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Language and communication in mathematics education: an overview of research in the field

Within the field of mathematics education, the central role language plays in the learning, teaching, and doing of mathematics is increasingly recognized, but there is not agreement about what this role (or these roles) might be or even about what the term 'language' itself encompasses. In this issue of ZDM we have compiled a collection of scholarship on language in mathematics education research, representing a range of approaches to the topic. In this introduction we outline a categorisation of ways of conceiving of language and its relevance to mathematics education, the theoretical resources drawn upon to systematise these conceptions, and the methodological approaches employed by researchers. We will also identify some outstanding issues and questions and suggest some ways of building upon the diversity in order to strengthen the coherence of the field and the utility of its outcomes.

1. Introduction

The pivotal role played by language in the learning, teaching, and doing of mathematics is increasingly being acknowledged by researchers in mathematics education. This is evident in the literature and in the extent of participation in groups focusing on language and mathematics at conferences including the International Congress on Mathematical Education, the Psychology of Mathematics Education, the Congress of European Research in Mathematics Education, and speciality conferences. However, there is not agreement about how best to describe this role (or these roles), about which language-related practices should be encouraged, or even about what the term *language* itself encompasses.

In this issue of *ZDM: The International Journal on Mathematics Education*, entitled "Language and Communication in Mathematics Education" we offer a broad overview of the areas that have become or are becoming important in contemporary research. We also

identify various subfields within the field, connections between these and connections to other domains of study both within mathematics education and beyond, though we recognize that subfields might be added or delineated differently.

Language has been a topic of research in mathematics education for a long time. An early review article by Austin and Howson (1979) published in *Educational Studies in Mathematics* drew on research from the previous two decades to provide a "state of the art" picture of the field at that time. We note that thinking and knowledge within the field have developed since then. Most notably, there has been a massive increase in the attention paid to language in mathematics education, with research developing both qualitatively and quantitatively, especially since the publication in 1987 of Pimm's seminal work "Speaking Mathematically". Further, it is important to note the context within which this increased attention to language has taken place. Mathematics education as a whole has been developing into a mature field of study with serious attention to theorisation and problematisation of the components, concepts and methods of the field, including language. Most relevantly, the development of attention to language reflects the "social turn" identified by Lerman (2000) in mathematics education. An orientation to the importance of the social environment within which mathematics education takes place has inevitably been accompanied by raised awareness of the significant roles of language and other forms of communication within that social environment. Further movement to embrace critical perspectives, sometimes called a socio-political turn (Valero, 2004), has further potential to draw attention to language.

In addition to the trends in the theoretical orientation of the field, developments in classroom practice, professional discourse, and policy have increasingly recognized the important role of language-rich activity in the classroom, often using the terms "conversation", "discussion" or "discourse" to describe such activity. Researchers are thus expected to provide a basis for changing the conventional practices of mathematics classrooms. However, recontextualisation of research findings into classroom practice is frequently over-simplified. For example, Aukerman (2007) demonstrates how a theoretical distinction between social and academic language that has proved useful in developing research into bilingualism can actually be applied in classrooms in ways that serve to disadvantage bilingual learners. Moreover, the expectation that education research should be directly relevant to practitioners can put pressure on researchers to adopt certain research directions thus restricting the scope of educational decision-making (Biesta, 2007).

The present collection focuses on the first step towards transforming conventional practice in relation to language in mathematics education – the development of a secure theoretical basis upon which to initiate changes in practice.

2. What is mathematical language?

First it is necessary to establish the scope of what might be meant by *language* within the domain of mathematics education. Looking at dictionary definitions of *language*, we find, for example:

1. the method of human communication, either spoken or written, consisting of the use of words in a structured and conventional way

    1.1. a non-verbal method of expression or communication e.g. body language

2. a system of communication used by a particular country or community […]
3. the style of a piece of writing
    3.1 the phraseology and vocabulary of a particular profession, domain or group

(http://oxforddictionaries.com/definition/english/language, accessed 4 August 2014)

Within mathematics education literature we find *language* used in each of these ways: dealing solely with words (referred to variously as natural language, verbal language, etc.) or including non-verbal modes of communication, especially (or indeed sometimes exclusively) mathematical symbolism, but also diagrams, graphs and other specialised mathematical modes as well as gestures and other modes of communication used in a variety of settings (Arzarello, Domingo, Robutti, & Sabena, 2009; Bjuland, Cestari, & Borgersen, 2008, 2009; Maschietto & Bartolini Bussi, 2009; Radford, 2009). There is also the second sense of language, encountered both in the context of working with multilingual learners and in doing and learning mathematics in different national languages.

