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Students' Linguistic Challenges when Learning Mathematics: Voices of Teachers from Seven Countries

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The teaching and learning of mathematics in linguistically diverse contexts present unique challenges, particularly owing to the specialised language of mathematics, the intersection of everyday and mathematical language, the impact of the language of teaching and the communication aspects of the mathematical language. This study investigates the linguistic challenges faced by students in secondary-school mathematics classrooms, as reported by 22 teachers from seven countries across three continents. Using interview data, we explored the questions: What are some of the linguistic challenges that students encounter when learning the topics of angles/probability/linear equations/proportional reasoning? Can you provide an example of a linguistic challenge one of your students experienced in a lesson, and the strategy you used to support them? In the interviews, teachers provided detailed examples of these challenges and the strategies they used to support students. Through iterative inductive coding, the findings reveal a range of linguistic challenges, including difficulties with mathematical vocabulary, reasoning and topic-specific language demands. Notably, the study highlights how the linguistic challenges that students encounter, as perceived by their teachers, vary across mathematical topics. These findings underscore the importance of integrating linguistic and mathematical support in teaching practices, especially in linguistically diverse settings.

Keywords: *Mathematics learning; teachers' voices; students' linguistic challenges*

Introduction

Further research is needed on school mathematics teaching with students from diverse linguistic backgrounds, particularly those who navigate multiple languages and are from low-income families. While these students bring valuable linguistic resources to the classroom, they often face systemic challenges related to socioeconomic conditions and educational structures that privilege monolingualism, the academic language of school and the academic language of mathematics (Moschkovich & Zahner, 2018). It is essential to acknowledge that a deficit conceptualisation of these students is controversial, and it has been effectively argued that adopting a resource-based approach to working with these students is the way forward (see e.g. Bailey & Wilkinson, 2022; Grapin & Llosa, 2024; Planas, 2018). Within this resource conceptualisation, a project was launched in 2022 to explore the challenges encountered by linguistically diverse students in secondary mathematics education and to support and develop mathematics teachers' professional knowledge. The project brought together an international team of researchers in mathematics education, language education, applied linguistics and psychology. This collaborative research environment facilitated the development of several initiatives (see, e.g. Ingram et al., 2024). In this paper, we present the work of a sub-team from mathematics education, applied linguistics and language education, focusing on teachers' experiences with the linguistic dynamics that students encounter while learning specific mathematical topics. The research question guiding our work is as follows: what are some of the linguistic challenges that secondary-school mathematics teachers report as impacting their students' mathematics learning?

Schleppegrell (2001) highlighted the linguistic challenges that students may encounter as they progress through the school system to produce and communicate academic language that school can regard as acceptable, but also to produce and communicate the language of the subject, which in mathematics includes 'the multi-semiotic formations of mathematics, its dense noun phrases that participate in relational processes, and the precise meanings of conjunctions and implicit logical relationships that link elements in mathematics discourse' (Schleppegrell, 2007: 139). Long before this, in work on the registers of schooling, Halliday (1978) described the linguistic demands of the specialised language of mathematics as a process of producing and communicating what he named the mathematics register, that is, 'a set of meanings that is appropriate to a particular function of language, together with the words and structures which express these meanings' (p. 178) for mathematical purposes. This relationship between language use and mathematical meaning can be especially complex for students whose social languages, forms and structures—i.e. those characteristic of their communities, families and other social groups—differ from the academic language of school (Cooper & Dunne, 2000). These challenges can be more pronounced for students whose home languages are not a school language of teaching (Adler, 2001), as seen in many country contexts where the teachers in our study work.

We examine the linguistic challenges of mathematics learning through the perspectives of mathematics teachers from seven country regions across three continents: Malawi and South Africa in Africa, India in Asia, and Catalonia, England, Germany and Norway in Europe. Our data sources are topic-specific interviews with teachers, in which we asked: what are some of the linguistic challenges that students encounter when learning the topic of angles/probability/linear equations/proportional reasoning? Could you give an example of a linguistic challenge that one of your students experienced during a lesson on this topic and the strategy you used to support them? These questions are vital because, in mathematics classrooms worldwide, students encounter the complexities of the specialised mathematical language, and the demands of the specific mathematical topics, alongside their varied social and home languages (Essien, 2024; Schleppegrell, 2007). These linguistic complexities can differ across mathematical topics, making it essential to consider these diverse student experiences and to learn from teachers how these experiences shape classroom practices and teaching. Drawing from the insights provided by teachers in the interviews, we take a sociocultural lens that views language as mediational in mathematics teaching and learning (Morgan, 2021), and mathematics learning as situated in social and cultural contexts of communication and practice (Hunter, 2016; Takeuchi, 2015).

