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Primary teacher education: A reflection on language in mathematics education

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Background: South Africa is implementing a mother tongue-based bilingual education strategy. This shift in language policy has significant implications for mathematics teaching and for the preparation of mathematics teachers in initial teacher education (ITE) programmes.

Objectives: The Primary Teacher Education (PrimTEd) knowledge and practice standards articulate the intended core curriculum for all primary teachers graduating from ITE programmes. This article examines the extent to which these standards are aligned with the emerging multilingual policy context.

Method: We analysed the content of the PrimTEd Mathematics Knowledge and Practice Standards', from a 'language(s) in mathematics education' perspective. All instances where language is explicitly referenced or implicitly invoked are identified and categorised. In critically reflecting on the findings, we note what is absent and illustrate how the policy framework could be strengthened.

Results: Three approaches to language(s) are evident: through general pedagogical standards; through standards related to mathematical acting and thinking; and through the specification of knowledge of various problem types. However, the standards remain generic and high level, offering limited guidance for mathematics course design. We make two contributions towards greater specification. Firstly, we propose performance-level descriptors that articulate levels of attainment for language-responsive teaching (using the example of addition and subtraction). Secondly, we provide illustrative examples of 'gap-generating' words and phrases known to contribute to learner confusion in this domain.

Conclusion: We argue for more explicit identification of gap-generating language and research that supports language-responsive teaching within the multilingual context envisaged for South African teacher education.

Contribution: This article clarifies how language and mathematics are conceptualised in the PrimTEd standards and offers illustrations that could be used to inform mathematics course design and programme strengthening.

Keywords: PrimTEd knowledge and practice standards; primary teacher mathematics education; Language in Mathematics Education; mother tongue-based bilingual education; gap-generating words.

Introduction

South Africa has long implemented an education policy under which most learners studied mathematics in either English or Afrikaans rather than in their dominant home languages (or mother tongues). A marked shift to English as the medium of instruction and assessment occurs in Grade 4. Thus, after 4 years of mother-tongue instruction in mathematics (Grade R to Grade 3), learners experience a sudden transition to mathematics being taught entirely in one of the colonial languages. The lack of alignment between the language of instruction and the child's linguistic resources (most likely their mother tongue) has posed numerous challenges to learners' ability to make sense of mathematics.

In 2024, this policy was revised to provide for the envisaged incremental introduction of a Mother Tongue-based Bilingual Education (MTbBE) strategy. This is expected to transform the teaching of mathematics through the adoption of translanguaging practices, teaching and learning support

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materials (LTSM) that present mathematics bilingually, and greater language responsiveness in teaching practices. Much remains to be done to prepare teachers already working in schools, as well as the textbook and LTSM environment, for this envisaged shift. At the same time, attention needs to be given to the preparation of student teachers enrolled in Initial Teacher Education (ITE) programmes. Following evidence of a lack of coherence and consistency in the way mathematics is taught in South African Bachelor of Education and Postgraduate Certificate in Education programmes (Bowie & Reed 2016), the Primary Teacher Education (PrimTEd) community of practice for mathematics embarked on the development of knowledge and practice standards to guide curriculum expectations in ITE programmes (PrimTEd 2022). The development of these standards preceded the shift in language policy towards MTbBE approaches. Nevertheless, language-responsive mathematics teaching was recognised as an important consideration within South Africa's multilingual classroom contexts.

In this article, we examine the PrimTEd mathematics knowledge and practice standards from the perspective of the Language in Mathematics Education (LiME) agenda, as Sfard (2021) has termed it.

Context

We outline the South African language context before turning to evidence of concern relating to the teaching of mathematics in English, with a particular focus on poor performance in word problems expressed in English.

The South African language context for mathematics

In the South African context, the LiME landscape is complex. Since 1997, South Africa has maintained a consistent *Language in Education Policy (LiEP)* which mandates that (Essien & Sapire 2022):

> [*S*]chool governing bodies (SGBs) should decide which of the country's 11 official languages will be used as the language of learning and teaching (LoLT) in the early grades … The LiEP also advocates additive bilingualism (an approach through which learners develop proficiency in a second language while continuing to develop proficiency in their first language). (p. 82)

In practice, the LiEP means that most South African learners in rural contexts learn mathematics in an African language from Grade R to Grade 3. In Grade 4, however, the Language of Learning, Teaching, and Assessment (LoLTA) shifts to English. Concerned about this sudden transition to learning in English, the Department of Basic Education (DBE 2024) introduced a policy shift towards MTbBE. This envisages teachers who are, at a minimum, bilingual and able to switch fluidly between languages when explaining concepts and providing instruction within a lesson. There is also an underlying assumption that teachers will adopt more language-responsive teaching practices and that LTSMs will be available bilingually and/or multilingually. Feza, Ramollo and Chiphambo (2022) have cautioned against simplistic assumptions regarding the introduction of mother tongue instruction, noting that there is often not a single home language shared by all children in a classroom. This has significant implications for the teaching of mathematics in South African primary schools and for the preparation of student teachers for their role as primary school mathematics teachers.

