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Enhancing Teacher Preparation to Support Students with Autism in Primary Mathematics Education

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There is a growing need for preservice primary teachers to be prepared to teach mathematics to students with autism spectrum disorder. Teacher education programs often lack opportunities to develop specialized knowledge for this purpose. This study addressed this gap by designing, implementing and evaluating the impact of an instructional unit for preservice primary teachers, focused on teaching word problem-solving strategies to students with autism. A teaching experiment involving 81 preservice primary teachers was conducted. The instructional unit was designed to improve teachers' knowledge on mathematics teaching and on features of learning mathematics. The experiment evaluated improvements in those two knowledge subdomains of the Mathematics Teacher's Specialized Knowledge model. A questionnaire was created to identify the knowledge that preservice teachers were expected to develop upon completing the unit. A list of observable indicators was designed to code the participants' responses. Results report the number or percentages of participants in whose responses the expected indicators were found. Findings show increased knowledge about representations, task statements, methodologies, common errors and aids adapted to autism. Lower achievement was detected in relating learning characteristics and autism cognitive features. Implications for teacher education are discussed.

Keywords: initial teacher education, mathematics education, special needs, autism, primary education, MTSK

INTRODUCTION

Primary education legislation in many countries recognizes that the education of students with special needs must be governed by the principles of inclusion, quality,

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equity, non-discrimination and universal accessibility. Under this inclusive approach, general education teachers are expected to teach neurodiverse students in their regular classrooms. However, initial teacher education does not usually include education on how to teach disciplinary content, particularly mathematics, to students with diverse learning needs (Scherer & Bertram, 2024). Even within special education teachers' preparation programs, instruction on mathematics education is frequently absent (Griffin et al., 2014). This gap persists, despite the fact that such training would meaningfully complement teachers' ability to recognize students' academic, cognitive, and emotional challenges (DeJarnette & Hord, 2025). The lack of preparation is reflected in teachers' own perceptions, as many teachers report feeling unprepared and lacking confidence to teach mathematics to students with special needs, particularly those with Autism Spectrum Disorder (ASD) (Anglim et al., 2018). It is necessary, therefore, to align the inclusive approach of educational legislation with the preparation teachers receive to implement it effectively in mathematics instruction.

Research in mathematics teacher education has focused on identifying the types of knowledge essential for effective mathematics' teaching. Models such as Mathematical Knowledge for Teaching (MKT) (Ball et al., 2008) and Mathematics Teacher's Specialized Knowledge (MTSK) (Carrillo et al., 2018) describe categories which capture teachers' knowledge in contexts that involve cognitive diversity, both in preservice and in-service programs (Chico et al., 2023; Firestone et al., 2021; Fung & Wang, 2020; Piñeiro & Calle, 2023; Rosli & Suib, 2020). However, the characterization of knowledge categories addressing both mathematics and cognitive diversity remains underdeveloped in those models. Further refining these frameworks and exploring their application to design initial teacher education programs that account for cognitive diversity is a promising line of research.

Although still limited and diverse in their scope, some initial teacher education programs have integrated mathematics education and learner diversity (Allsopp & Haley, 2015). Perspectives combining mathematics education, special education and disciplines addressing students' emotional aspect are frequently emphasized (Fung & Wang, 2020; Scherer & Bertram, 2024). Some of them include practical experiences, such as mentoring or tutoring, co-teaching, collaborative teaching practices, peer collaboration, classroom observation, consultation to address the mathematics learning of students with special education needs within inclusive classrooms and incorporate the use of technology (Green et al., 2020; Lisenbee & Tan, 2019; Scherer, 2021; Van Ingen et al., 2024; Watt & Wasburn-Moses, 2018). These initiatives highlight the potential for rethinking initial teacher education programs by explicitly aligning mathematics instruction with the competencies needed to support diverse learners.

The limited preservice teacher preparation to address mathematics cognitive diversity contrasts with some statistics data on special educational needs. This is the case of the ASD. Recent studies show that there has been a huge rise in the prevalence rates for ASD, both in educational and health settings, which is currently thought to be 1 in 44 (Bella, 2023). In addition, in recent years there has been a significant increase in research on the teaching and learning of mathematics to students with ASD (see, for instance, reviews by Gevarter et al. 2016; King, et al., 2016; Siregar et al. 2020;

Fauziyah et al., 2022). Despite the heterogeneity of the cases, emerging research is providing adaptable methodologies that can be tailored to a range of mathematical learning characteristics. Examples include Schema-Based Instruction (SBI) for word-problem-solving (Jitendra et al., 2002) and the Concrete-Representational-Abstract (CRA) approach for a variety of mathematical content (see, for example, Strozier et al. 2015). This growing body of research should be integrated into initial teacher education programs to prepare teachers to address the demands they will encounter in their classrooms.

Given the diverse existing models of initial primary teacher education programs, and the challenges in addressing the wide spectrum of cognitive diversity in mathematics education, it is pertinent to develop concrete proposals and evaluate their efficacy. Our research group advocates that initial teacher education programmes incorporate units focused on methodologies for teaching a specific mathematical content to students with a particular special educational need. Our assumption is that, by learning these methodologies, preservice teachers develop a knowledge that they can later extend and adapt to meet the specific needs of each student they encounter in their future professional practice. In this study, we focus on arithmetic word problem solving (AWPS) to students with autism. Thus, the research question that we address is to determine the impact that a unit, oriented to teach arithmetic word problem solving to students with autism, has on the knowledge developed by preservice teachers. In addressing this research question, we design an original unit integrated into a mathematics education course in an initial teacher education program oriented to develop two subdomains of the MTSK model that are most directly related to special needs: Knowledge of Mathematics Teaching (KMT) and Knowledge of Features of Learning Mathematics (KFLM). We design a set of observable indicators specifically adapted to identify both types of knowledge in teachers' responses to a questionnaire. In doing so, a characterization of knowledge subdomains of the MTSK model adapted to the context of inclusive mathematics education is provided. The empirical evidence we obtain on the knowledge acquired by preservice teachers indicate significant progress in many categories, while also highlighting aspects that require further attention.