Dimensions of Linguistic Challenges in Mathematics Education

Research into language and communication in mathematics teaching and learning reveals several overlapping dimensions that are crucial for understanding and addressing the notion of linguistic challenge, from the view of the learning experiences of the students. We use the term linguistic challenges to refer to the experiences in which students are faced with some demanding use of aspects of language through which the mathematics to be learned is produced and communicated. These challenges can impact students' opportunities to engage with mathematical reasoning and understand mathematical concepts. Chan (2015), Pimm (1987) and Schleppegrell (2007), taking a linguistic view in their examinations of mathematics education, highlight the intricacies of the specialised language of mathematics, including complex symbolic notation, graphical representations, distinct grammatical patterns and several other challenging situations at the level of discourse and teaching pedagogies, which can be substantial barriers to comprehension. In our wider study (see, e.g. Ingram et al., 2024), the consideration of these and other works on mathematics education and language led us to identify four intersecting dimensions. We use them as a framework for examining the linguistic challenges described by the teachers as experienced by their students in the rest of this paper. The four dimensions of our framework are: (1) the specialised language of mathematics; (2) the intersection of the specialised language of mathematics and everyday language; (3) the impact of the language of teaching; and (4) the communication aspects of the specialised language of mathematics.

The Specialised Language of Mathematics

The framework dimension that we call specialised language of mathematics refers to the mathematics register (Halliday, 1978), and it focuses on challenges around understanding and using mathematical vocabulary, phrases, syntax and symbolic notation in the particular social practice of school mathematics. Making this register or specialised language accessible to students is essential for creating learning environments where they can leverage their cognitive and linguistic abilities effectively (Wilkinson, 2018). However, understanding and using the mathematics register can be challenging, particularly for students learning in a second language (Kazima, 2007; Otuma et al., 2022), those with limited prior mathematical knowledge (Leyva & Joseph, 2023) or those less familiar with academic language (Civil & Hunter, 2015). For example, Otuma et al. (2022) found that Kenyan students struggled to understand mathematical terms and phrases, often defaulting to their general meanings. Similarly, Kazima (2007) reported that Malawian students faced difficulties interpreting probability vocabulary and phrases, with their explanations often diverging from the intended mathematical meanings in the classroom.

In the research literature on mathematics education, language and communication, the issue of the specialised vocabulary and the dense noun phrases has been documented extensively. Terms such as 'likely' and 'certain' (Kazima, 2007: 171), and phrases such as 'area under a curve' (Wilkinson, 2018: 169), carry specialised meanings in mathematics that may differ greatly from their everyday interpretations, highlighting the need for dedicated teaching strategies (Erath et al., 2021). Grammar-focused studies further reveal the challenges of complex grammatical structures. Morgan (2021) shows how passive constructions in mathematical texts can obscure agents and actions, making it harder for students to follow mathematical arguments. Not less demanding is the understanding and use of symbolic notation in school mathematics, where for example the equals sign can differently bring the meaning of computational result, relational identity, substitution or assignment of a rule to a function (Jones & Pratt, 2012). All these complexities underscore the need for scaffolding instruction to support students' language development in mathematics.

The Intersection of the Specialised Language of Mathematics and Everyday Language

The second dimension of our framework refers to challenges associated with the intersection of the specialised language of mathematics and everyday language. This dimension in turn intersects with the first dimension, because the mathematical vocabulary, phrases, syntax and symbolic notation includes linguistic elements that are exclusively mathematical, but also linguistic elements that are part of the everyday language and produced as specialised within the mathematics register. Mathematical understanding requires students to move fluidly between everyday language and the mathematics register, where common terms can take on precise meanings. For example, Conner et al. (2014) demonstrate how Grade 9 students learning about regular polygons needed to reconcile the everyday meaning of 'regular' with its mathematical definition ('all sides congruent, all angles congruent', p. 406). Moschkovich (2010) further emphasises that mathematical thinking is deeply intertwined with language, as students navigate between their everyday language and the specialised language of mathematics. Her work shows how multilingual students use their linguistic resources to interpret mathematical concepts, underscoring the need for pedagogies that integrate and support students' existing linguistic and everyday knowledge.