Concerns about teaching mathematics in English, and recurrent difficulties with word problems expressed in English

Evidence suggests that teaching mathematics in English, when most children speak other languages as their mother tongue, is not working effectively. Hoadley (2012) identified poor performance in mathematics, particularly in relation to word problems, as stemming in part from the disjuncture between learners' home language and the language of instruction in the mathematics classroom. It remains unclear whether recurrent difficulties with word problems arise from 'mathematics', 'language', or a combination of both. Almost two decades ago, concerns were raised about whether generally low levels of English reading proficiency, and the need to read mathematics word problems in English, were contributing to poorer performance on word problems than on calculation tasks in mathematics (Ensor et al. 2002; Schollar 2008).

When responses to word problems presented in English (the language of learning and teaching [LoLT]) to Grade 9 learners in township schools in Grahamstown were compared with responses to the same problems expressed in isiXhosa (their home language), computation errors appeared to stem from an inability to use either language effectively to solve problems situated in realistic contexts. Sepeng (2014:22) suggests that learners should be encouraged to 'use their everyday knowledge and personal life experiences when making sense of word problems', thereby facilitating 'a bond between learners' (informal) spoken language and formal (classroom) written mathematical language'. From this perspective, learners' home language and English play complementary roles in supporting learners to make sense of and solve word problems.

Theoretical framework

It is important to make explicit our theory of what mathematics is and how it relates to language, as this informs our content analysis of the PrimTEd mathematics standards. In reflecting on language-responsive teaching, we draw on Sfard's articulation of the LiME research agenda. Working from the premise that mathematics is a human activity rather than an abstract structure, Sfard (2021) counters a dualist conceptualisation of language in mathematics with a 'discursive conceptualization' in which:

> [*T*]he objects one believes to be juggling while engaged in mathematical discourse are, in themselves, discursive constructs: rather than being merely represented in mathematical language, these objects are products of certain linguistic operations. (p. 45)

Within this conceptualisation, the distinction between thinking and communicating collapses. Sfard's claim is distinct from the oft-repeated monistic refrain that 'mathematics is a language' (which collapses mathematics into a type of language). Mathematics is clearly not a language, as it requires a language through which it can be expressed. The fact that mathematics can be expressed in multiple languages, and that its meaning is derived from the language in which it is expressed, bears testimony to this. What Sfard argues is that learning mathematics entails engaging in mathematical discourse, and that the meaning of the constructs under discussion is brought into being through the use of a particular language.

If one adopts Sfard's discursive conceptualisation of language and mathematics, communication (with oneself and others) is placed at the centre of mathematics learning. As a result, the language(s) through which such communication takes place must be front and centre. Language is both a fundamental and a necessary component of learning mathematics (Anghileri 2005):

> It is the nature of mathematics that concise communication is achieved through the use of symbols and formalised 'expressions' to convey information and to pose questions. However, the route to understanding such mathematics is by successively broadening children's experiences of the language and meanings associated with formal mathematical expressions. (p. 90)

For young children, sense-making is supported through imagination and expression, with an interplay between a meaningful context (one that is meaningful within the learner's real or imagined world) and a formal mathematical situation.

Conceptual framework

There are two concepts used in this article that warrant clarification:

- Word problems or story sums.
- Gap-generating words or phrases.

The role of word problems or story sums

A mathematical calculation (such as 3 + 4 = __) is not learned abstractly and only later applied to familiar situations. Rather, when introducing the notions of 3 and 4 as numbers, the operation 'plus', and the relationship 'equals', a mathematical calculation is imbued with meaning only when it emerges from a familiar real-world situation, whether directly experienced or expressed through narrative.

By way of example, the concept of 'three plus four' acquires meaning when learners reflect on real-world situations involving the joining of two sets of objects. The concept 'three plus four' is given meaning in situations where groups of discrete objects are joined and quantified, such as 'three people are in a room, and four more people enter the room'. Alternatively, the same phrase, 'three plus four', may refer to a measurement situation: 'a child is three steps away from a tree. The child continues moving and takes another four steps, moving even further from the tree'. To make sense of the mathematical abstraction '3 + 4', it is essential to invoke such 'real-world' situations. These situations may be real or imagined and are usually conveyed through narration. Understanding mathematics as the process of revisiting familiar (or recognisable) situations through a mathematical lens is particularly helpful when reflecting on the role and purpose of mathematical word problems or story sums.

Verschaffel et al. (2020) conceptualise word problems as mathematical problems embedded in a narrative or situational context and expressed in natural language. They describe them as tasks in which quantitative relationships are presented through a realistic scenario, requiring the solver to construct a mathematical model of the situation being described. Word problems involve processes of interpretation, modelling, and validation. A successful solution requires the coordination of linguistic comprehension, situational modelling, and mathematical reasoning. In the domain of mathematical word problems, language is used to tell a story from which mathematical calculations can be inferred. Learners' responses to the word-problem context are expected to be expressed mathematically through numbers and symbols. The 'words and symbols need to be read and interpreted with words or phrases being used to convey meanings of arithmetic expressions' (Anghileri 2005:84).

The South African school curriculum does not define word problems or story sums. It does, however, list word problems and story sums as concepts or skills to be taught. Teachers are tasked with teaching learners how to solve word problems in context and how to explain their own solutions to problems, thereby implying the use of language. However, the Curriculum and Assessment Policy Statement (CAPS) Mathematics Grade 1–3 document (DBE 2011) does not refer explicitly to language as a strategy for problem-solving. As a result, teachers may not become aware of the significance of language in mathematics teaching unless this is addressed during their ITE programme. This underscores the importance of explicitly describing the role of language in the PrimTEd standards for mathematics (PrimTEd 2022).

