específicas do estudante com SD, com valorização das diferentes visões dos professores e da importância de compartilhar seus conhecimentos e experiências, atendendo as necessidades que emergem do grupo, articulando seus interesses e práticas.
Palavras-chave: Educação especial, Educação matemática inclusiva, Formação de professores, Síndrome de Down, Ensino de números.

Aspects of knowledge for teaching mathematics to students with Down syndrome: insights from a community of teachers

Promoting an inclusive school, where everyone is integrated and collective support services are provided, presents challenges for educational institutions traditionally operated on exclusionary and selective principles. This article specifically addresses the challenges within the context of teacher training. When discussing training from an inclusive perspective, we aim to develop approaches that consider classroom diversity. This necessitates a fresh examination of teachers' knowledge, skills, beliefs, and attitudes, which are essential for inclusive education. Professional knowledge stands out among the various factors associated with teacher training and performance. A teacher's professional knowledge is a collection of more specific knowledge that encompasses classroom practice and is connected to academic knowledge.

Therefore, it is posited that the "fundamental basis for professional knowledge is experience and reflection on experience" (Ponte, 2002). Training primarily focused on creating and revising the knowledge necessary for effective and inclusive practice is an important aspect of developing professional teaching knowledge. This training should prioritize reflection and a collective and accountable commitment to the profession. It is important to note that teacher training needs to be tailored to the recipient's needs. With this in mind, this article endeavors to explore the influences of a community of teachers who specialize in teaching mathematics to students with DS on the development of professional knowledge associated with teaching mathematics.

In this regard, we understand that teachers with shared interests, who exchange practices, experiences, needs, and concerns, can form a teacher's community. This community, characterized by social interdependence, collaboratively engages in discussions and decision-making processes while simultaneously sharing and seeking strategies to enhance their knowledge as education professionals (Grossman, Wineburg & Woolworth, 2001). Undoubtedly, there is a need for a renewed diversification of theoretical and practical knowledge in order to address the unique needs of students with Down syndrome (DS).

A teacher's community comprises individuals working in specialized educational institutions and mainstream schools. These professionals possess a wealth of knowledge and practices. At times, they may not have received specific training in mathematics despite being tasked with teaching the subject. Thus, they lack opportunities to develop this professional knowledge to create contexts that foster innovative practices and value knowledge (Modenutte, Monteiro & Susiki, 2019). Consequently, a teacher's community can provide a shared training environment that prioritizes commitment and responsibility, thereby promoting teachers'

individual and collective growth (Grossman, Wineburg & Woolworth, 2001). Another reason for conducting this research is the need for teachers to know about their students and the specific characteristics of their disabilities, as this is essential for effective teaching and learning (Rodrigues, 2008). Our focus in this study was students with DS, who commonly exhibit a shorter auditory short-term memory capacity, among other characteristics. This shorter capacity often leads to difficulties following oral instructions, although their visual memory is often not compromised. It is important to acknowledge that each student is unique in their characteristics, which necessitates individualized teaching approaches, particularly for students with disabilities who have historically been excluded from the school system. By understanding students' individual needs, teachers can tailor their instructional strategies to maximize their potential and abilities.

With these goals in mind, we established a study group composed of teachers from Special Education schools and teachers from mainstream schools who teach mathematics to students with DS. This group served as a teacher's community, engaging in training activities focused on fostering collaborative interactions and reflective practice. We firmly believe that Special Education in Brazil, when approached from an inclusive perspective (Brasil, 2008), provides an ideal context for sharing practices that bridge different educational settings, such as specialized and regular schools. Ultimately, we are all united in the pursuit of a common good- high-quality education—and we can learn from one another's diverse perspectives.

To accomplish these objectives, this study encompassed discussions and interactions among the participants, including the trainer (the first author of this study) in the training group sessions. Considering the insights derived from these interactions, we also explored the potential of utilizing multisensory materials to enhance the construction of mathematical knowledge among students with DS and the significance of their integration into the teaching process. We opted not to delve into isolated theoretical subtopics in this text due to space constraints. Instead, theoretical discussions are presented alongside the data analysis whenever deemed relevant. The research methodology is provided in the following section.

Research design

This study utilized a qualitative research approach (Bogdan & Biklen, 1994), which is descriptive and interpretative in nature. Among the various options for qualitative research, an intervention research design was adopted. According to Rocha and Aguiar (2003), intervention research is a participatory research trend that aims to examine the lives of collectives in their qualitative diversity with a socio-analytical intervention.

In intervention research, the researchers do not position themselves outside the practice, and the context of interaction and communication between the participants is considered. Therefore, this research focused on investigating training in a teacher's community based on an intervention collaboratively designed and discussed with the community members. The researcher (the first author) was directly involved in this intervention. The investigation considered the interactions, dialogues, and reflections among the participants. The researcher's participation in the training group was recognized as a member of the teacher's community, and the results impacted both the collaborators and the researcher.