Studies in mathematics education suggest that moving across the specialised language of mathematics and everyday language requires a holistic approach to teaching. Erath (2018) advocates for classroom environments where students can actively participate in mathematics through their own linguistic resources. This approach not only supports linguistic and mathematical understanding but also fosters meaningful engagement. Pedagogies like using everyday contexts as a means to model mathematical concepts and reasoning, alongside switching languages in multilingual settings, have proven effective in enhancing student engagement and understanding in mathematics (Planas & Civil, 2009). In South African classrooms, Nkambule (2016) observed that connecting mathematical problems, situated in everyday contexts, to students' personal experiences through their home languages helped make mathematical ideas more accessible and relatable. The ambiguities raised by some linguistic elements being used in either a mathematical or an everyday sense remain nonetheless an issue in mathematics classrooms (Moschkovich, 2002).

The Impact of the Language of Teaching

The first and second dimensions of our framework are specific to the mathematics register, what it involves and how it is learned by students in situated contexts of everyday language. The third dimension refers to challenges more directly associated with the impact of the language of teaching on the students' learning. This impact has been studied in the language education literature, with evidence of how the language of teaching plays a crucial role in shaping students' learning experiences, especially in multilingual contexts. Research in content and language integrated learning (Rose & McKinley, 2024) highlights both the opportunities and challenges that arise from instruction in a second language. Our understanding of the language of teaching, however, goes beyond the identification of the linguistic system in which the teaching develops (e.g. English), to include the moves between the specialised language of mathematics and everyday language in teaching. Although Cummins' (2000) seminal notions of Basic Interpersonal Communicative Skills (BICS) and Cognitive Academic Language Proficiency (CALP) are more generally linked with a conceptualisation of language proficiency, in our study BICS can be seen as related to everyday language proficiency and CALP as related to the proficiency modelled by the teacher in teaching for the students to understand and use the specialised language of mathematics.

In the mathematics education literature, more than two decades ago, Adler (1998, 2001) characterised dilemmas of the language of teaching. She particularly discussed the dilemma of code-switching in multilingual mathematics teaching, and the dilemma of mediation in reference to meaning mediation and modelling the specialised language of mathematics. The ways in which the specialised language of mathematics is modelled, possibly alongside practices of code-switching or switching languages, in teaching have an impact on the students' learning. Tai and Li's (2021) study in Hong Kong, for instance, illustrates the complexities of English-medium mathematics instruction, where translation challenges impacted the understanding of terms like 'slope'. Their work reflects Cummins' (2000) distinction between BICS and CALP, explaining why students might perform well in everyday conversations but struggle with academic language demands. This BICS and CALP distinction suggests the need for policies and practices that foster students' academic language development, as also discussed by Tshabalala and Clarkson (2016), who identify the additional challenges faced by students learning mathematics in a second or third language.

The Communication Aspects of the Specialised Language of Mathematics

Linguistic challenges in mathematics education cannot be separated from the idea of communication (Chan, 2015; Planas & Pimm, 2024) and the challenges associated with any demanding use of linguistic and non-linguistic modes for producing and sharing mathematics understanding. The fourth dimension of our framework thus considers linguistic challenges associated with the understanding and use of non-linguistic modes of communication in interaction with or in place of the specialised language of mathematics. Different authors emphasise differently this relationship between linguistic and non-linguistic communication in mathematics, with some authors for example outlining the semiotics of multimodality (e.g. O'Halloran, 2015; Radford, 2014), and some others outlining the discursive nature of language and multimodality (e.g. Alshwaikh, 2016; Sfard, 2008). Radford (2014) explores how linguistic and semiotic resources shape mathematical thinking, showing that students' understanding is influenced by their broader sociocultural contexts and the artefacts in these contexts including the students' own body and gestures. Sfard (2008) highlights how mathematical practices, and ways of speaking and reasoning mathematically, are shaped by word use that is often subsumed under non-linguistic modes of communication with visual mediators such as graphs and diagrams.