Background

We structure the background by exploring the intersections between (pre)service teacher education, specialized teacher knowledge and instructional strategies in mathematics education for students with ASD.

Preparing (Pre)service Teachers to Teach Mathematics to Students with ASD

Primary teachers often receive limited initial education on teaching mathematics to students with ASD, even within professional development programs (Lessner Listiakova & Preece, 2020). Most programs focus on general ASD knowledge (e.g., diagnostic characteristics, behaviour management, communication strategies) rather than subject-specific pedagogy (Sanz-Cervera et al., 2017). Gómez-Marí et al. (2021) conducted a systematic review of 25 studies, between 2015 and 2020, focused on teachers' knowledge and perceptions of ASD. They found that many general education teachers lack in-depth knowledge of educational characteristics of ASD, which limits their ability to effectively adapt curriculum and may lead to misinterpretations of mathematics learning difficulties of student with ASD. This situation is reflected in day-to-day teaching, as teachers who have students with ASD in their classrooms report that they do not feel adequately prepared to teach them (Anglim et al, 2018; Al Jaffal, 2022; Lisak Šegota et al., 2022). As a consequence, it seems to be an implicit reluctance to teach mathematics to students with ASD, even though mathematical processes hold significant value for their development (Rosli & Suib, 2020).

Recent research suggests the need to innovate teaching methodologies in preservice teacher education courses, proving that even brief training promotes positive attitudes toward inclusion and improves teachers' self-efficacy (Scherer & Bertram, 2024; Saade et al., 2021; Sanz-Cervera et al., 2017). These studies advocate for programs that bridge theoretical understanding of special needs with practical classroom applications, and underscore the necessity of embedding ASD-focused instructional strategies and opportunities for preservice teachers to reflect on teaching experiences. Although not exclusively focused on mathematics, this approach has clear implications for teacher preparation on mathematics. Effective preservice teacher education programs should foster that future teachers understand how ASD diagnosis can affect student's learning of mathematical contents. By recognizing the underlying causes of students learning difficulties, teachers can make concrete adaptations to support their understanding. To this purpose, preservice teachers should also know key teaching strategies in ASD, such as involving the use of visual supports to make abstract mathematical concepts more accessible, structured and predictable activities, clear and concise instructions for problem-solving tasks or mathematical representation systems adapted.

Grounded in this approach, the present work includes the design of a unit oriented to prepare preservice teachers to teach arithmetic word problem-solving to students with ASD.

Teacher Knowledge. The MTSK Model

The teacher knowledge has been studied by several authors from Shulman (1986) seminal paper, who emphasised that, in addition to subject matter knowledge, pedagogical, didactic and curricular knowledge is required for teaching. Ball et al. (2008) develop this idea in the field of mathematics, proposing the Mathematical Knowledge for Teaching (MKT) model, in which two domains are characterised: subject matter knowledge (SMK) and pedagogical content knowledge (PCK). Explicitly addressing special education teachers' knowledge, Rosli & Suib (2020) presents a systematic literature review focusing on the essential knowledge needed to effectively teach mathematics to students with learning disabilities, adding a third domain, Knowledge of Students with Learning Disabilities (KSWLD), oriented to capture the awareness of common learning challenges faced by students with LD and the insights into behavioural patterns that affect learning in mathematics. Van Ingen et al. (2024) introduce the Mathematics–Special Education Pedagogical Content Knowledge (M-SEPACK) model. This model, which builds on the MKT model, is used to prepare both general and special education teachers to collaborate effectively in mathematics-specific consultations.

Carrillo et al. (2018) propose the Mathematics Teachers' Specialised Knowledge model (MTSK), oriented to characterize the specialized knowledge that teachers put into practice in mathematics teaching and learning situations. This model presents a reconfiguration of the previous MTSK model, together with a dimension of beliefs. It considers the domain Mathematical Knowledge (MK), which is composed of three subdomains: Knowledge of Topics (KoT), Knowledge of the Structure of Mathematics (KSM) and Knowledge of Practices in Mathematics (KPM); and the domain pedagogical content knowledge (PCK), which is composed by three subdomains: Knowledge of Mathematics Teaching (KMT), Knowledge of Features of Learning Mathematics (KFLM) and Knowledge of Mathematics Learning Standards (KMLS). Given its emphasis on the interconnected nature of teaching and mathematical thinking—particularly its focus on how students learn mathematics—we have chosen the MTSK model to guide both the design and the evaluation of the impact of the instructional unit for preservice primary teachers presented in this study. In particular, we focus on the KMT and the KFLM subdomains of MTSK, as our approach for preservice teacher education in ASD and word problem solving emphasizes the development of these two types of knowledge. KMT refers to teachers' knowledge about theories and principles of mathematics teaching associated with mathematical content, knowledge generated through the different activities, tasks, analogies or examples that the teacher uses, and about recognizing the potential and limitations of material and virtual resources that can be used to teach mathematical content. General teaching strategies are excluded, as KMT focuses only on strategies specific to mathematics instruction. KFLM refers to the teacher's knowledge about how students learn mathematical content. This usually includes what the teacher knows about the way students think when solving mathematical tasks and the strategies they employ, and knowledge about the source of the errors and difficulties that students may encounter during the process of learning mathematical content. The teacher uses this knowledge to make informed decisions in the classroom or to interpret students' answers.