The research was conducted in a municipality located in the southern region of the state of Paraná. The Municipal Department of Education and the State Department of Education, to which the schools involved belonged, were contacted, and the research project was then approved by the Ethics Committee (opinion no. 3.852.099).

The first school, where some of the participants work, provides special education to students with intellectual disabilities and multiple disabilities. The second school, referred to as an ordinary school, offers early childhood education and the early years of primary school. The training group consisted of teachers from nursery classes (with students aged between 4 and 6) and primary classes (with students aged 7–14 years) who had at least one student with DS among their students. Initially, the group of teachers included eight members, consisting of seven invited teachers and the researcher/trainer.

In terms of characterizing the participating teachers in the community, their identities have been kept anonymous. The presented biographical data reveals that all of them hold a degree in Pedagogy and specialize in Special Education, which is a requirement for teachers in this research. There is also diversity in terms of their experience, with teachers having worked for 5 to 23 years. Originally, the training sessions were scheduled to be held fortnightly in face-to-face meetings over a period of six months. However, the sessions had to be modified due to the suspension of in-person classes due to COVID-19 containment measures. A combination of face-to-face, remote synchronous, and remote asynchronous meetings were conducted. Face-to-face classes were temporarily halted, and students from regular and Special Education schools were assigned home-based learning activities with the help of their families. Despite these changes, our focus remained on the collaborating teachers, and the research continued.

The training sessions included face-to-face and remote meetings, alternating between dialogue, idea sharing, and studying and planning customized math tasks for their students. These tasks were designed based on the recommended guidelines in light of the current epidemiological situation. The concept of number was collectively chosen as the main topic of

discussion during the training sessions. The selected tasks, meant to be implemented in the classroom, were developed with the researcher. This concept was chosen due to its relevance to the subjects taught by the participants and its cross-curricular importance across all grade levels.

However, as face-to-face classes were suspended, it was not possible to observe the students and teachers carrying out the tasks at school directly. Nevertheless, some parents of students with DS provided videos of their children completing the tasks at home. These aspects, new to the participants, influenced our research focus and provided valuable elements for discussion with the teachers in training. All meetings were recorded using audio and video, and selected images were captured to illustrate the discussions. Additionally, the researcher maintained a field diary to document observations and insights. Many interactions occurred asynchronously in a WhatsApp group, allowing for greater teacher engagement and flexibility based on their availability. Reflections and experiences were shared and discussed within this platform. Relevant texts were also shared via email (Table 1), with instructions for individual reading followed by face-to-face discussions. Table 1 provides an overview of the interactions and activities in the teachers' community, along with their respective dates and objectives. This table offers valuable insights into the training process. It is important to note that the program was collaboratively developed to address the specific needs of the group of teachers during the pandemic. The following acronyms were used for the meetings in Table 1: FM (face-to-face meeting) and RM (remote meeting).

Table 1.

Overview of the teacher's community (prepared by the authors)

Training	Objectives	Activities
1st FM 14/02/2020	▪ Introduce the training proposal and define study objects collectively	▪ Conduct a dynamic exercise using number plates from zero to ten, ordering and quantifying them; Presentation of the training proposal, defining study dynamics and possible developments.
2nd FM 03/03/2020	▪ Conduct a questionnaire for biographical data collection ▪ Study and discuss DS	▪ Interaction through a dynamic exercise with a number line and collection of biographical data via questionnaire; ▪ Study the text "Cognitive Development and the Learning Process in Individuals with DS: Reviewing Conceptions and Educational Perspectives" (Bissoto, 2005).
3rd RM 23/03/2020	▪ Identify students with DS	▪ Presentation of the students with DS to the group of teachers via WhatsApp. Each teacher presented their student, age, class, and evidence related to learning mathematics.
4th RM	▪ Know/characterize	▪ Videos available for discussion about DS with Dr. Zan