Gap-generating words

There is a particularly important concept in LiME, advanced by Sfard (2021), that is relevant to this article: gap-generating words. In reflecting on language-responsive teaching, Sfard (2021) explains that mathematics teaching is replete with unintended linguistic gaps. She argues that these gap-generating words (or phrases) are often overlooked and that only through close linguistic examination does the confusion they create become apparent. She contends that mathematics education communities need to identify gap-generating words and subject them to explicit and careful study. We return to this concept in our discussion of the PrimTEd mathematics standards (PrimTEd 2022) and the extent to which they respond to the changing policy landscape for language and mathematics education in South Africa.

Research methods and design

Given the recent shift towards MTbBE, this article considers the following research questions:

- Research Question 1 (RQ1) – What expectations relating to LiME are set out in the PrimTEd knowledge and practice standards for mathematics?
- Research Question 2 (RQ2) – What additional information and research might further strengthen the interpretation of LiME in the PrimTEd standards for mathematics?
- Research Question 3 (RQ3) – How might we begin to differentiate attainment relating to knowledge of LiME within the envisaged performance-level descriptors for PrimTEd mathematics?

By responding to these research questions (RQs), we aim to clarify how language and mathematics are conceptualised in the PrimTEd standards (PrimTEd 2022), reflect on what is missing, and offer concrete illustrations of how the standards could better inform mathematics course design and programme strengthening. As our theoretical approach to mathematics adopts a discursive perspective (Sfard 2021), it follows that our methodology should draw on traditions of discourse analysis. In particular, we first conducted a content analysis of the written document (PrimTEd 2022) and then reflected critically on the recurrent themes and patterns that emerged in order to consider what might be missing. Having identified a lack of specification and exemplification in what was articulated at a highly general level, we sought to address this gap. We purposively selected the CAPS topic of additive relations in Foundation Phase mathematics. This forms part of the largest content area Number, Operations and Relationships, and addition and subtraction receive the greatest proportion of teaching time in these early grades. Within addition and subtraction, we focused on word problems, as these are rich in language and thought and therefore suitable to illustrate what we identified as absent from the PrimTEd standards (PrimTEd 2022).

The process of analysing the PrimTEd standards evolved through a dialectical engagement between the PrimTEd mathematics standards document (PrimTEd 2022), our use and interpretation of the document for course design through the Maths4 Primary Teachers collective, and the use of an Artificial Intelligence (AI) tool, NotebookLM, to generate possible ways of categorising the standards, which we could then critique and refine.

Our decision to use an AI tool (in this case NotebookLM) as part of the methodology was deliberate.

We needed to analyse the content of a lengthy written document (PrimTEd 2022). Artificial intelligence tools, when restricted to specified source materials, are well suited to identifying patterns and themes within large bodies of given texts. Artificial intelligence can rapidly process substantial amounts of information and synthesise content from the materials provided. In our case, this was the PrimTEd mathematics standards document. We were mindful of the risks associated with using AI tools for this purpose. Current algorithms do not necessarily generate accurate or unbiased outputs (University of Washington [UW] Graduate School 2024).

We sought to mitigate this risk in four important ways (Public Relations Society of America [PRSA] 2023). Firstly, we verified that the source material was credible. By limiting the AI tool to the PrimTEd standards (PrimTEd 2022), we were confident that the source material was credible and relevant to ITE curriculum design. Secondly, we proofread and fact-checked all AI-generated outputs. We carefully reviewed and edited responses to our prompts, looking for hallucinations, inaccurate examples, or quotations incorrectly drawn from the source document. Very few errors were identified, which we attribute to the fact that the tool was restricted to a single written source. Thirdly, we used our own expertise to align the AI outputs with our research. This enabled us to assess the coherence of the AI-generated content in relation to our own practice and to reflect on the extent to which we might have arrived at similar content-analysis claims independently of the AI tool. For this reason, we carefully scrutinised the generated performance-level descriptors and supplemented them with descriptors derived from our study of LiME. Finally, we sought to report transparently on how and why AI was used within the research process.

Given the role of our own expertise in the study, it was necessary to make explicit our roles and relationship to the PrimTEd mathematics standards (PrimTEd 2022). The first author was responsible for the PrimTEd assessment workstream when the standards were collaboratively developed and facilitated the formation of South African mathematics expert lecturers' workstreams that contributed to their development. In addition, she leads the Maths4 Primary Teachers collective – a research project aimed at improving ITE mathematics course materials through collaborative design and trialing. The second author has been an ITE mathematics lecturer at a rural university, where she used both the PrimTEd assessment and the Maths4 Primary Teachers collective course materials. She is also the coordinator of the PrimTEd mathematics community of practice.