Although the MTSK domains and subdomains have been described without considering the particularities of special needs education, under an inclusive approach it is possible to adapt the model at the level of the observable indicators needed to identify teachers knowledge on the teaching and learning of students with ASD when learning specific mathematical contents. In this study, we purpose a set of such indicators for the KMT and KFLM identification.

Learning and teaching Arithmetic Word Problem-Solving to Students with ASD

Some of the cognitive features frequently observed in people diagnosed with ASD have a direct impact on their ability to solve word problems (Bae et al., 2015). For example, weak executive functioning can lead to difficulties in following the consecutive steps needed to solve a problem. Some aspects of language comprehension, such as literalness or understanding of mathematical words, as well as a strong visual processing or a different auditory style, can condition the meaning that students with ASD attribute to the problem statements. Language comprehension may also affect the identification of the arithmetic operations required to solve the problem. A positive correlation has also been observed between theory of mind –the ability to make inferences about other's mental state– and the strategies used in arithmetic problem-solving by students with ASD (Author et al. 2024); weak central coherence –the ability to bring details together into a whole concept or idea– can generate difficulties seeing the global comprehension of problem sentences although can also be responsible of strong skills in activities that require focused attention on details (Happé & Booth, 2008).

To take these characteristics into account, research has provided effective methodologies to improve aritmetic problem-solving skills in students with ASD (Gevarter et al. 2016; Root et al., 2021). Among the most effective, we highlight the Schema-Based Instruction (SBI) methodology (Cox & Root, 2020; Kasap & Ergenekon, 2017; Rockwell et al., 2011). SBI combines explicit instruction, heuristics and schematic diagrams adapted to the semantic structure of the problems to provide a visual representation that emphasizes conceptual understanding of increases, decreases, and combinations involving quantities (Jitendra & Krawec, 2021). In addition to exploiting the preference of students with ASD for visual strategies, SBI methodology helps to organise the resolution process. In a recent study, Root et al. (2021) established SBI as an evidence-based practice for students with ASD.

Another methodology of general interest in mathematics learning is the Concrete-Representational-Abstract (CRA) approach, which has been shown to be effective for teaching problem-solving to students with ASD (Yakubova et al., 2016). CRA follows a teaching process that begins by manipulating physical objects to solve problems using informal counting strategies, continues by depicting graphic images to represent the objects in the problem and ends by introducing numbers and symbols of arithmetic operations. CRA implemented by following the steps of explicit instruction ensure the active participation of the student through small and sequential steps, feedback and orientation (Strozier et al. 2015).

Additionally, any of these approaches should be implemented in a suitable environment. The Treatment and Education of Autistic and related Communication-handicapped CHildren (TEACCH) method (Mesibov et al., 2005) focuses on adapting the environment to the characteristics of ASD. In the teaching situations involved in word problem-solving, the disposition of pictogram sequences, checklists, pre-established activity sequences or other adapted materials can help to text comprehension, problem-solving strategies and emotional engagement for students with ASD (Root et al., 2021).

METHOD

This research is conducted as a teaching experiment (Kelly, 2013) framed within the design research paradigm (Collins et al., 2004). This approach is characterized by conducting constructive research, in context, whose findings are used to improve the teaching designs that are subject to observation and evaluation. The process has three phases –design, implementation and retrospective analysis– that can be repeated cyclically.

During the design phase, researchers formulate initial hypotheses about the learning process, establish the objectives of the sessions, develop learning activities, and create data collection instruments. We have designed a unit for future teachers to learn how to teach arithmetic word problem solving (AWPS) to students with ASD. The unit is part of a Mathematics Education course in the Primary Education Degree program at a Spanish university. The unit consists of six sessions of one hour duration (see Table 1). During the implementation phase teacher educators, some of whom are also researchers, focus on enhance preservice knowledge in the subdomains KMT and KFLM of the MTSK model. In the retrospective analysis phase, the results are evaluated to inform the next cycle. This paper presents the findings from the first implemented cycle. The identified areas for improvement will guide the unit's design in subsequent editions of the course.

Participants

A purposive sample was selected, comprising individuals enrolled in a four-year university degree program to become primary teachers, without any prior education related to special educational needs nor teaching practice experience. Eighty-one preservice primary education teachers, enrolled in the second year participated voluntarily during the first semester of the 2021-2022 academic year. Their ages ranged between 18 and 21 years old. Concerning their mathematical background, during the previous academic year they had completed a 60 hour course named Mathematics for Primary School Teachers. This course provides a general overview of the basic mathematical skills required for primary educators, including numerical operations, calculation techniques, geometry, visualization, estimation and measurement.

The unit

The unit designed considers the hypotheses, objectives and learning activities presented in the central column of Table 1. As complementary information, the main content of each session is presented in the right column.