Training	Objectives	Activities
25 and 26/03/2020	DS ▪ Reflect on the syndrome using the videos	Mustacchi: https://youtu.be/Se5n_FN72gY - https://youtu.be/P5Nb7JeLTKA ▪ Discussions via WhatsApp about the videos.
5th RM 31/03/2020	▪ Disseminate and suggest multisensory stimulus material	▪ The researcher prepared multisensory material using empty jars (20 jars, which had to be organized by the students to form equal pairs. Two games were made and raffled off among the teachers).
6th RM 09/07/2020	▪ Discuss and reflect on the text (03/03) and the videos (25 and 26/03)	▪ A retrospective of the course of studies with reflections based on the texts and videos to learn more about the syndrome and the possible interferences in teaching and learning.
7th RM 17/07/2020	▪ Disseminate and suggest multisensory stimulus material	▪ They made a memory game using instant coffee lids. There were 12 lids, and different objects were glued to each pair of lids (trolley, doll, spoon).
8th RM 27/07/2020	▪ Interact with the group of teachers	▪ At the teachers' request, the game with the lids was played again, but with a variation, forming pairs with the numeral and the quantity.
9th RM 30/07/2020	▪ Define what a number is ▪ Present the difficulties and potential of students with DS in Mathematics	▪ Research and definition of number; ▪ Study and dialog about difficulties and strengths in mathematics for students with DS. *Primer on Attitudinal Practices for School Inclusion and DS* (*DSAWM - DS Association of West Michigan*, 2019).
10th RM 05 to 12/08/2020	▪ A theoretical retrospective	▪ Through WhatsApp, each teacher could write about the trajectory of their studies and their reflections on the knowledge shared.
11th RM 14 to 28/08/2020	▪ Observe the performance of mathematical tasks by students with DS	▪ Sharing videos on the WhatsApp group of students doing math tasks (defined by the group) at home with their families.
12th RM 17/09/2020	▪ Discuss mathematical tasks carried out by students with DS (videos)	▪ Observe, discuss, and evaluate the tasks carried out by the students, their performance, and the need to adapt the tasks/materials.
13th RM 23/10/2020	▪ Analyze the contributions to the teaching of mathematics for students with DS	▪ Observe and analyze what the teacher presents about mathematics for students with DS. Video: *Inclusive Mathematics for children with DS*, by Prof. Dr. Leo Akio Yokoyama https://youtu.be/WIXK562iqul.
14th FM 28/10/2020	▪ Converse about the video *Inclusive Mathematics by children with DS* ▪ Creating tasks using recyclable materials	▪ Collectively discuss impressions of the video and make tasks/materials to be used by students with DS.

Training	Objectives	Activities
15th RM 16/11/2020	▪ Finish the training for 2020 with a retrospective and evaluation	▪ Discuss the training, ending with considerations about the course's progress, surveying the positive and negative aspects highlighted by the participants.
16th RM 09/02/2021	▪ Resume training with reading guidance	▪ Individualized reading of the book *Mathematics and DS*, from pages 22 to 40 (Yokoyama, 2014).
17th RM 17/02/2021	▪ Get to know the Akio Material	▪ Get to know the Akio material available at http://professoresdematematica.com.br/msd-materiais.html. Reading support *Mathematics and Down's syndrome* pages 41 to 58 (Yokoyama, 2014).
18th RM 03/03/2021	▪ Discuss about reading *Mathematics and DS* and the Akio material	▪ Reflections and sharing of notes related to reading *Mathematics and DS* (Yokoyama, 2014) and the possibilities related to the Akio material. ▪ Suggest further research: DSE (DS Education), DS education organizations. DS Education International. DS Education, USA. https://www.seeandlearn.org/en-us/numbers/design/
19th RM 05/03/2021	▪ Share a video about Mathematics and DS	▪ Watch the video *Mathematics and DS*, by Professor Dr. Leo Akio Yokoyama https://fb.watch/4_NF3QAqPB/; ▪ Identify the Numicon material and how it can be used.
20th RM 10/03/2021	▪ Support reading available	▪ Number and arithmetic skills in children with DS (Brigstocke S., Hulme, C. & Nye, J, 2008)
21st RM 14/03/2021	▪ Make inferences about the studies	▪ Through WhatsApp, make inferences about the studies, thinking of multisensory materials adapted to students with DS.
22nd RM 18/03/2021	▪ Recognize the stages of learning numbers	▪ Identifying the stages of learning numbers; ▪ Resumption of DS Education studies.
23rd RM 22/03 to 01/04/2021	▪ Share suggestions for different multisensory materials	▪ Through WhatsApp, share the different suggestions for multisensory materials made by the teachers. Reflections and possible adjustments.
24th RM 05 to 09/04/2021	▪ Evaluate the use of multisensory materials	▪ Watching the students' videos on using multisensory materials, made available by the families, enabling reflections/discussions in the group.
25th RM 16/04/2021	▪ Evaluate training	▪ Retrospective and evaluation of the training through dialog between the participating teachers.

From this context, the elements that comprise the results emerge, which will be presented and discussed in the following section.

Results and Discussions on the Trajectory and Actions of the teacher's community

Table 1 highlights the different interactions that took place in/with the group. We believe that the group offers a promising possibility through collectively agreed and developed projects, providing a fruitful relationship between theory and practice (Estevam & Cyrino, 2019). We recognize that the development of teacher knowledge should not occur in isolation, and we argue that shared practices in the group are an opportunity to reevaluate knowledge and practices in the classroom. Another perspective that stands out in the study is that the teacher's community refers its actions to the interest and commitment between ongoing learning and providing high-quality teaching (Grossman, Wineburg & Woolworth, 2001), seeking tasks that are more appropriate to the specificities of students with DS for the teaching and learning of Mathematics (Tabaka, Borges & Estevam, 2020). Thus, based on the prominent elements in the developed training actions, we identified the three most relevant and evident aspects of the teacher's community interactions. These aspects have led us to reflect on the development of professional knowledge regarding the teaching and learning of the concept of number for students with DS. The three aspects are as follows: a) the potential and difficulties related to mathematics in students with DS; b) the knowledge of the concept of number for teaching and learning in students with DS; and c) curriculum adaptation and the use of multisensory materials.