When using NotebookLM, we provided the AI tool with the full PrimTEd mathematics standards document (PrimTEd 2022) and posed the following questions: 'Looking specifically at word problems in the PrimTEd standards, provide a description of the interplay between language and mathematics, and how the PrimTEd standards describe this'. The NotebookLM analysis yielded a framework illustrating three ways in which language and mathematics interact. These categories were then reviewed by revisiting the PrimTEd standards (PrimTEd 2022), with a particular focus on word problems and their relationship to the LiME agenda. These standards were compared with the three categories identified by NotebookLM, and considerable alignment was found. We adopted the framework proposed by NotebookLM and then manually integrated the relevant PrimTEd standards into a narrative account of how each standard aligned with a

specific category. We shared our interpretations and discussed ways of strengthening the illustration of each category. Through further refinement, we ensured that the categorisation and related descriptions of the standards provided both a robust account of the standards themselves, and an explicit explanation of how they relate to LiME.

Throughout this process of writing and refinement, both authors considered what remained unclear in the PrimTEd standards (PrimTEd 2022) and what additional information might be useful to course designers. We agreed that the standards were necessarily generic and shared concerns about the lack of specificity regarding LiME within particular content domains. Through discussion, we purposively selected addition and subtraction word problems as an important and language-rich topic within the Number, Operations and Relationships content area of the Foundation Phase mathematics curriculum.

Suggestions for enhancing the PrimTEd standards relating to addition and subtraction word problems were drawn from course materials that had already been designed and trialed with Prospective Primary Teachers (PPTs), the authors' own theoretical knowledge of LiME, and existing research contrasting mathematical expression in English and isiXhosa. To illustrate the concept of gap-generating words and phrases, which is absent from the PrimTEd standards, we selected examples from prior research conducted by the first author on word problems in English and isiXhosa. We seek to show how teacher knowledge of the ways in which mathematics is expressed in different languages deepens reflection on the mathematical concepts in question. These ideas inform our final RQ.

To address the final RQ, the authors returned to the AI tool for a preliminary analysis. The instruction provided to NotebookLM was: 'Develop three levels of proficiency for using language and the application of language in word problems and mathematical acting-and-thinking tasks, using the language and tone of the PrimTEd standards'. These initial performance-level descriptors were then interrogated by the authors and expanded with reference to the theoretical arguments developed in this article. The resulting first iteration of performance-level descriptors for the use of language in mathematical tasks, such as word problems, is proposed as a means of articulating levels of attainment for language-responsive teaching.

Ethical considerations

Ethical clearance to conduct this study was obtained from the Faculty of Education Research Ethics Committee of the University of Johannesburg. The ethical clearance number is 2017-072.

Findings and discussion

Drawing on discourse analysis traditions, we conducted a content analysis of the PrimTEd knowledge and practice standards for mathematics, moving iteratively between our expert interpretations, the standards document, and the course materials we had developed as expressions of particular standards. Our analysis therefore emerged through a dialectical engagement between these sources, with preliminary findings prompting discussion and further enquiry, which, in turn, refined our findings and generated new lines of discussion. Accordingly, we present our findings and discuss our responses to each RQ.

Research question 1

> What expectations relating language in mathematics education are set out in the primary teacher education knowledge and practice standards for mathematics?

The PrimTEd standards (PrimTEd 2022) recognise the critical interdependence of language and mathematics and provide a framework through which PPTs can utilise linguistic awareness when addressing mathematical tasks, including word problems. Three approaches to LiME emerged from our analysis of the PrimTEd standards (PrimTEd 2022). We discuss each in turn.

Language as a foundational pedagogic tool

The PrimTEd standards for mathematics establish language proficiency as a guiding principle for effective mathematics teaching (PrimTEd 2022). This is made explicit through two of the General Principles (GPs) articulated in the standards. The first is, GP3, which refers to knowledge of learners' linguistic environments (PrimTEd 2022):

> PPTs should acquire an understanding of how children develop mathematical understanding, including awareness of learners' socio-cultural and linguistic environments, as this is needed to make connections between out-of-school and in-school understandings. Knowledge of how to access children's prior understandings is important for building secure trajectories of understanding. (p. 3)

Prospective primary teachers are expected to recognise language as a pedagogical tool for teaching mathematics by understanding children's linguistic contexts and environments, making appropriate use of code-switching and translanguaging,[1] and relating school mathematics to learners' out-of-school experiences while actively integrating general pedagogic standards for mathematics teaching (GPM). This includes the ability to describe and define phenomena mathematically using appropriate mathematical terms and symbols (GPM3.1). Furthermore, teachers are explicitly encouraged to incorporate home languages[2] when planning and delivering lessons (GPM3.2).

1. It is assumed that PPTs are able to translanguage and code-switch, which necessarily means movement between at least two languages. However, the PrimTEd standards do not explicitly state that South African PPTs are expected to be, at a minimum, bilingual in South African languages. This expectation is therefore implicit rather than explicit.

2. This standard implies that teachers are expected to incorporate both the 'Home Language' of the class (the language designated as the LOLTA) and the dominant or most comfortable home languages of the learners. However, the standard does not explicitly indicate that teachers could provide opportunities for mathematical talk and mathematical writing in multiple languages, including languages that the teacher may not share with learners.

Prospective primary teachers are also expected to engage learners and develop their thinking through discourse, while communicating mathematical concepts, procedures, and ideas (GPM3.1).[3] A core pedagogical expectation is the capacity to connect school mathematics to learners' out-of-school context while actively integrating the home language. GPM3.3 specifically addresses the relationship between school mathematics, learners' lived experiences, and the integration of home language. In addition, GPM3.4 seeks to standardise the development of tasks that enhance learners' mathematical language, thereby supporting the development of mathematical understanding.