Table 1
Summary of the unit

Sess.	Module	Objectives, activities and learning hypotheses	Contents
1	Introduction	O1: To know the current state of addressing educational needs in curricular areas (math). A1: Lecture delivered by teaching staff. H1: Preservice teachers recognize the necessity of learning specific methodologies to support special needs in maths.	Diversity and mathematics curriculum
	Identification of educational needs in mathematics	O2: To know instruments to diagnose special needs in maths. A2: Lecture Test of Early Mathematics Ability (TEMA-3; Ginsburg & Baroody, 2003) and exercise to identify mathematical age. H2: Preservice teachers recognizes the need to use specific procedures to diagnose diversity in mathematics and learns to use an instrument.	Instruments to identify diversity in mathematics
2	ASD and difficulties in mathematics	O3: To know the particularities of mathematics learning in ASD and to relate them to the cognitive profile. A3: Lecture activity by the teacher by means of examples. H3: The future teacher is aware of learning characteristics of AWPS in ASD and interprets them in relation to the cognitive profile in ASD.	Learning-related characteristics of ASD
3,4	Knowledge of methodologies adapted to ASD	O4: To know methodologies (representation systems, materials,tasks) suitable for teaching AWPS adapted to ASD. A4: Description of TEACCH, CRA and SBI, exemplification in teaching AWPS and effectiveness results. H4: The future teacher knows concrete examples of representation systems, materials, and tasks and argues why they work.	Useful teaching methodologies for teaching mathematical problem solving to students with ASD (SBI, CRA and TEACCH).
5,6	Incorporation of the teaching practice: application of methodologies adapted to ASD	O5: To design detailed teaching sequences for teaching some type of arithmetic word problem to students with ASD. A5: Lecture activity by the teacher by means of a real example, subsequent design of teaching sequence in another mathematical content and another educational need. H5: The preservice teacher knows/proposes/adapts a detailed sequence for teaching a mathematical content.	Proposals for teaching AWPS to students with ASD.

The sessions focused on knowledge development in the KMT and KFLM subdomains. The first two sessions contextualize the way in which educational needs are addressed in mathematics (KMT). They also describe the characteristics of ASD that influence the learning of mathematics (KFLM). Sessions 3 and 4 deal with the selection of appropriate representation systems (KMT), the justification of the didactic material used (KMT), the identification of common errors and their relationship with the characteristics of ASD (KFLM). Sessions 5 and 6 present and focus on designing AWPS teaching activities for learners with ASD (KMT and KFLM).

Data collection instrument

A questionnaire (Figure 1) was designed by four experts in ASD and mathematics education, three of whom were also teacher educators in the course where the study took place. The items were formulated to elicit the KMT and KFLM knowledge that preservice teachers expected to develop upon completing the unit (Table 2). Experts in the MTSK model, together with a comparison with other questionnaires analysing the subdomains of this model for teacher education in mathematics for students with ASD (Chico et al., 2023) validated these items.

1. a) Write an arithmetic word problem that requires solving the arithmetic operation of subtraction 8-5=3 for a student with ASD.
   b) Indicate which format you would use to pose the problem to the student.
2. What visual scheme would you use to guide a student with ASD in solving the above problem?
3. How would you organize the physical space of the classroom in which a student with ASD will solve an arithmetic word problem?
4. a) Indicate two difficulties that a student with ASD might have in solving the following statement: "Jack has 2 pieces of candy. Lucas has triple the candies that Jack has. How much candy does Lucas have?"
   b) In the previous answer, also indicate which characteristic(s) of ASD do you think may be causing the difficulties you have mentioned.
5. a) What type of method would you use to help a student diagnosed with ASD to solve the problem considering the previous difficulty? Explain in detail how this method would be developed.
   b) In the previous answer, also indicate which characteristic(s) of ASD you are considering in your proposal.
6. What help would you provide to a student with ASD who has distributed 10 pens in 5 cups as shown in the following image?

Figure 1
Questionnaire to identify preservice teachers' KMT and KFLM knowledge

Items 1 to 3 focused in the KMT subdomain, examining how teaching is conditioned by the nature of the mathematical content and the characteristics of students with ASD. These items emphasized the use of appropriate representation systems for teaching AWPS to students with ASD (1 and 2) and task design and materials (1 and 3). Items 4 to 6 addressed KFLM, examining teacher-student (item 4) and student-content relationships (5 and 6), with a focus on identifying student errors and difficulties, which reflect teachers' awareness of ASD learning characteristics. Responses were expected to justify instructional decisions in terms of ASD learning traits (items 4b and 5b).

Data Coding

The questionnaire was completed independently and anonymously by every participant.

To code the responses, we linked the KMT and KFLM categories and subcategories to each questionnaire item, adapting the definitions of the selected subcategories to ASD and AWPS contexts (see Table 2).

Table 2
Categories and subcategories of KMT and KFLM associated to questionnaire items

Subdomain	Category	Subcategory adapted to ASD and AWPS	Ítem
KMT	Representation systems	**R1.** Choose an appropriate representation system for AWPS, for students with ASD.	1b, 2
		R2. Know multiple representation systems adapted to ASD.	1b, 2
		R3. Use fixed sequences to structure the steps in solving a problem.	2
	Mathematical tasks	**T1.** Propose task statements adapted to the characteristics of ASD.	1
		T2. Explicitly justify task design or use of material in relation to cognitive features of ASD.	1, 3
		T3. Use specific methodologies appropriate for teaching-learning in ASD.	1, 2, 3
	Materials and resources	**M1.** Use teaching materials and resources appropriate for ASD.	1, 2, 3
		M2. Use measures for time and space allocation appropriate for ASD.	1, 2, 3
KFLM	Errors and difficulties associated with learning	**E1.** Know the most common errors typical of ASD.	4a
		E2. Attribute errors to characteristics of ASD.	4b, 5b
		E3. Present ASD-adapted explanations for students when they have difficulties.	5a, 6

Then, based on the expected responses to the questionnaire, we defined a first set of indicators for each subcategory. As coding progressed, the participants' responses provided additional insights, allowing us to expand and refine the initial set of indicators beyond those originally anticipated by the researchers.