Down syndrome, potential and difficulties related to mathematics

The difficulties in mathematics faced by students with DS are undoubtedly connected to the syndrome itself, albeit not exclusively. Other factors, such as health conditions and physical characteristics, can also contribute to these difficulties. Additionally, the type of previous experiences that students have had with mathematics plays a role in their difficulties. Table 2 provides a summary of the physical and health characteristics of students with DS that were discussed within the Teachers' Community.

Table 2.

Physical characteristics and health conditions of students with DS (prepared by the authors)

Characteristics	Description
Muscle hypotonia (decreased muscle tone)	Students with DS may experience mobility, posture, breathing, and speech difficulties due to low muscle tone. They may become discouraged when they lack the necessary skills to perform tasks.
Communication, speech, and language difficulties	Speech may be unintelligible due to low muscle tone and difficulty with jaw movement. A significant difference exists between receptive language skills (comprehension) and expressive language skills (spoken language).
Memory	Most individuals with DS struggle with short-term or working memory. This

Characteristics	Description
	makes accessing, understanding, and processing information challenging; however, it does not prevent them from learning. It simply takes them longer to process the information.
Compact ear, nose, and throat structure	Students with DS are more prone to respiratory and sinus infections. They may also be more sensitive to loud or vibrating sounds. High noise levels in the classroom can be distracting.
Sleep apnea[4]	Sleep apnea can cause memory loss, intellectual impairment, and increased fatigue in students with DS. It can also result in hyperactivity, which may sometimes be misinterpreted as Attention Deficit Hyperactivity Disorder.
Hearing, vision, and thyroid problems	Some children with DS may experience hearing loss and visual problems. Additionally, there are cases of hypothyroidism, which can lead to sluggishness, weight gain, and intellectual disability.

Among the various physical and health characteristics of students with DS, the studies conducted by the teacher's community (DSAWM, 2019; Bissoto, 2005) and the emerging reports have highlighted those listed in Table 2. Throughout their efforts, the teachers emphasize the importance of understanding these characteristics in order to select appropriate mathematical tasks for students with DS. After all, poorly chosen tasks can create barriers to the learning process for any student, especially those who already face multiple obstacles imposed by the school.

Having knowledge of these potential characteristics, which influence and hinder the learning of students with DS, can assist teachers in understanding why the student may be struggling to learn or carry out certain activities in specific circumstances, as well as why students with DS may forget what they have previously learned. Furthermore, teachers recognize that certain behaviors are associated with the syndrome itself.

Schwartzman (2003) suggests that there is significant clinical variability in terms of the physical, health, and cognitive aspects of students with DS, and some of these aspects are more prominent than others, with varying degrees of impairment. When discussing these aspects within the teacher's community, the prevailing argument advocates for recognizing and utilizing the potential of every student, regardless of disability, in the teaching and learning process. Therefore, it is essential to understand the specific abilities of DS and integrate them into thestudent's developmental process.

Regarding students with DS, Schwartzman (2003, p. 279) points out that "visual memory facilitates learning." He further explains that "learning situations should prioritize visual information, as it is more likely to be processed by children with DS" (Schwartzman,

[4] Term used when someone stops breathing for short periods during sleep, generally 10–20 seconds.

2003, p. 279). These discussions corroborate the views of Buckeu and Bird (1994 apud Bissoto, 2005, p. 82), who argue that the visual processing skills of students with DS are more advanced compared to their auditory processing and memory abilities.

It is crucial to "review and repeat tasks that facilitate students in retaining what they have been taught" (DSWM, 2019, p. 39). We recognize the importance of providing students with opportunities to demonstrate their learning, which can also serve as a means to assess their understanding of the subject matter. In this regard, in discussing manipulatives, the teachers within the community have highlighted that these materials allow students to engage in repeated tasks. A teacher can facilitate the activity with the students, offering instruction and guidance before allowing them to complete it independently to gauge their level of comprehension. It is noteworthy that even if students can successfully complete the activity on their own once, it does not guarantee that learning has occurred. Hence, it is suggested that the same material be used again at subsequent times as a review of the task.

Therefore, based on the research conducted within the Teachers' Community, utilizing the works of Yokoyama (2014), DSWM (2019), Brigstocke, Hulme, and Nye (2008), and Abdelahmeed (2007), a table was devised to align with the existing literature and the discussions and reflections that have emerged from the group. This table references the potential of students with DS, accompanied by a succinct description and the pedagogical strategies formulated by the Teachers' Community for teaching mathematics to these students.

Table 3.