The distinction between different kinds of language proficiency has been developed in relation to second-language learners in English-speaking countries. Cummins's much-cited idea of "Cognitive Academic Language Proficiency" (2000) is a useful concept, though it is oriented towards deficits. Cummins distinguishes "academic language proficiency" from "conversational language proficiency", suggesting that children quickly learn abilities in their second language that they are able to apply in everyday situations, but need significantly more time to achieve the educational-language competencies required for success in the classroom. This distinction may also be useful to bear in mind when thinking about the language experiences of all mathematics learners, not only those learning in a second or additional language.

Elaborating the third definition of *language* as phraseology and vocabulary of a particular domain or group, Halliday (1974) used the term *register* to refer to the specialised method of communication used in a particular social practice. The mathematics register, for example, would include words unique to mathematical communication, but also specialised uses of everyday words, which take on unique meaning in mathematical contexts. We use this term with caution, however, as Pimm (2007) and Barwell (2007) have argued that the specialised language of mathematicians should not be conflated with the specialised language of mathematics classroom dialogue.

While communication within the practice or practices of mathematics education and of doing mathematics is of central interest, it is also relevant to consider how this relates to other practices. On the one hand, considering how the practices of mathematicians are similar to those of other scientific or academic fields allows us to make use of knowledge about language and communication developed in those fields. The extensive literature related to language for special purposes, including academic purposes, can inform our thinking here. On the other hand, recognising that our students are participants in a range of extra-mathematical practices may enable us to understand better their experience of communication in mathematics classrooms.

In recent years, thinking about language in mathematics education has broadened from considering primarily either words or mathematical symbolism towards a more comprehensive concern with a range of other means of communication. This development coincides with increasing recognition in the field as a whole of the significance of the social

environment in the learning, teaching and doing of mathematics. By focusing on the social environment, the face-to-face communication that takes place in classrooms has come more into focus, moving attention away from written texts to the spoken word and leading to recognition that the spoken discourse of mathematics classrooms also has specialised features. This has also led to greater use of naturalistic data arising in classrooms and elsewhere together with qualitative methodologies that recognise and attempt to deal with the complexity of social situations.

When observing in a classroom it is hard to miss the fact that words and mathematical symbols form only part of the communication that is going on. Whereas there are well established means of describing language, drawing on the field of linguistics, as well as attention to the syntax of mathematical symbolism (e.g. Ervinck, 1992), recognition of the multimodal nature of mathematical communication demands the development of means of describing and studying other modalities, including those offered by new technologies. Developments in the general fields of communication and media studies offer some ways of theorising and analysing this wider range of resources, adding to what may be taken from linguistics, semiotics and theories of discourse (e.g. Kress & van Leeuwen, 2001; O'Halloran, 2005). However, at the heart of any research in mathematics education we must find mathematics itself. Our conceptions of mathematics inform how we choose, use, interpret and adapt the theoretical and methodological tools offered by other fields.

We need not only to describe the language used in mathematical and mathematics education settings but also to be able to address questions such as:

- What is distinctly mathematical (or not) about the way language is being used?
- How does the language function to establish what is and what is not to count as mathematics in this setting?
- What role does the language play in the processes of doing mathematics and producing mathematical knowledge?
- How does a person's use of language position them or others in relation to mathematics?

3. What is the relationship between mathematics and language?

One of the major theoretical issues that informs and divides research in this field relates to the claim that language has a special role in relation to mathematics because the entities of mathematics are not accessible materially. On the one hand, some take the position that mathematical objects have an independent existence, even though they are only experienced through language. We do not have any perceptual or instrumental access to mathematical objects. The only way of gaining access to them is using signs, words, symbols, expressions or drawings. But, at the same time, mathematical objects must not be confused with the semiotic representations used. Mathematical knowledge is thus characterized and constituted by this conflicting requirement to deal with objects that exist objectively yet are recognized and experienced only indirectly (Duval, 2000; 2006). On the other hand, those working with Sfard's theory of cognition and communication reject any dualist separation of mathematical object and language, arguing that mathematics is an entirely discursive activity and that mathematical objects are no more than the total of the ways of communicating about them (Sfard, 2008).

These different theorisations of language and mathematics have consequences for how researchers may think about the development of mathematical knowledge – as a process mediated by language or as the development of mathematical ways of using language. These theorisations also impact the way researchers use language in researching mathematical thinking and reporting on this research. In brief, the question is this: Is language taken to be the means by which we get limited and partial access to learners' mathematical thinking or is the communication itself the object of study?