The categories, subcategories and final set of indicators used in for coding are outlined in the next section. Researchers independently indexed the responses with these codes and collaborated to resolve any doubts or discrepancies. To ensure internal validity, an additional evaluator independently recoded the responses of a randomly selected one-third of the participants. Inter-rater agreement was calculated by dividing the number of agreements by the total number of coding decisions and multiplying the result by 100. The inter-rater agreement was 100%, 96%, 93%, 96%, 89%, 93%, 93%, 93%, 100%, 94%, and 92% for R1, R2, R3, T1, T2, T3, M1, M2, E1, E2, and E3, respectively.

Categories, subcategories and indicators for characterizing KMT and KFLM knowledge in ASD and AWPS

1. Representation Systems: knowledge of different representation systems for teaching.

R1: To choose appropriate representation system for teaching AWPS to students with ASD. This type of knowledge is identified in an answer if the future teacher:

- R1.1: Uses a concrete representation.
- R1.2: Uses pictorial representation.
- R1.3: Uses a symbolic representation using a visual scheme, e.g., following the SBI methodology.
- R1.4: Uses a manipulative representation.
- R1.5: Uses a representation through keywords and synonyms to express quantities and actions in AWPS.

R2: To know multiple representation systems for teaching-learning arithmetic word problems to students with ASD. Future teacher shows this knowledge if he/she:

- R2.1: Uses or mentions of more than one representation system suitable for teaching AWPS (diagrams, pictograms, etc.).

R3: To use fixed sequences to structure the steps in the AWPS process, considering the potential weaknesses in executive function characteristic of ASD students. The future teacher shows this knowledge when:

- R3.1: Proposes the use of pictogram sequences that indicate the steps to complete a task, considering the potential low executive functions of students with ASD.
- R3.2: Knows how to develop a work system that enables autonomous work through fixed sequences of activities (e.g., checklists).

2. Mathematical tasks: knowledge that the teacher puts into practice when designing the tasks proposed to the students.

T1: To propose task statements adapted to the characteristics of students with ASD.

- T1.1: The teacher formulates a simple and coherent verbal statement for an arithmetic word problem, avoiding superfluous elements or logical-semantic conflicts.

T2: To justify the design of the tasks proposed or the didactic material chosen in relation to cognitive features commonly found in students with ASD. It is checked if at least one argument is found reflecting at least one of the following associations:

- T2.1: Use of pictograms, schemas, or concrete material in relation to different styles of auditory and frequent strong visual processing.
- T2.2: Use of diagrams, pictograms, manipulative material or different synonyms in the problem statement in relation to understanding texts difficulties.
- T2.3: Aspects of task design to compensate potential weaknesses in executive functions.
- T2.4: Aspects of task design concerning possible weak central coherence.
- T2.5: Aspects of task design concerning potential low theory of mind.

T3: To use specific methodologies for the teaching and learning of AWPS to students with ASD. The aim is to verify that the teacher is aware of, and considers in the task design, at least one of the following specific methodologies shown during the unit:

- T3.1: The concrete-representational-abstract sequence (CRA).
- T3.2: Schema-based instruction (SBI).

3. Materials and resources: knowledge related to the choice of materials and resources used in the classroom.

M1: To use didactic materials and resources adapted to teach AWPS to students with ASD. When designing arithmetic word problem sentences or problem-solving teaching sequences, future teachers mention at least one of the following elements:

- M1.1: Pictograms and drawings.
- M1.2: Heuristics, checklists and anticipation panels.
- M1.3: Manipulative materials.
- M1.4: A prior demonstration of problem solving by the teacher.
- M1.5: Use of storytelling or contexts of interest.

M2: To propose actions to ensure an appropriate distribution of time and space in the classroom for students with ASD. It is checked whether the future teacher proposes at least one of the following actions:

- M2.1: Presence of few elements so as to avoid distraction and visual barriers.
- M2.2: Use of specific areas for different tasks.
- M2.3: Use of organizers, calendars and schedules, as well as anticipating activity changes.
- M2.4: Careful arrangement or classification of materials.

4. Errors and difficulties: knowledge about common errors and difficulties of students.

E1. To know the most common errors and difficulties that a future teacher must consider when teaching AWPS to students with ASD. Future teachers show this type of knowledge when mentioning any of the following errors or difficulties:

- E1.1: Difficulty in understanding the arithmetic word problem statement.
- E1.2: Difficulties in understanding key words, such as “triple”.
- E1.3: Difficulty in identifying the arithmetic operation to be performed.
- E1.4: Difficulty in performing the arithmetic operation.
- E1.5: Error in interpreting the numerical answer in the context of the problem.
- E1.6: Difficulty in planning and executing the complete problem-solving process.
- E1.7: Difficulty in using symbolic representations of numbers or operations.

E2. To explain the causes of common errors and difficulties in terms of the cognitive features of ASD. Future teachers show this type of knowledge when they mention:

- E2.1: Theory of mind to explain at least one of the following difficulties: imagining/understanding what is happening in the scene, comprehension of unknown words and mathematical vocabulary, use of numerical symbols.
- E2.2: Executive functions to explain at least one of the following difficulties: planning the steps needed to solve a problem, performing calculations or operations.
- E2.3: Weak central coherence to explain the difficulty of global comprehension of problem sentences.
- E2.4: Different auditory and strong visual processing to justify at least one of the following: dominant use of visuospatial strategies; slow processing of auditory or linguistic information.
- E2.5: Other criteria associated with potential features of students with ASD, such as having a limited repertoire of interests or adherence to routines.