Potential, Descriptions, and Strategies for Teaching Mathematics to Students with Down Syndrome (compiled by the authors)

Potential	Description	Strategies
Improved visual processing	Presenting information with visual support, featuring clear and consistent representations	▪ Using images, objects, and gestures; ▪ Using step-by-step explanatory videos; ▪ Using manipulative materials; ▪ Becoming aware of the potential of one's fingers to represent quantities
Repetition for retention	Carrying out practices that can hold attention and be repeated regularly	▪ Building on previous knowledge; ▪ Reviewing concepts already learned when starting mathematical tasks; ▪ Practicing skills in different contexts and with a variety of materials; ▪ Allowing students to repeat at home what they have been taught at school; ▪ Using activities that are fun and relevant to the student's life
Small	Teaching in an	▪ Starting with number words and proceeding in

Potential	Description	Strategies
development steps	understandable/clear way at each stage	small developmental steps through initial number concepts and skills
Recording progress	Keeping records to identify when it will be possible to move on and make progress	▪ Making notes of the student's progress and always reviewing them; ▪ Progressing when the prerequisite skills for the next step have been learned
Appropriate language	Giving priority to simple and objective oral instructions	▪ Repeating information and instructions; ▪ Presenting the instructions in small steps
Time	Considering the time to move on to the next step	▪ Waiting for the student to carry out the activity according to their ability; ▪ Being objective in one's tasks, reducing the number of steps where possible
Space	Considering the classroom space	▪ Putting the student close to the teacher in the classroom; ▪ Minimizing noise and distractions
Interaction	Considering the interaction of the teacher, colleagues, and family members	▪ Demonstrating empathy and sympathy with the student; ▪ Being close to the student, looking at them; ▪ Promoting joint study between teacher and student; ▪ Promoting joint study between a student and a colleague with a similar interest; ▪ Partnering with the family to support teaching and learning
Motivation	Encouraging students to participate and complete tasks to foster a desire to learn	▪ Using the student's interests, things from their context; ▪ Preventing students from making frequent mistakes (this is discouraging); ▪ Using manipulative materials; ▪ Using digital technologies; ▪ Using positive reinforcement and praise

In addition to explaining the potential for teaching mathematics, Table 3 aims to describe and provide possible strategies for teaching (and learning), focusing on numbers, for students with DS. Systematizing these ideas within the community context benefits participating teachers and contributes to the field of research.

Understanding the difficulties of students with DS is undoubtedly relevant to supporting teaching actions. However, teachers must also consider strategies that enhance these students' abilities to learn mathematics. Using resources such as manipulative materials can improve concentration and expand the cognitive development of these students (Costa & Souza, 2015).

To engage students in math classes, the teacher's community believes that starting with what is sensitive, familiar, and meaningful to them is essential, as it can promote math learning. Students with DS may require more time to process newly acquired skills before learning new ones (even if they may forget them later). It is also important not to compare their abilities with those of other students in the class but rather assess their progress based on their own individual growth. We recognize that each student is unique and learning is personal to them, rather than that of other students or the class as a whole. In this way, the training provided the teachers with opportunities for exposure and discussion. This allowed them to recognize their limitations in understanding the difficulties and potential of students with DS, as well as the commitment they made in the community to seek professional development. It is important to note that the difficulties and potentialities of students with DS do not require more complex interventions in mathematics teaching than those already commonly faced by teachers. However, teachers must have the knowledge required to work closely with the specific needs of these students.

Knowledge of the concept of number for teaching and learning by students with Down syndrome

The discussions in the teachers' community facilitated shared reflections on the development of numerical skills. When students enter school, they already have experiences related to the concept of number such as counting objects while playing, which aids in their learning process. However, students with DS still require specific counting activities, as professionals who understand their differences and needs play a vital role.

The group resumed the discussion on the potential and difficulties related to students with DS, aiming to connect them with the concept of number and employ more appropriate strategies for teaching and learning. The reflections from the discussions held in the teachers' community are based on the stages of learning numbers described in the DSE (Down Syndrome Education, n.d.). The group studied these stages and, combined with the reflections that emerged in the teachers' community, created Table 4.

Table 4.

Stages of learning numbers by students with DS (prepared by the authors)

Stages	Description
Learning number words	Reciting a list of number words in the correct order. Example: one, two, three, four, ...
Learning numerals	Linking spoken number words to written numerals. Example: The word one corresponds to 1, and the word two corresponds to 2.
Relating quantities to numbers	Understanding that number words and numerals represent quantities. Example: Five and 5 can be represented by ///// (five stripes).