The second guiding principle that explicitly refers to language is GP4, which focuses on knowledge of code-switching and translanguaging (PrimTEd 2022):

> PPTs should acquire knowledge of language that develops learners' mathematics, be aware of the positive features and intentional use of code-switching and translanguaging, and know when and how to apply these. They must be mindful that learners will use prior linguistic schema, will learn when there is a need to communicate and to learn, and they will learn when they are motivated to do so. (p. 3)

These pedagogical principles are further elaborated in GPM4, providing additional evidence of sensitivity to LiME. GPM4.1 states that a balanced mathematics curriculum should be taught through the communication of concepts and procedures using a variety of representational forms. GPM4.2 requires teachers to create opportunities for children to engage in the processes of problem solving, conjecturing, reasoning, justifying, and generalising. Finally, GPM4.5 expects PPTs to connect different representations to a single mathematical idea.

Language in mathematics education is evident in the mathematical acting and thinking standard

In addition to LiME being in focus as a GP articulated in the PrimTEd standards (PrimTEd 2022), there is a recurrent mention and expectation of language responsiveness in relation to one of the core PrimTEd standards: Mathematical Acting and Thinking (MAT). This is particularly evident in relation to modelling and problem structures. Effective engagement in MAT requires learners to see themselves as doers of mathematics rather than passive consumers. This orientation builds on children's natural curiosity, playfulness, willingness to explore, and desire to make sense of and act in their world. Teachers' facilitation of learners' engagement in mathematical practice contributes to the development of mathematical language through discourse and multiple forms of representations. Although the PrimTEd standards for MAT do not explicitly use the term 'language', the activities described for PPTs are enacted through language: verbal discussion, reading, explaining, arguing, and, ultimately, writing mathematical calculation. Prospective primary teachers therefore need to develop their own language skills to participate effectively in modelling activities.

If one adopts Sfard's discursive conceptualisation of language and mathematics, communication (with oneself and others) is placed at the centre of mathematics learning. The MAT standards reflect the need for teachers to be able to talk about mathematics themselves. Implicitly, they also suggest that teachers must foster mathematical discourse among children. The PrimTEd standards (PrimTEd 2022) explicitly require teachers to develop learners' capacity to communicate mathematical ideas, which is essential for translating word problems into meaningful mathematical operations. Mathematical Acting and Thinking Standards 1, 2, and 3 are all relevant in this regard.

While teaching, teachers should engage learners' thinking through discourse and communicate mathematical concepts, procedures, and ideas through various modes of representation. The expectation that PPTs should be able to describe mathematical thinking is clarified through several standards within the MAT strand. MAT1.2 states that, during the exploration of a contextual problem, teachers should be able to describe relationships observed in patterns or processes (MAT1.2.1) and explain these relationships with reference to underlying mathematical structures (MAT1.2.1). Prospective primary teachers must also be able to articulate relational or analogous connections between different mathematical and/or contextual situations (MAT1.3.1), as well as connections between mathematical representations (MAT1.3.2). More broadly, PPTs should use mathematics to understand and regulate engagement with the world and work with mathematical representations in a variety of forms to develop mathematical thinking and action.

The second MAT standard makes explicit that, when tackling contextual problems (word problems), PPTs must demonstrate competence in modelling. During the modelling process, there is a crucial linguistic interplay involved in interpreting model-based conclusions in relation to the original context. These demands require PPTs to translate abstract mathematical results back into the concrete linguistic context of the word problem. In addition, effective problem-solving requires the ability to represent, explain, and justify all choices made throughout the problem-solving process, all of which rely fundamentally on precise mathematical language.

MAT2 is elaborated in several ways that again point explicitly to LiME concerns. Prospective primary teachers must be able to describe and define phenomena using appropriate mathematical terms (MAT 2.2.1). During the modelling process, PPTs should be able to analyse situations, pose questions about situations, and interpret conclusions. They should also be able to select, construct, or manipulate mathematical representations, including labels, names, diagrams, figures, symbol systems, and mappings appropriate to the concepts, operations, and

3.This standard could be strengthened by including the phrase 'in at least two South African languages', thereby making the expectation of bilingual proficiency for mathematics teaching explicit.

relationships being investigated (MAT2.5). Furthermore, PPTs should be able to compare the strengths and weaknesses of different representations (MAT 2.5.3).

MAT3 makes clear that PPTs ought to be able to reason mathematically by giving and interrogating reasons for mathematical actions (MAT3). This includes formulating and explaining general forms of patterns, relationships, and attributes (MAT3.2); generating and testing conjectures (MAT3.3); and justifying or refuting claims through counter-examples (MAT3.4). Prospective primary teachers are expected to provide mathematically convincing reasons to justify decisions, processes, and/or claims (MAT3.4.1), or to construct counter-examples and demonstrate how these show that a conjecture is false (MAT3.4.2). They must also be able to evaluate reasons used to justify claims (MAT3.4.3) and prove or validate conjectures (MAT3.5), including formulating sound and complete mathematical arguments to validate conjectures (MAT3.5.1).

Specific problem types

The third category through which LiME features in the PrimTEd standards (PrimTEd 2022) language use is reflected in the Number and Algebra (NA) strand. The PrimTEd standards on NA specify that PPTs must possess knowledge of various 'problem types', which typically take the form of word problems in the primary classroom. In this article, we focus specifically on additive relations and, more particularly, on word problems.