E3. To present explanations adapted to ASD features when errors or difficulties occur. The future teachers show this type of knowledge when they indicate that they will use any of the following methods in their explanations to students when solving a problem:

- E3.1: Use of SBI strategy or schemas.
- E3.2: Use of pictograms.
- E3.3: Use of checklist.
- E3.4: Contextualize the problem in student's repertoire of interests.
- E3.5: Rephrase the problem statement using simpler (non-mathematical) words.
- E3.6: Use the TEACCH approach or other requirements related to the teaching environment.
- E3.7: Use of visual representations or manipulative materials, with mention of CRA.
- E3.8: Explanation of the meaning of one-to-one sharing.
- E3.9: Explanation of the meaning of equal-groups distribution.

FINDINGS AND DISCUSION

We report the results by showing the number or percentages of participants in whose responses the expected KMT and KFLM indicators were found.

we find that in the *Representation systems* most of the participants chose representation systems adapted for teaching AWPS to students with ASD (R1). The distribution of indicators presented in Figure 2a shows that 75.3% (61 of 81) of the participants chose the use of a symbolic representation (R1.3), which is the expected result considering the importance given to the SBI methodology during the unit. They also mentioned other representation systems that were presented during the instruction: 27.1% used the concrete representation (R1.1), 16% the pictorial representation (R1.2), and 16% the manipulative representation (R1.4). It is worth noting that only 3 participants proposed the use of key words and synonyms (R1.5), despite the reading comprehension difficulties that students with ASD may have. In subcategory R2, *knowledge of multiple representation systems*, only 28.4% showed knowledge of more than one ASD-adapted representation system (R2.1). The R3 indicators show that few participants proposed the use of fixed sequences to structure the steps for solving a problem. Only 2.5% (2 participants, R3.1) considered the use of a sequence of pictograms to indicate the steps needed to complete a task, and 1.2% (only one participant, R3.2) proposed using a checklist to promote autonomous work. Although the unit included instruction on the potential low executive functions, the results show that most participants either did not recall or did not see the need to address this condition explicitly.

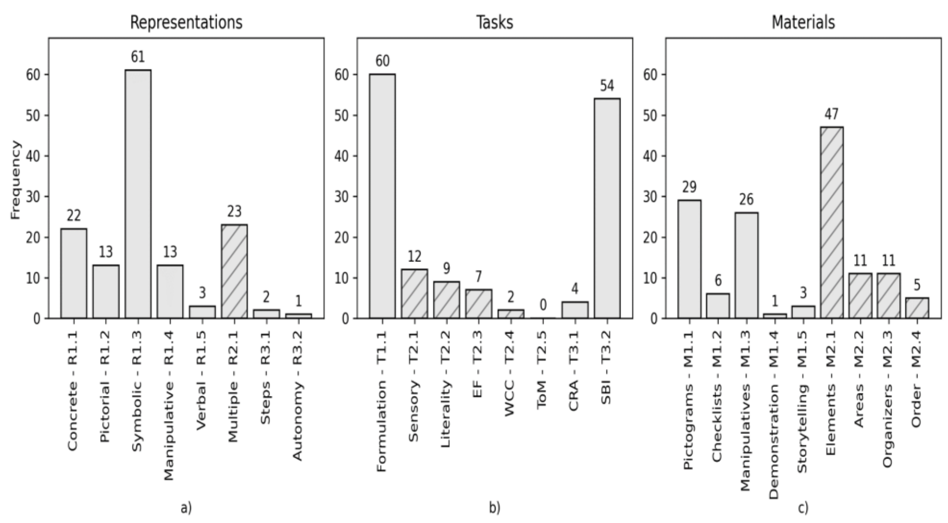

Figure 2
Numbers of teachers that expressed the indicators of the KMT domain

The distribution of indicators presented in Figure 2b shows that, in the KMT category *Tasks,* 74% of the participants wrote a simple and coherent statement for the task proposed in item 1 (T1.1). However, only 25.9% of them explicitly justified their task design by referring to specific features of ASD (T2 in Figure 4). The most recurrent arguments are the different visual and auditory processing in students with ASD (14.8%, T2.1) and the comprehension difficulties in non-literal texts (11.1%, T2.2), followed by potential weaknesses in executive functions (8.6%, T2.3). Only 2 participants evoked the weak central coherence theory to justify task design (2.5%, T1.4) and none mentioned potential low theory of mind (T1.5). The KFLM indicators (E2.1, E2.2, E2.3) reveal that the absence of explicit mention of these cognitive features of ASD by preservice teachers in task design does not necessarily mean they are unaware of them. Rather, it suggests that they have not spontaneously utilized this knowledge in the given context. Notably, unlike items 4 and 5, the items oriented to identify KMT indicators do not explicitly request such justifications. Regarding specific methodologies for designing tasks for students with ASD, 66.7% of preservice teachers cited the SBI methodology (T3.2).

Within the questionnaire, SBI emerges as the more intuitive choice for answering KMT items, which makes the low number of participants who employed CRA for task design (4.9%, T3.1) less significant. The KFLM indicators (particularly E3.7) indicate that a larger number of participants are familiar with the CRA methodology, yet they did not utilize it in the KMT items. A relevant result is that 70.4% of the participants mentioned at least one of the two specific teaching methodologies (T3 in Figure 4).