Stages	Description
Learning to count	Using number words in the correct order to count objects.
Learn *how many*	Grasping the concept that we count to determine the number of items we have, and that when we count all the items, the last number word we say indicates the total number of items. Example: When we count the fingers on one hand and reach the last finger in our count, that final word represents the total number of fingers on one hand.
Learning the cardinality principle	Taking a smaller quantity from a larger set can be illustrated through an example. For instance, when there are five objects, and we take away two, the student can remove two of the five objects.
Understanding equivalence	Understanding equivalence involves recognizing that if we distribute items evenly in two sets and then count the items in one set, this also reveals the number of items in the second set. For instance, if one has 10 objects and separates them into two boxes, counting them in one of the boxes, which is 5, will indicate that the other box also contains 5 objects.
Learning ordinality	Identifying that the position of each number in the counting sequence is fixed and that an equal unit is added to each subsequent number. For instance, when counting 1, 2, 3, 4, ..., a unit is consistently added, and this order remains unchanged.
Understanding the uniqueness of numbers	Understanding the uniqueness of numbers involves recognizing that each number represents a specific quantity. For example, the number 1 represents one unit, while the number 2 represents two units.
Recognize the relative value of numbers	Recognizing the relative value of numbers requires understanding that each number has a different size or value than another. For instance, 9 is larger than 5, and 4 is twice as big as 2 or two units larger than 2.
Learning comparative words and applying them to numbers	Learning comparative words and applying them to numbers involves understanding the words used to compare sets, such as equal/different, more/less, greater/lesser, and so on. For example, recognizing that 2 and 2 are equal, 4 and 5 are different, and 7 is more than 6.
Add items using a count-all strategy	When calculating 5 + 2, count 5 objects, count 2 objects and then count all 7 objects together, starting from 1. Example: With the same operation 5 + 2, count 1, 2, 3, 4, 5 (referring to the 5 of the first part), then count 1, 2 (referring to the 2 of the second part), and finish by counting everything together, starting again at 1, which will result in: "1, 2, 3, 4, 5, 6, 7."
Add items using a completion strategy	When calculating 5 + 2, count 5 objects, count 2 objects and then count on from 5 until all have been counted. Example: With the same 5 + 2 operation, count 1, 2, 3, 4, 5 (referring to the 5 of the first part), then count 1, 2 (referring to the 2 of the second installment), and finish by counting everything together, continuing from 5, leading to 5, 6, 7.
Learning the inversion principle	Understanding the inversion principle involves recognizing that adding is the inverse of subtracting. For example, by subtracting 2 and then adding 2 again, there will be the same number of items as at the beginning.

The stages presented in Table 4 indicate that in order to advance their understanding of numbers, students must learn these stages. Although there is no fixed order, students need to comprehend these concepts at some point. The dialogues that emerged from the teachers' community studies were centered around recognizing the significance of these stages for

teachers and identifying these stages in students' learning. Additionally, the group emphasized the importance of this knowledge in order to design teaching strategies that cater to the learning needs of each stage effectively.

Reflections among the teacher's community involved discussions on various experiences, such as engaging in games and counting activities in everyday life, both at home and with families, to enhance comprehension and learning of numbers. During these discussions, several points were highlighted, drawing from research conducted by Porter (1999), Gelman and Gallistel (1986), and Abdelahmeed (2007), which identified common errors made by children with DS while counting. The discussions yielded the following aspects:

1. *Number sequence:* Errors in reciting the sequence of number words, skipping numbers, or repeating numbers already recited.
2. *Pointing without labeling:* Pointing to an object without associating it with any specific number word.
3. *Ignored objects:* Failing to include certain objects in the one-to-one correspondence, neither assigning them a number word nor pointing to them.
4. *Various words for one pointing:* Associating multiple number words with a single object when pointing to it.
5. *Double counting:* Using two number words to represent the same object during the counting process.
6. *Understanding quantity:* When asked, "How many objects do we have here?" the student neglects to state the last number word indicating cardinality and restarts the counting process (Yokoyama, 2014).

By intertwining the stages in the development of numerical counting and the main errors in counting with discussions pertaining to the students' potential, the group considered these aspects as fundamental knowledge to guide thoughtful and appropriate strategies that can address the specific needs of students with DS in understanding the concept of number.

In this manner, it was possible to observe, during the training, the development of the teachers' knowledge, who expressed the belief that the mathematical concept should not be foreign to the student but rather connected to what the student already possesses for their development and potential. When contemplating approaches to teaching the concept of number to students with DS, creating adapted materials could be one such approach, acknowledging that "adaptation is the process of adjusting the material to fit the characteristics of the students" (Shulman, 1987, p. 219). However, when designing material tailored to the specificities of students with DS, it is important not to overlook that other students in the class may also benefit

from these materials. This is because other students may struggle to comprehend discussions when mathematical concepts are presented in a narrow range of methodological explorations and limited resources. We believe that diversifying methodologies and materials ultimately enhances the understanding of more students.

Being a teacher necessitates recognizing the uniqueness of our students, acknowledging their potential and difficulties, and understanding that this does not imply simplifying discussions but rather finding alternative approaches that can cater to the specific needs of students with DS, enabling them to learn numbers and other concepts, and progress in mathematics.

Having analyzed these initial aspects, the participating teachers recognized the importance of evaluating the curriculum and using materials that promote the teaching and learning of students with DS, which will be discussed in the subsequent section.