The NA standards concern teachers' knowledge for teaching additive relations. NA3.4 states that PPTs must be able to describe and use addition and subtraction problem types, together with the range of associated representations. In addition, NA3.5 requires PPTs to support learners in identifying the strategies they use to solve addition and subtraction problems and to introduce them to increasingly sophisticated mathematical strategies.

Within these two standards, language use is implicit. The standards specify how teachers should use language, rather than how they should support learners in using language while solving problems. The standards also require teachers to identify the strategies learners use to solve problems; however, they do not explicitly recognise language itself as a problem-solving strategy.

In summary, the PrimTEd standards (PrimTEd 2022) portray the relationship between language and mathematics not merely as a matter of translation, but as a broader pedagogical requirement. In some instances, language is explicitly referenced, as in Guiding Principle 2 and Guiding Principle 4, where PPTs are expected to be acutely aware of how linguistic background, including home languages, code-switching, and prior linguistic schema, influences comprehension. In other instances, language is invoked implicitly through the nature of problem-solving contexts, as reflected in the MAT standards, where mathematical discourse is used to model, solve, and interpret conclusions from models considering the situations encountered in word problems. In addition, the NA standards focus on the teacher's language use rather than on how children use language during specific problem-solving situations.

Research question 2

> What additional information and research may further strengthen the interpretation of language in mathematics education in the primary teacher education standards for mathematics?

We have shown that the PrimTEd mathematics standards (PrimTEd 2022) contain two clearly articulated principles relating to the importance of LiME and that these are further elaborated within the knowledge and practice standards, such as mathematics acting and thinking, and in NA. However, we contend that the PrimTEd standards remain generic and high-level, offering limited guidance for mathematics course design. We therefore reflect on what we consider to be missing and on what could be added to strengthen the PrimTEd standards relating to LiME.

What might greater specification within the PrimTEd standards look like? We recognise that there is unlikely to be a one-size-fits-all approach to the teaching of mathematics. Academics working in different ITE programmes need to respond to their local contexts and to the particular characteristics of their student cohorts. Consequently, we do not suggest that the standards should become rigid or prescriptive. Rather, we argue that illustrative examples would assist course designers in interpreting and enacting the standards.

Firstly, the PrimTEd mathematics standards (PrimTEd 2022) would be strengthened by making explicit the expectation that PPTs should be, at a minimum, bilingual in South African languages and possess sufficient linguistic proficiency to express mathematical ideas in at least two languages, one of which should be the LOLTA of the classroom. In addition, the standards could elaborate strategies through which PPTs might draw on the linguistic repertoires of learners in their classrooms.

When some children do not regard the LOLTA as their most comfortable language, their dominant language can be drawn upon if teachers provide explicit opportunities for learners to express mathematics in multiple languages. Mathematical talk and mathematical writing, for example, may be presented bilingually.

Secondly, it would be helpful if the PrimTEd standards (PrimTEd 2022) provided greater clarity regarding what is meant by knowledge of problem types and their associated representations. Leaving these concepts at a highly generic level renders the standards open to a wide range of interpretations, potentially resulting in considerable variation across higher education institutions and even among individual lecturers responsible for mathematics course design.

Considering the NA3.4: 'Describe and use addition and subtraction problem types and the range of associated

representations', it would be helpful to illustrate what is meant by 'addition and subtraction problem types' and by preferred or prioritised representations. There is no universal agreement regarding typologies of addition and subtraction word problems, although relevant research exists within the South African literature. Roberts (2016) critiqued the ways in which the CAPS for mathematics in the Foundation and Intermediate Phases specified addition and subtraction problem types in English. Mostert (2019) subsequently refined the Roberts typology by considering the expression of addition and subtraction problem types in both English and isiXhosa. Ensuring that this research reaches ITE contexts could be facilitated if the PrimTEd knowledge and practice standards (PrimTEd 2022) provided illustrative examples of what was meant by the addition and subtraction 'problem types' referred to in the standards.

By way of example, the Maths4 Primary Teachers collective has interpreted Standard NA3.4 as referring to four basic addition and subtraction problem types:

- Learners first learn about adding and subtracting as 'a change'. For adding, there is an action of joining or combining. For subtraction, there is an action of removing or taking away. In both change (increase) and change (decrease) problems, there is an action. The general form is *start-change-result*.
- A *change* (increase) problem is an additive relation word problem type which involves a *start*, then there is a *change* which increases the start to get a bigger *result*. For example: You have 5 sweets. You get 2 more sweets. How many sweets do you have now?
- A *change* (decrease) problem is an additive relation word problem type which involves a *start*, then there is a *change* which decreases the start to get a smaller *result*. For example: You have 5 sweets. You eat 2 sweets. How many sweets do you have now?
- But situations involving addition and subtraction are not *always* about change. Sometimes there is *no action*. The situation is not like a movie. It is more like a photograph. You have to imagine or introduce an action into the situation. This is the case for collection and compare problems. The general form is *part-part-whole*.
- A collection problem is an additive relation word problem type that is static. There are *two parts* which together make a *whole* collection. For example: You have 7 sweets. 5 of your sweets are red. The rest are blue. How many blue sweets do you have?
- A compare problem is an additive relation word problem type that is static. A smaller *part* is compared to the bigger *whole*, to find the difference. For example: You have 7 sweets. I have 5 sweets. How many more sweets do you have than me? (Roberts et al. 2025)

Thirdly, we argue that the PrimTEd standards (PrimTEd 2022) could be considerably more explicit about the benefits of multilingual mathematics teaching and learning, particularly given the affordances that emerge when mathematical ideas are contrasted across different languages. Mostert and Roberts (2020) argue that teachers 'need to be aware of linguistic issues such as those concepts in mathematics which are expressed differently in the language of instruction and the home language of learners'. These may be understood as gap-generating words or phrases in Sfard's (2021) terms.