Duval (2017) adds to this by discussing visual representations, such as pie charts, number lines or figures and shapes in the teaching of fractions, noting that these representations require types of cognitive processing distinct from verbal thinking. Understanding and working with these representations demand that students separate the visual from the mathematical meaning embedded. This challenge is often overlooked in teaching that does not explicitly address the explanation and discussion of artefacts such as diagrams and the labels and symbols used to convey some specialised meaning in mathematics regarding related points, line intersections, angle equivalences or coordinates (Alshwaikh, 2016). These insights advocate for teaching approaches that value students' linguistic and non-linguistic resources and modes of communication, which address the varied cognitive, linguistic and communication demands of learning mathematics. In this respect, the impact of the language of teaching can also be examined from the perspective of how this language builds on, supports and connects with non-linguistic elements in classroom interactions with students.

Methods

This study investigates the linguistic challenges reported by secondary-school mathematics teachers in diverse linguistic contexts, with a focus on understanding how these challenges impact students' mathematics learning. By adopting a qualitative, cross-country design, our study employed semi-structured interviews to gather detailed, context-specific insights alongside content insights enacted by the consideration of four mathematical topics present in the secondary-school curricula of the teachers' countries. The study is part of a broader project exploring mathematics teaching practices in linguistically diverse classrooms, designed to combine elements of both mathematical content and country-and-classroom context specificity (Ingram et al., 2024). The methodological design ensured cross-contextual comparability while capturing the unique linguistic dynamics of each setting. The steps taken to ensure rigour and reliability in data collection, coding and further analysis are detailed below.

Participant Recruitment and Sampling

Participants comprised 22 mathematics teachers recruited from seven countries: Catalonia, England, Germany, India, Malawi, Norway and South Africa—three in each country except for four in South Africa. The overrepresentation of Europe in the data is due to the origins of the broader project, whose planning was initiated as a result of regular collaboration in a European conference working group on mathematics and language. The conditions of the funding obtained allowed us to expand the initial planning so as to include, in a second phase of planning, non-European countries in Asia and Africa. The selection of India, Malawi and South Africa was based on former research collaborations with mathematics education teams established therein. In all the countries, the teacher participants were purposively sampled based on their extensive experience working with students facing linguistic and educational disadvantages for a variety of reasons, with a minimum of 7 years of teaching secondary-school mathematics in such contexts. Additionally, recruitment efforts considered teachers' reputations within their schools or districts for addressing the linguistic and educational needs of their students, although specific measures of effectiveness (e.g. student outcomes or peer evaluations) were not formally documented. Priority was given to teachers who demonstrated a clear commitment to supporting linguistically diverse students, as evidenced through recommendations from school administrators or participation in professional development programmes focused on inclusion and equity in education. We thus looked for the participation of teachers with awareness of the learning potentialities of the students and of the challenges inherent in the mathematics and in the way that mathematics is taught.

Data Collection

Data were collected through semi-structured individual interviews, with each teacher participating in up to four 40 minute interviews, one per mathematical topic (linear equations, proportional reasoning, probability and angles). Teachers were asked questions in their language of choice, defined here as the language they felt most comfortable using during the interview. This often aligned with either the language of teaching or a widely spoken local or heritage language. The languages used included Catalan, English, German, Hindi and Norwegian, all of which were shared by at least one member of the research team. Since interview topics were specific to the identified mathematical areas, where a teacher lacked teaching experience with a topic, they were excluded from the corresponding interview, resulting in a total of 79 interviews—20 on each topic except for probability, with 19. For the interviews, two core questions guided data collection for this paper: (1) what are some of the linguistic challenges that students encounter when learning the topic of angles/probability/linear equations/proportional reasoning; and (2) can you provide an example of a linguistic challenge one of your students experienced in a lesson, and the strategy you used to support them?