Curricular Adaptation and the Utilization of Multisensory Materials

The group of teachers discussed the importance of curricular adaptations in preserving the flexible and dynamic nature of the curriculum while considering the specific characteristics of students with DS and aligning them with the goals of teaching and learning. They explored specific curricular adaptations aimed at teaching and learning numbers to students with DS.

Curricular adaptations offer educational possibilities for addressing the learning difficulties and potential of students with DS. The teachers emphasized that curricular adaptations do not involve completely redesigning the curriculum but rather creating a dynamic framework that can be modified and expanded to effectively teach and reinforce the concept of numbers.

To ensure appropriate curricular adaptations, the teachers emphasized careful planning based on criteria determining what students with DS need to learn and how to best achieve it. Additionally, the teachers highlighted that such adaptations should consider the students' difficulties, but more importantly, they should be structured to leverage the students' potential. The teachers argued that these adaptations can compensate for or even help overcome the difficulties in learning numbers. They also emphasized the significant visual processing potential of students with DS and recommended utilizing multisensory manipulatives as part of the adapted curriculum.

During their discussions, the teachers noted a lack of suitable materials for teaching numbers in schools and recognized the need to develop materials tailored to the needs of students with DS. The teachers' community shared and discussed various multisensory

materials, selecting those that facilitated the most reflective interactions among the group. Due to the pandemic, some materials were not made available to the students, while others were distributed to the students who received support from their families to engage in the activities.

The teachers acknowledged that fingers are the human being's first sensory instrument (Brissiaud, 1989) and can aid in developing the concept of numbers. Finger-based activities were included in the repertoire of studies conducted in the teachers' community:

> Students can physically sense the quantities from zero to ten with their fingers. The tactile experience of feeling the numbers raised through fingers is much more intense than relying solely on visual perception (Brissiaud, 1989 *apud* Yokoyama, 2014, p. 43).

The teachers attempted to adapt activities involving fingers and shared these activities through a WhatsApp group, as depicted in Figure 1.

Figure 1.

Fingers and numbers (participating teachers)

The suggestions for carrying out the activities displayed in Figure 1 involved organizing the numbers in ascending order and associating them with the corresponding number of raised fingers and bottle caps. During the training session, the group of teachers emphasized the importance of relating the activities to the potential of students with DS. They also recognized that multisensory materials can be beneficial, especially those that engage touch and vision.

At another event organized by the teacher's community, disposable bottle caps of various colors were collected and distributed among the group. Along with the caps, the researcher provided suggestions for tasks and shared them to encourage everyone to participate. The images below illustrate the materials that were shared. Students were required to count, select colors, and quantify using the bottle caps.

Figure 2.

Bottle cap collection (participating teachers)

Another consideration during the interactions revolved around adaptations that could positively impact the teaching of number counting, particularly in learning to trace or write numbers. The teachers acknowledged the challenges associated with fine motor skills, taking into account the hypotonia (reduced muscle tone) characteristic of DS. They intended to associate the teaching of numbers with something related to tracing (numerals) that would not lead to frustration, fatigue, or discouragement among the students. The following are some of the suggestions that were discussed within the group.

Figure 3.

Numbers in cornmeal (participating teachers)

In Figure 3, a student is seen completing their homework with the assistance of their family. After quantifying the numerals, the student reproduced the tracing of the numbers on a plate filled with cornmeal using their index finger.

Figure 4.

Plates with sequential numbering (participating teachers)

Hollowed-out numbers made from medium-density fiberboard enabled students to position the board on a piece of paper for tracing (Figure 4). However, the group did not receive this material well because the numbers 0, 2, 6, 8, and 9 required small gaps in the pencil's paths. This made it challenging to trace continuously without lifting the marker from the paper.

Figure 5.

Boards with number sequences (participating teachers)

Considering the limitations of the previous materials, an alternative was presented. This alternative consists of sequences of numerals made from two overlapping and glued medium-density fiberboard boards. The numbers are hollowed out on the top board, allowing the student's tracing to appear on the bottom board using a pencil to imitate the tracing. The sequences were separated into two, with numbers worked up to 5 and numbers up to 10 being considered on both plates. After extensive discussion, the teachers in the group considered this material to be more suitable.

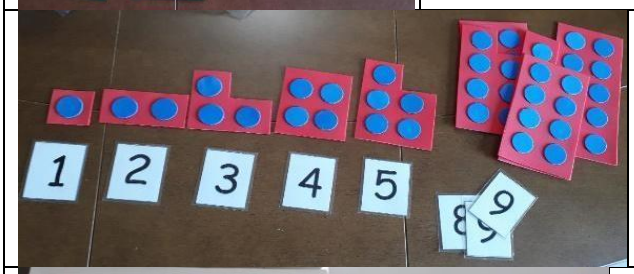
In the problematized suggestions, we observed a planned adaptation for the student with DS. However, we added that materials may not align with our purposes, as shown in Figure 4. The Community teachers pointed out that tracing the numeral must be done without

interruptions, which would not be possible with that material.