Regarding the KMT category *Materials and resources,* 56.8% of participants mentioned the use of ASD adapted materials to facilitate teaching-learning processes (M1 in Figure 4). 35.8% of them considered the use of pictograms and drawings (M1.1), while 32.1% cited manipulative materials (M1.3) (Figure 2c). However, only 7.4% mentioned heuristics (M1.2), 3.7% contemplated the use of students' repertoires of interest, and only one participant considered a prior demonstration of the resolution of an arithmetic word problem to serve as a model (M1.4). A total of 69.1% considered time and space management in the classroom (M2 in Figure 4). The distribution of indicators in Figure 2c shows us that 58% of participants believed they should accommodate the environment by simplifying decoration and introducing visual supports to avoid distractions (M2.1). A smaller number of participants considered utilizing special environments for certain tasks, or implementing organizers or strategies for anticipating changes in activity (13.6% in both cases; M2.2 and M2.3, respectively). On the other hand, only 6.2% focus on the order and classification of materials in the classroom (M2.4).

In the KFLM subdomain, most participants showed the expected knowledge in the subcategories E1 and E3 within the *Errors and Difficulties* category: 82.7% of them were familiar with the common errors and difficulties of students diagnosed with ASD in learning AWPS and 92.6% adapted explanations for ASD features when students show errors or difficulties (Figure 4). In E2, only 44.4% of participants explained the causes of common errors and difficulties in terms of ASD features. Delving into the details related to common errors and difficulties (E1), we can see in Figure 3 that participants focused on the difficulty of understanding the problem statement (E1.1 and E1.2), and on identifying and executing the arithmetic operations (E1.3 and E1.4), but they ignored other frequent difficulties in students with ASD, such as interpreting the numerical answer (E1.5, absent from all the answers), planning and executing the complete problem-solving process (E1.6; present in only 3.7%) or using symbolic representations of numbers and operations (E1.7, present in one answer, 1.2%).

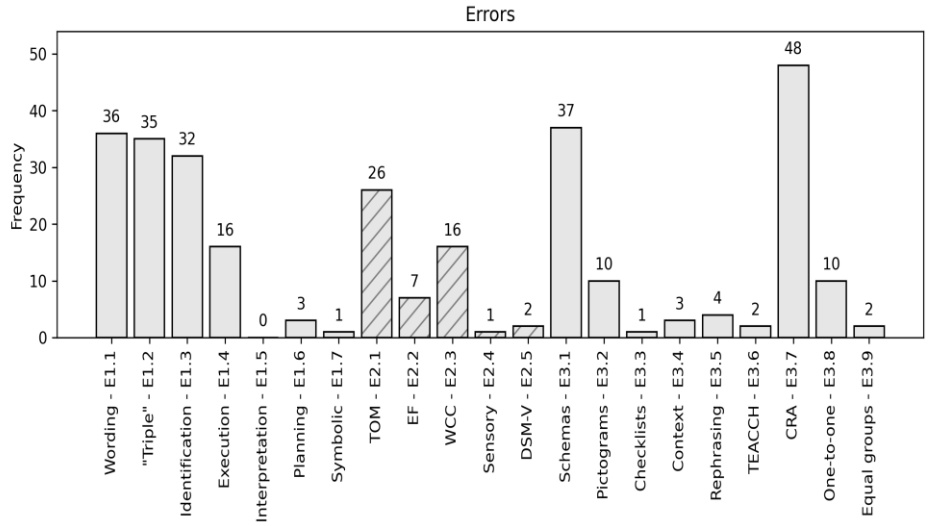

Figure 3
Numbers of teachers that expressed the indicators of the KFLM domain

The explanations participants provided to help students with ASD to overcome errors (E3) are consistent with the errors they mentioned, since they focus on helping students understand the problem statement through visual representations or manipulative materials (CRA; E3.7) and on assisting them in choosing the arithmetic operation using schemas (SBI; E3.1). However, there was little mention of the utilization of checklists (E3.3), the contextualization of the problem in student's repertoire of interests (E3.4) or other techniques related to the teaching environment (E3.5, E3.6, E3.8 and E3.9). In explaining the causes of errors (E2), they mentioned theory of mind (E2.1) and weak central coherence (E2.3), but they practically ignored executive functions (E2.2) and the frequent strong visual processing of students with ASD (E2.4).

Figure 4 summarizes the number of preservice teachers whose responses showed the presence of at least one of the expected indicators. These values help us understand the strengths and weaknesses of the different types of knowledge expressed by the participants.