The interviews were online because of the physical distance between the geographical locations of the teachers and the researchers, and verbal consent was always asked before audio-recording. All interviews were transcribed, and the teachers' responses were afterwards summarised in English using a structured proforma for all the team researchers to have access. Extracts referencing specific linguistic challenges were transcribed verbatim and translated into English to facilitate analysis by the multilingual research team. Translation of materials was handled collaboratively, with multilingual team members ensuring linguistic and cultural accuracy. For quality control, translations were cross-checked by a second researcher fluent in both the source and target languages. This process aimed to preserve meaning and ensure comparability across the diverse country contexts studied (Thompson & Dooley, 2020).

Data Analysis and Thematic Coding

The teachers' responses were subjected to inductive thematic coding to identify patterns and themes relating to linguistic challenges. The coding process was iterative and collaborative. All of the paper's authors engaged in the coding process, following a four-step procedure. For the initial open coding, two researchers individually coded data from Catalonia, India and Norway, and then met to discuss the codes and how they applied to interview quotes. The codes and related quotes resulting were then shared with the research team and reviewed in online meetings to ensure clarity and reliability. In discussions among the team, researchers identified overlaps between codes, leading to their organisation into wider codes. Linguistic challenges were grouped into three main types: those related to mathematical vocabulary, to mathematical reasoning and to topic-specificity intersecting with mathematical vocabulary, reasoning and communication. At this point, the refined codebook was applied to data from all countries and teachers. Additional subcodes emerged during this process, which were incorporated into the final coding framework after group discussions. The discussion of the revised codebook, in order to identify redundancies and relationships between subcodes, was the last step. As a result, the three wider codes were confirmed as themes that were common in some of the teachers' responses to the question about the linguistic challenges impacting on students' mathematics learning.

The coding process prioritised qualitative interpretation over frequency counts, drawing on the methodological approach outlined by Auerback and Silverstein (2003). Themes were identified collaboratively, ensuring a holistic and nuanced understanding of the data. To ensure reliability, the coding framework was consistently applied across the dataset by multiple researchers, and any discrepancies were resolved through discussion. Moreover, in the initial open coding, the researchers initially worked independently so as to reduce bias in the coding process and to ensure that the codes induced could be consistently applied by different coders. The iterative nature of coding and the inclusion of multilingual perspectives strengthened the validity of the findings in the form of common themes, where common is taken to imply that the theme serves to interpret responses of at least two teachers in two countries. Although we did not count frequencies, we searched for themes that while remaining specific could be applicable to more than one country context and teacher. During the analysis, the coding and the production of themes were influenced by the four dimensions of the framework shared among the team. Since these dimensions were broad and related to each other, the process developed inductively and reflexively to identify aspects of linguistic challenges that we had not anticipated in the framework. We also came into instances where teachers framed students' linguistic challenges as their own instructional challenges when modelling mathematical reasoning or supporting the specialised language of mathematics with diverse modes of communication. The interviews were nonetheless oriented to investigate the linguistic challenges that the teachers attributed to their students when learning mathematics.

Findings

Our analysis of the teachers' interview responses revealed three major themes regarding the linguistic challenges faced by secondary-school students in mathematics learning: challenges related to mathematical vocabulary, to mathematical reasoning, and to topic-specific linguistic challenges. These themes align in several ways with one or more dimensions outlined in our framework. For example, the linguistic challenges related to mathematical vocabulary and reasoning include challenges regarding the use of the specialised language of mathematics alongside everyday language and diverse modes of communication in mathematics. As we summarise below, the linguistic challenges with mathematical vocabulary and reasoning, attributed to students by the teachers, are findings consistent with the research literature, hence not particularly novel.

Like in Kazima (2007) and Otuma et al. (2022), mathematical vocabulary is in focus and present in most of the interviews. Teachers across countries highlighted that their students encountered difficulties related to mathematical vocabulary. The challenges were not merely about unfamiliar terms but about the specialised meaning of words within the mathematics register. Teachers noted how students could understand mathematical concepts but struggled to align those concepts with the correct vocabulary or to adapt meanings of everyday words to their mathematical contexts. A teacher from England emphasised how students often needed to expand their understanding of everyday words, such as 'event' and 'outcome', to fit the mathematical register. In South Africa, a teacher noted the difficulty around an everyday scenario expressed in English into students' home language when explaining terms like 'inverse' in 'additive inverse' or 'multiplicative inverse'. This teacher argued that this contributed to making translation from oral/written to symbolic mathematics challenging for students. The challenge extended beyond learning new terms to recontextualising known words with new, discipline-specific meanings. A teacher in Norway explained how students worked with 'blunt' and 'pointy' to describe angles, reflecting translations from their everyday Norwegian language rather than the specialised English terms 'obtuse' and 'acute'. While students could differentiate the concepts, they struggled to use the terminology. This teacher commented:

> The words like blunt and pointy. Which is which? Like they understand the difference—they understand the concept of a blunt or a pointy angle—but they struggle with putting the right words to the right concept. The most important thing is that they understand what it means or understanding of the mathematical concept. They don't necessarily need the right word for it … But still, it's useful to know those words because if somebody asks, it's nice that they know what they're being asked.

Our data regarding mathematical reasoning also provide confirmation rather than new contributions to existing literature. Teachers across countries referred to linguistic challenges associated with mathematical reasoning, where students must navigate among words, symbols, diagrams and the linguistic communication of mathematical arguments. Like in Erath (2018) and Moschkovich (2010), the challenges were often compounded by students' struggles to articulate their reasoning or integrate various semiotic resources into coherent explanations. For example, a teacher from South Africa described how the word 'slope' in students' home languages implied movement or incline, conflicting with the mathematical concept of 'gradient' as an invariant, and how this led to difficulties in understanding and reasoning about linear functions in multilingual classrooms with issues of language switching and translation. The language of instruction was thus seen as significantly shaping students' experiences of linguistic challenges in multilingual classrooms. A teacher from Catalonia built on Thales' theorem to indicate the complexity of reasoning across words, symbols and annotated diagrams. While diagrams often assume mathematical properties, such as parallelism, students might not understand how these assumptions are conveyed or why they are relevant to the reasoning. This teacher commented:

> The famous sentence of given two lines, and then the capital letters combined in pairs such as AB and CD, and two segment lines drew as parallel when the wording does not mention parallelism … because of course the fact of parallelism will happen if AB and CD accomplish this and that, but parallelism is already taken as shared in the diagram that goes with the wording. The wording and the diagram together are a mess for most learners. The diagrams in the materials already represent parallelism and congruent triangles and angles as given, when the wording is just posing the conditions for these facts to happen.

The third theme—linguistic challenges specific to mathematical topics—represents the primary contribution of this study, offering new insights into the nuanced, topic-specific ways in which language influences mathematics learning, as seen by teachers. In the subsection below, we present and discuss this finding, providing teacher quotes across country contexts. The description of linguistic challenges specific to mathematical topics focused not only on the topic but also on how the challenges associated with specific topics, as interpreted by the teachers, were comparable among them.

Linguistic Challenges Specific to Mathematical Topics

While the examples above reveal valuable insights into linguistic challenges with mathematical vocabulary and in mathematical reasoning, they primarily reflect topic-general issues. The most substantial contribution of our study lies in how topic-specific challenges emerge across interviews and countries. The topics of angles, probability, linear equations and proportional reasoning were selected because of their centrality to secondary-school mathematics curricula, but also because they represent a range of mathematical content areas where language plays a critical role. We had not anticipated, however, the importance that the teachers across countries would give to topic specificity in their considerations about their students' linguistic challenges. Teachers noted that linguistic challenges varied significantly across topics, each presenting unique challenges that extended beyond general issues of mathematical vocabulary and reasoning. By highlighting these topic-specific linguistic challenges, our study extends the research literature on language and communication in mathematics education.

Specific mathematical topics have indeed been addressed in relation to language, communication, teaching and learning in the research literature, but there is a dearth of literature on how these topics are comparable with each other in terms of students' linguistic challenges. Several teachers suggested a notion of topic specificity by comparing the linguistic challenges in one of the mathematical topics with those that they had mentioned in relation to the mathematical topics in focus in some of their former interviews. These teachers talked about linguistic challenges in probability learning, for example, by also posing these challenges in relation to those specific for angles learning or for proportional reasoning. Thus, our finding regarding topic specificity refers to both the detail involved in describing the linguistic challenges for a mathematical topic and the relationship suggested between these challenges and those outlined for a different mathematical topic. The emergence of this notion of topic specificity from our data shows that, to make sense of the students' linguistic challenges associated with the learning of a mathematical topic, some teachers need to situate these challenges in relation to challenges associated with the learning of another topic.