Some of the elements explained in the group's trajectory allow us to recognize the importance of these studies in developing the teachers' knowledge. These elements involve the use of multisensory materials identified in the studies by Yokoyama (2014), Abdelahmeed (2007), and Brigstocke, Hulme, and Nye (2008), which were part of the discussions in the community. Table 5 shows other materials made by the teachers.

Table 5.

Materials made for teaching numbers to students with DS (prepared by the authors based on the productions of the participating teachers)

	Memory game based on the Akio material (Yokoyama, 2014). The material was made of ethylene-vinyl acetate (EVA), a soft, flexible, and durable material commonly used in craft and educational activities.
	Memory game based on Akio material (Yokoyama, 2014). The material was made of EVA with similar numbers of circles arranged in different positions.
	Numicon game, based on Numicon material. The material was made of EVA and cards with the corresponding numbers. This material, of English origin, is discussed in Yokoyama (2014).
	Numicon game with EVA pieces, with the quantities represented by hollowed-out circles and small EVA circles or caps to fit the hollowed-out pieces.

The materials in Table 5 indicate other research and have shown positive results in teaching and learning numbers for students with DS (Yokoyama, 2014; Brigstocke, Hulme & Nye, 2008). Therefore, by replicating and using them, we intend to value and recognize other research contributions to our studies. Our intention is not to create something new but to capitalize on promising results by adapting them to our interests and needs. After all, our focus was not on student learning, although on the teachers' reflections and knowledge based on interactions in a community. Thus, the curricular adaptation discussed in this paper is a didactic

pedagogical strategy tailored to the concept of number. These adaptations affect the way the concept is taught and may involve modifying the materials or tasks used in the classroom. However, the core concept itself remains unchanged. This approach is particularly important when teaching students with DS. It is worth noting that the intention of these adaptations is not to infantilize the concept but rather to use engaging and appealing tasks that motivate the student and facilitate learning, which is the primary objective.

The group also recognizes the necessity of curriculum adaptation based on the literature reviewed and the experiences shared. They emphasize the importance of adapting multisensory materials to suit the needs and potential of students with DS. This topic has also contributed to the professional development of the participating teachers.

Conclusions and Considerations

In this study, we adopted the concept of a teacher's community as a space for professional development, acknowledging that teacher learning is an ongoing process guided by the knowledge and practices of the participating teachers. This community's reflective and collective interactions provide opportunities for growth and expansion. The teachers specializing in teaching mathematics to students with Down syndrome sought to enhance their professional knowledge and skills through interactions and exchanging information, beliefs, feelings, and experiences. This requires a commitment to teaching and learning based on the group's shared experiences. The community has become a pathway for teachers to address their professional development needs as educators.

The training dynamics employed in this study successfully addressed the participants' needs through studies, reflections, discussions, and the preparation and adaptation of materials. Despite the social isolation imposed by the pandemic, the group was able to analyze and understand the specific characteristics of students with Down syndrome. They discussed potential aspects and strategies, which are systematized in Table 3, and these findings can serve as guidance for other teachers, collaborative groups, and future research on this topic.

The interaction within the group, even in challenging times, allowed for fruitful exchange among teachers with diverse experiences. This process strengthened the relationships within the community of teachers. The discussions on teaching and learning the concept of number to students with Down syndrome and implementing curricular adaptations using multisensory materials provided valuable insights into professional knowledge and reflected real classroom practices. In fact, the interactions within the teacher's community emphasized the connection between theory and practice, which is a promising and necessary avenue for

developing professional knowledge. Additionally, we would like to highlight the reflections that emerged from the discussions within the group regarding the concept of number and its relation to the teaching and learning experiences of students with Down syndrome. This discussion enabled a deeper understanding of the learning stages and potential errors that students with Down syndrome may encounter.

Based on the findings of this research, it is crucial to recognize the significance of curriculum adaptation as a teaching strategy, allowing for the customization of instruction to meet the specific needs of students with Down syndrome. The use of multisensory materials, as observed by the group, showed great potential in enhancing the teaching of the concept of number.

The teacher's community served as a promising platform that fostered collaborative work among teachers who shared a common goal of teaching mathematics to students with Down syndrome despite being affiliated with different educational settings (special education schools and regular schools). In this group, the convergence of diverse perspectives facilitated the sharing of effective practices and created valuable learning opportunities for all involved.

Implementing a formative action within a teacher's community framework allowed for a flexible work plan tailored to address the emerging needs, interests, and practices of the participating teachers. Consequently, we propose that the dynamics of a teacher's community are essential in developing professional knowledge. In contrast to unilateral training that does not encourage open discussions, this type of collectively constructed training demonstrated tremendous potential in our case. Nevertheless, it is important to note that the success of such an approach depends on the willingness of collaborators and teachers to engage in respectful dialogues that acknowledge and respect the differences that define our individuality as human beings.

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