Examples of gap-generating words and phrases relevant to early-grade addition and subtraction include:

- **Comparison:** the identification and/or quantification of difference(s), including more/less, more than/less than, exceed/reduce, additional/fall short/insufficient, and increase/decrease.
- **Specification:** an, another, this, these.
- **Generalisation:** each, every, always.
- **Subtraction/minus:** meaning both take away and find the difference (or compare to equalise).
- **Equals:** meaning the same as (rather than makes or results in).

This list is illustrative rather than exhaustive.

To demonstrate the type of research and linguistic knowledge required to make South African primary teachers truly language-responsive, we focus on the first concept in the list: comparison.

Mostert and Roberts (2020) examined how comparison is expressed in English and isiXhosa, drawing on South African mathematics texts. Comparison is a foundational concept in Foundation Phase mathematics. Kennedy (2009) explains that comparisons consist of two linguistic components: (1) an ordering of superiority or inferiority; and (2) a standard against which an object is compared. Which linguistic components are required, depends on the language in which the mathematics is expressed. This may involve specialised morphology (e.g. words, prefixes, or suffxes) and/or specialised syntax (e.g. rules governing word order) to construct comparative statements (Kennedy 2009). Mostert and Roberts (2020:19–20) identify eight features of the language of comparison, expressed in English and isiXhosa, that mathematics teachers would benefit from understanding:

- General comparisons consist of two components: an ordering of superiority or inferiority and a standard against which an object is compared (the referent).
- Some languages use a specialised word to express an ordering of superiority, while in other languages the ordering is inferred by the presence of a referent.
- How comparison is expressed in English depends on whether the referent is implicit or explicit.
- Mathematics teachers should be deliberate about comparing nouns, comparing objects belonging to people, or comparing number names.
- When comparing objects in terms of quantity, there are three components to consider: the compared quantity, the referent, and the difference.

- Mathematics teachers should be aware of the distinction between situations in which the difference is not quantified and those in which it is.
- Rather than using statements like '8 is 3 more than 5', teachers of mathematics in English could make the difference in comparative statements more explicit by (at least initially) using a less common phrasing such as '8 is more than 5 by 3'.
- Mathematics teachers would benefit from being sensitive to the fact that in some languages (such as isiXhosa), the order of superiority may be expressed using a locative adverb, for example, when an ordering of superiority is expressed by a locative adverb that also means 'above'.

Fourthly, we think it is important to recognise that translanguaging in a mathematics classroom involves far more than simply mapping between a source and a target language. Rather, the process of comparing how mathematics is expressed in different languages deepens both teachers' and learners' understanding of the mathematical concept itself.

Mostert and Roberts (2020) assert that:

> By keeping the mathematical concept invariant while changing the language in which it is expressed, we see the concept in a new way and become aware of the constraints imposed as well as the affordances enabled when working mathematically in a particular language. Having examples of languages with different linguistic structures is therefore a powerful resource for thinking about particular mathematical concepts. Rather than assuming that the linguistic diversity in a mathematics classroom is a challenge to be overcome, it can be viewed as an opportunity to be harnessed for supporting children in learning mathematics. (p. 21)

Code-switching, translanguaging, and attentiveness to discourse and representations in the mathematics classroom are therefore not merely practical responses to multilingualism. Rather, movement between languages and representations can deepen mathematical understanding itself.

Research question 3

> How might we describe knowledge of language issues in mathematics within the envisaged performance-level descriptors for Primary Teacher Education mathematics, limited to addition and subtraction?

The relationship between language use and mathematical cognition is central to the PrimTEd standards (PrimTEd 2022) as reflected in two guiding principles (GP2 and GP4). Prospective primary teachers are expected to develop pedagogical content knowledge that bridges learners' natural language use and formal mathematical thinking. This requires moving beyond a general awareness of linguistic diversity towards the strategic and intentional use of language to support mathematical understanding.

Our analysis has shown that the PrimTEd standards (PrimTEd 2022) both explicitly reference and implicitly invoke the strategic use of language in mathematics teaching. We therefore consider how progression towards increasingly sophisticated forms of language-responsive mathematics teaching might be described. The performance-level descriptors for the use of language in mathematical tasks, such as word problems, were initially generated using NotebookLM. This was subsequently reviewed and adapted by the authors to align more closely with LiME and the specific multilingual realities of the South African context. These descriptors are presented in Table 1-A1 (see Appendix 1).