The teacher from Catalonia who talked about the challenges of mathematical reasoning in Thales' theorem, during the interview on angles, is an example of how linguistic challenges and topic specificity were approached by thinking of a variety of mathematical topics, which were seen as varying in terms of linguistic and communication demands. This teacher was explicit about the specificity of the challenges around multimodal communication in the learning of angles, and how these challenges were different from those associated with proportional reasoning and the interpretation of everyday comparative phrases within word problems. It was highlighted how phrases like 'twice as much sugar' often led to misconceptions, such as interpreting 'twice' as additive rather than multiplicative. The intersection of everyday and mathematical language was a recurring point in the teachers' responses, particularly in relation to proportional reasoning and word problems. Although these challenges were not seen as linguistic only but intertwined with conceptual understanding as students struggled to translate everyday language into mathematical reasoning, issues of non-linguistic communication remained exclusively associated with angles. In thinking about angles, some contrast was also established with probability. The topic of probability was in turn also associated with linguistic challenges, often stemming from the lexical diversity of the mathematics register and conflating mathematical terms with the everyday meanings. This teacher commented:

> Proportional reasoning is not like angles and the diagrams, and the lines, and how you draw everything. There are many difficult phrases for learners like twice as much sugar and, from there, the thinking of adding two instead of multiplying. They got lost with complicated phrases … Probability is not like angles either. A learner used the idea of conditional to mean any condition. He was like making the meaning of conditional probability by joining the meaning of condition and the condition of probability.

A teacher from Germany also referred to the idea that students' linguistic challenges varied across mathematical topics, and outlined 'the symbolic sophistication in angles reasoning', compared with probability reasoning, which was regarded as more verbal, less dependent on symbolic notation and 'everyday tricky words'. A teacher from India was explicit about 'how different algebra is', and the related linguistic challenges in students' learning, compared with other mathematical topics. In the interviews, the challenges raised for the topic in focus were explained or exemplified not without insisting on how distinctive they were of that topic: 'very much for algebra', 'these are not angles' or 'linear equations are algebraic, angles are not'. This teacher provided detailed insights into students' challenges with algebraic reasoning, particularly the manipulation of symbols and letters. It was emphasised that students struggled not only with understanding the role of symbolic notation like x but also with verbalising the processes involved in solving equations. This teacher commented:

> For instance, explaining the transposition of terms in an equation poses significant challenges … They need to understand the movement of what is happening with the letter and the symbols. It's so difficult when they have to verbalise this … When you're seeing a child and you're seeing the expression on their face.

These challenges are a consequence of the different ways that letters and symbols are used in mathematics, with letters such as x representing objects, unknown values and variables in different mathematical contexts (Küchemann, 1978) and symbols such as = having different meanings in different contexts (Jones & Pratt, 2012; Ward-Penny et al., 2026). This idea of the linguistic challenge being in the way mathematics is represented was also introduced by a teacher from Malawi, who discussed challenges related to reading and interpreting diagrams in geometry as specific of this topic learning. This teacher outlined the role of letters and symbols as distinctive in the learning of angles as compared with the learning of algebra and extended this distinctiveness to the related challenges for each topic. In algebra, 'letters are not letters in diagrams', whereas in the learning of angles, the complexity of diagrams requires some letters for labelling and, even so, this complexity often creates disconnects between what is visually represented and what is verbally discussed. This teacher commented:

> You now have two lines parallel and the angles. They need to find the corresponding angle in a diagram. Not easy because I'm picturing. They need to see the transversal line in a complicated diagram … You've

> moved from a simple diagram as an example to a complex diagram different from what you've discussed … The letters in the diagrams … For the lines in complex diagrams.