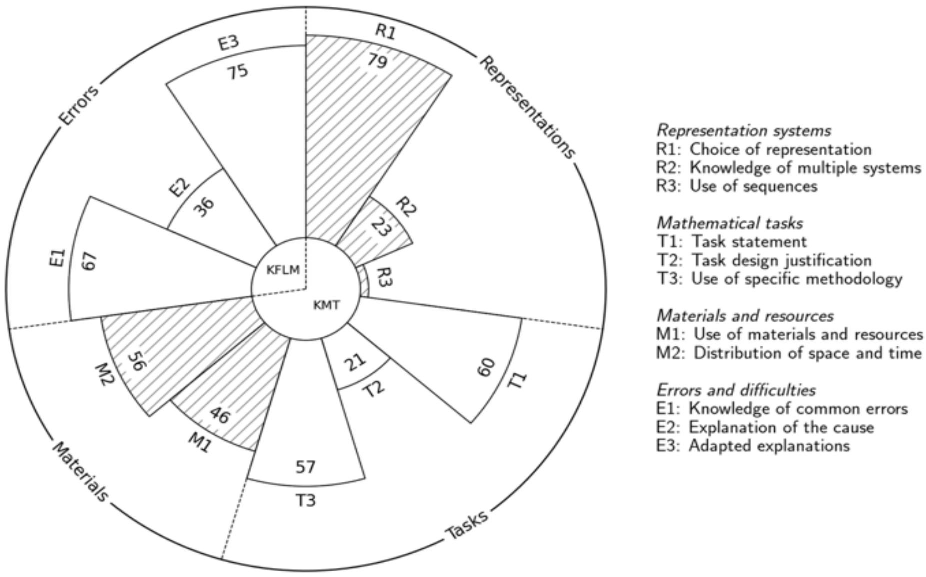

Figure 4
Summary of teachers who expressed at least one of the indicators for each subcategory

We found that a significant majority of participants have shown knowledge related to KFLM, particularly in recognizing errors made by students with ASD and in adapting their aids to align with ASD characteristics. Concerning KMT, most participants have mentioned the appropriate representation systems for teaching AWPS to students with ASD, they took into account ASD characteristics when designing tasks, selecting materials, or choosing methodologies. However, they have not expressed their understanding of the underlying causes of their decisions in relation to ASD learning characteristics and have not explored the resources available to structure the steps in the AWPS process, considering the potential low executive functions frequent in ASD students.

CONCLUSION

The research literature on teacher education for students with autism often overlooks the teaching of mathematical content (Lessner Listiakova & Preece, 2020). The focus is typically on special education teachers in continuous education settings, rather than on preservice teachers' education (Griffin et al., 2014; Scherer 2021). Much of the existing work emphasizes inclusion (Abtahi & Planas, 2024; Marlina et al., 2023; Scherer & Bertram, 2024) or discusses general characteristics of mathematics learning for students with intellectual disabilities (e.g., Allsopp & Haley, 2015; Rosli & Suib, 2020), without deepening in strategies adapted to ASD nor specific mathematical contents.

Our contribution in this study has been to show the potential of a unit in enhancing preservice teachers' specialized knowledge for inclusive mathematics education, particularly focused in teaching arithmetic word problem-solving to students with ASD. This approach aligns with broader research advocating for the integration of academic research on ASD-specific mathematics teaching strategies (Cox & Root, 2020; Jitendra & Krawec, 2021) into inclusive initial teacher education programs (Scherer & Bertram, 2024; Root et al., 2021).

Additionally, we have concretised the MTSK model, by developing indicators to identify teachers' knowledge in the KMT and KFML subdomains. Some studies on teacher education are framed in models of content knowledge and pedagogical content knowledge (e.g., Firestone et al., 2021), but only a limited number have applied the MTSK model in special education or inclusive contexts (e.g., Chico et al., 2023; Piñeiro & Calle, 2023). The MTSK model has proven highly effective in guiding the design of the unit and evaluating their impact, given its emphasis on the interconnected nature of teaching and mathematical thinking, echoing Fung & Wang's (2020) call for deeper methodological integration to teach subject content to diverse students'.Given the brief duration of the instruction of the unit - six-hours-, the results were remarkable. Most of the preservice teachers demonstrated strong awareness of common errors (e.g., text comprehension difficulties) and adapted explanations using visual aids, consistent with studies emphasizing the role of visual processing strengths in ASD (Happé & Booth, 2008; Yakubova et al., 2016). Yet, their limited attribution of errors to executive function challenges or weak central coherence reflects gaps in linking instructional decisions to ASD cognitive profiles, a concern raised by Gómez-Marí et al. (2021). This aligns with broader critiques of teacher preparation programs that prioritize general ASD knowledge over subject-specific adaptations (Sanz-Cervera et al., 2017).

The study's design, grounded in design research (Collins et al., 2004), offers a replicable framework for iterative improvements, such as emphasizing structured sequences to address executive function challenges, as proposed in TEACCH (Mesibov et al., 2005). Future iterations could strengthen preservice teachers' ability to contextualize problems with students' interests and leverage methodologies like CRA, which showed underutilization despite its proven efficacy (Strozier et al., 2015).In relation to the questionnaire as a data collection instrument, the appearance or absence of certain indicators may have been conditioned by the items' formulation. This is the case, for example, for the relational aspects analysed by KMT subcategory T2, whose items did not ask for justifications on the decisions taken in the task design. Consequently, in the future we will refine the questionnaire by incorporating explicit request for a justification of the task design based on the cognitive characteristics of students with ASD. We also plan to incorporate more data collection methods in the future, including interviewing and observation of practice where possible.As a continuation of this research line, although our research focuses on the impact of teacher education on supporting students with ASD in solving AWPS, we believe that such education also serves to sensitize preservice teachers and to provide them with a first base from which they can address the wider range of diversity and mathematical content that they will encounter in their professional practice, ensuring alignment with the holistic, equity-driven approaches advocated in contemporary literature (Abtahi & Planas, 2024; DeJarnette & Hord, 2025). To further explore this potential, we seek to investigate, through longitudinal studies, how this knowledge manifests and evolves in teaching practice, thus aligning ourselves with studies that suggest the need for teacher education programmes to integrate theoretical frameworks with practical experiences (e.g., Scherer 2021), not only to enhance content or pedagogical teachers' knowledge but also to improve their attitudes and beliefs about diversity.

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