Four level descriptors differentiate the capabilities of PPTs with regard to language-responsive mathematics teaching. Level I represents non-attainment. Level II focuses on recognising learners' linguistic environments and identifying problem types; at this level, a PPT may be monolingual but demonstrates responsiveness to linguistic diversity within the classroom. Level III focuses on translating between natural language and formal mathematical representations and assumes a bilingual PPT. Level IV assumes (at least) a bilingual PPT who strategically leverages language to mediate mathematical understanding, support reasoning, and provide justification within authentic and complex contexts. The first iteration of the performance-level descriptors (see Appendix 1) is intended to articulate progressive levels of attainment for language-responsive teaching within the LiME framework.

Conclusion

The PrimTEd mathematical knowledge and practice standards (PrimTEd 2022) were developed to guide the preparation of future primary school teachers in South Africa. The standards are underpinned by key guiding principles, including the importance of understanding child development, drawing on learners' home languages through code-switching, and developing pedagogical strategies that address learner misconceptions.

However, the principle of using home languages and code-switching in the PrimTEd standards (PrimTEd 2022) remains articulated at a very high level, and the specific standards provide limited guidance to lecturers and course designers who may not have in-depth knowledge of the LiME agenda. The standards were also developed before MTbBE became a formal policy strategy. As such, we argue that the PrimTEd standards should make explicit the expectation that PPTs demonstrate, at least, bilingual proficiency in mathematical expression. Furthermore, PPTs should be able to model language-responsive teaching practices appropriate to the multilingual environments in which they will teach, recognising that they may not share the language resources of all the learners in their class. In addition, we argue that the PrimTEd mathematics standards should provide illustrative examples for key content related standards. For example, they could offer greater specifications regarding what is meant by problem types and representations in the teaching of additive relations.

Mindful of the incremental implementation of MTbBE in South Africa, we have offered an initial attempt to differentiate levels of awareness of LiME among future mathematics teachers. We present these descriptors as a basis for further refinement and critique. Additional theories and perspectives within the LiME agenda should be made more explicit in a subsequent iteration, which can then yield more meaningful. Such developments may support the creation of more robust performance-level descriptors and, in turn, contribute to better curriculum design and assessment practices within ITE.

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During the preparation of this work, the authors used Notebook LM to summarise language in the standards and the first iteration of the descriptors. The content was reviewed and edited by the authors, who take full responsibility for its accuracy.

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CRediT authorship contribution

Nicky Roberts: Conceptualisation, Investigation, Validation, Writing – original draft. Lyn Kok: Formal analysis, Methodology, Software, Validation, Writing – original draft, Writing – review & editing. Both authors reviewed the article, contributed to the discussion of results, approved the final version for submission and publication, and take responsibility for the integrity of its findings.

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Data availability

The authors confirm that the data supporting this study and its findings are available within the article and its listed references.

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Appendix starts on the next page →

Appendix 1: Proposed performance level descriptions for language responsive teaching in Foundation Phase mathematics.

TABLE 1-A1: Table of performance level descriptors for the relationship between language and mathematics, specifically in word problems.

Levels	Performance level descriptions
Level I:	The PPT is not yet displaying knowledge of LiME.
Level II: Foundational linguistic recognition and translation	At this foundational level, the PPT demonstrates a basic knowledge of how language structures mathematics and possesses the capacity to recognize and utilise linguistic contexts relevant to problem types. The PPT: • Displays awareness of learners' *socio-cultural and linguistic environments* and their *prior linguistic schema*, using this knowledge to begin connecting out-of-school understandings with in-school mathematics. The PPT can: ▪ *Incorporates the use of home languages* when planning and delivering lessons. ▪ Describes and identifies the *linguistic structures* inherent in various problem types.
Level III: Procedural language development and modelling competence	This intermediate level requires the PPT to actively facilitate the development of the learners' *mathematical language* through targeted tasks and to competently employ at least two languages during the critical steps of modelling and representation. The PPT can: • Move between at least two different languages when expressing mathematics ideas. • *Develop tasks to enhance learners' mathematical language.* This linguistic enhancement is aimed at improving the learners' mathematical understandings. • Engage and develop learners' thinking through *discourse*. Furthermore, they communicate mathematical concepts, procedures, and ideas through various *modes of representation*. • *Mathematically describe and define phenomena* using appropriate mathematical terms and symbols. • Analyse contextual situations (word problems) and *construct mathematical models*, including standard mathematical models.
Level IV: Integrated strategic and interpretive mastery	This advanced level requires the PPT to demonstrate integrated pedagogical knowledge, employing at least two languages as a powerful strategic tool for teaching, justification, and making comprehensive contextual interpretations. The PPT can: • Demonstrate *knowledge of language that develops learners' mathematics*. In particular this includes awareness of gap-generating words and phrases and bringing these to the attention of learners in at least two languages. • Describe the positive features and the *intentional use of code-switching and translanguaging* and know when and how to apply these strategies. • *Relate school mathematics to learners' out-of-school context*, while effectively *integrating their home languages* to solidify understanding. • Demonstrate proficiency in the full cycle of mathematical acting and thinking, which crucially requires: ▪ The capacity to *interpret conclusions from models in the light of the situations* encountered in the word problem. ▪ The ability to *represent, explain, and justify all choices* made within the problem-solving process. ▪ Provision of *mathematically convincing reasons* to justify decisions, processes, and claims.

PPT, prospective primary teacher; LiME, language in mathematics education.