With cross-country evidence, four mathematical topics in focus and a total of 22 teachers from three continents, our study reinforces the argument put forward by Adler and Essien (2024), regarding the need for topic-specific attention to language in teaching and for strategies that support students' experiences of linguistic challenges that are topic-specific. It thus takes topic specificity a step further than the discipline-specific approaches (e.g. O'Halloran, 2015; Pimm, 1987) and the dilemma-specific approaches (e.g. Adler, 1998, 2001) in the mathematics education literature on language and communication. The fact that the questions and the inputs in the interviews were formulated topic-specifically (e.g. 'when learning the topic of angles'), with one topic in focus per interview, allowed us to listen to the description of both discipline-specific linguistic challenges—primarily aligned with the dimensions of our framework—and topic-specific linguistic challenges—primarily aligned with the classroom experiences reported by the teachers. Some of the above-illustrated quotes of the teachers that represent the cross-country findings around topic specificity and students' linguistic challenges are as follows: 'Linear equations are algebraic', 'Angles [involve] complex diagrams', 'Proportional reasoning [involves] many difficult phrases' and 'Probability [involves] everyday tricky words'.

Discussion and Conclusions

This study explored the linguistic challenges that 22 secondary-school mathematics teachers reported as impacting their students' mathematics learning. The participant teachers were from different countries, cultures and educational systems, and had different language backgrounds, professional characteristics and years of teaching experience. Despite this diversity and the variety of possible understandings of the notion of linguistic challenge, which had not been presented to them as part of the study, they shared common experiences and views of the linguistic challenges that their students encounter when learning the topics of angles, probability, linear equations and proportional reasoning. The study therefore provides findings that transcend the diverse contexts represented by the participant teachers. The experiences and voices of each teacher are indeed unique, and the analyses of the individual interviews raise significant context-dependent and individual differences, but our interest was in what could be learned by examining the data of the 79 interviews together. We were interested in findings that echoed and expanded other country-based studies, and specifically in findings or nuances that were new to research.

Our findings reveal the complex interplay between language, communication and mathematical topics, highlighting how linguistic challenges vary across and are seen as distinctive of mathematical topics. The teachers identified several key challenges documented in the research literature, including those associated with the understanding and use of specialised mathematical vocabulary, and the modelling of mathematical reasoning. Teachers reported that the specialised language of mathematics emerged as a significant barrier for students, with terms like 'conditional probability' misunderstood owing to their divergence from everyday usage. Similarly, the symbolic language of algebra posed challenges, with students finding it difficult to reason without clear verbal explanations. These challenges are not isolated but deeply interconnected, often mediated by students' linguistic and conceptual resources (Moschkovich, 2002, 2010) and the impact of the language of teaching (Adler, 1998, 2001). For example, students' difficulties with proportional reasoning, such as interpreting phrases like 'twice as much', reflect gaps in knowledge of both the mathematical concept of proportionality and its linguistic representation. Similarly, challenges with algebraic reasoning, such as verbalising the movement of terms in equations, underscore the importance of prior exposure to mathematical conventions and terminology.

Importantly, our findings contribute to the growing body of research on mathematics education, language and communication by highlighting the topic-specific nature of linguistic challenges in secondary-school mathematics. By connecting these findings to the four discipline-specific dimensions of linguistic challenges—the specialised language of mathematics, the intersection of the specialised language of mathematics and everyday language, the impact of the language of teaching, and the communication aspects of the specialised language of mathematics—we provide a framework for understanding how language shapes students' experiences of mathematics learning. Future research could explore how specific teaching strategies can mitigate these challenges and examine the role of teachers' own linguistic practices in shaping students' mathematical and mathematically topic-specific understanding. Ultimately, addressing the linguistic demands of mathematics is essential for creating equitable and inclusive teaching environments that support all students' learning.

The findings of this study have several implications for mathematics teaching and research. First, they highlight the importance of addressing linguistic challenges as an integral part of mathematics instruction. Teachers must be equipped to recognise and respond to the linguistic demands of specific topics, such as proportional reasoning, linear equations, probability and angles, and to adapt their pedagogical strategies accordingly. Second, the findings underscore the need for professional development programmes that help mathematics teachers build their capacity to support linguistically diverse students. This includes training in strategies for integrating students' resources into instruction, and for addressing the cognitive, linguistic and sociocultural demands of school mathematics. Finally, this study points to the value of interdisciplinary collaboration between researchers in mathematics education, applied linguistics and language education. Even if many mathematics education researchers endorse collaboration with language experts, it is not commonly undertaken. By integrating insights from these academic fields, educators and researchers can develop more comprehensive approaches to supporting students' linguistic and mathematical progress, including attention to the language needed for reasoning in relation to specific topics.

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