One recurring theme in attempts to outline research on language and communication in mathematics education is the growing recognition of the complexity of the field both empirically and theoretically. This may relate to a perception amongst some mathematics educators that language is a source of difficulty in mathematics learning – a perception that has framed, and continues to frame, some research within the field. This perception rests upon a dualist conceptualisation of language and mathematics as separate domains, which may be a result of theorising mathematics as comprising objects that have an independent existence, though experienced through language. However, dualist distinctions between mathematics and language vary from a naïve view of language as a barrier to learning that must be overcome to more sophisticated theorisation of language practices embedded within particular social contexts.

Early research in the field identified a number of features of mathematical language that students at all stages of education appeared to have difficulties understanding and using correctly. These included difficulties with vocabulary, with algebraic notation and with handling logical connectives, but also difficulties at the level of more extended texts. Analysis of reasons for these difficulties was, however, less evident. The issue of confusions with everyday language was recognised, especially in relation to young children, for example in Durkin and Shire's (1991) analysis of ambiguities in elementary mathematics, identifying words that have different meanings in mathematical and in everyday contexts. We suggest that this relatively untheorised notion of confusion between different meanings of words may be described as a naïve view of language as a barrier to learning. As thinking about relationships between language and learning change, ways of interpreting "confusion" between everyday and mathematical meanings also develop. We thus see more complex analyses of difficulties and attempts to theorise what happens as students encounter mathematical forms of language. While difficulty and failure to communicate effectively is still a relevant area for research, the focus now is not so much on what children cannot do or what they fail to understand as on what is actually happening in classroom interactions, on the nature of communication among students and teachers, on the sources and functioning of apparent miscommunication, and on the effects of particular language choices.

Relationships between mathematical and everyday language continue to be a focus of research but we now see more theoretical subtlety in attempts to understand why difficulties arise. There are several notable theoretical ideas that contribute to this understanding, including situatedness, discourse theoretical perspectives and the study of semiotic systems.

Situatedness is the idea that people make sense and behave differently when situated in different practices. Using a word in its everyday sense may thus be seen as the result of failure to recognise the situation as mathematical rather than failure to distinguish the correct mathematical sense of the word (Moschkovich, 2002).

Moving away from the dualist separation of language from mathematics, *discourse theoretical perspectives* suggest that we think of mathematics as a discursive practice: doing mathematics essentially entails speaking mathematically (or writing or using other communicational modes). The influence of discourse theoretical approaches provides alternative ways of thinking about miscommunication, in particular as non-arbitrary combinations of resources drawn from different discourses (Morgan & Alshwaikh, 2012).

While difficulty in learning and using mathematical forms of language is still evidently an issue in classrooms and for research, efforts to understand the sources of difficulty have led researchers to orient towards analysing what students do communicate as well as what they do not. Related research, arising from increasing interest in the multi-semiotic nature of mathematical communication recognises that moving from one *semiotic system* to another is not a straightforward matter of translation, just as translation from one 'national' language to another affects the possibilities for meaning making. Such research explores how students choose from and make use of available semiotic resources to do mathematics (Radford, 2000).

4. What does attention to language enable us to study?

Building on approaches to language that recognise that the language we use construes the nature of our experience of the world and also construes our identities, relationships and attitudes, we identify four broad, but related, categories of research in mathematics education to organise our discussion:

- analysis of the development of students' mathematical knowledge
- understanding the shaping of mathematical activity
- understanding processes of teaching and learning in relation to other social interactions
- multilingual contexts

These categories do not comprise the only basis for thinking about the field, nor should they be assumed to be exhaustive.

4.1 Analysis of the development of students' mathematical knowledge

Many areas of research within mathematics education have used data consisting of what students say (or other signs they produce) as evidence of their mathematical understanding. Developments in understanding the way language works challenge some of the assumptions that lie behind such research and have also produced theoretical and methodological tools that contribute to understanding the development of mathematical thinking and enable a more grounded analysis of linguistic data.

Naïve conceptions of language as a transparent means of transmission of ideas from speaker to listener have been seriously challenged by current thinking about communication. Moreover, a number of influential theoretical frameworks, including Peirceian semiotics, Wittgenstein's notion of language games, and post-structuralist theories, reject any fixed relationship between word and referent. These have been taken up and developed within mathematics education to address the specific problems of mathematical learning.

Work in semiotics has offered sophisticated means of conceptualising and investigating relationships between signs and mathematical meaning making. In particular, we have seen the notion of the epistemological triangle, introduced by (Steinbring, 2006), used as a means of describing the nature and development of mathematical knowledge in classroom situations, focusing on the role of the symbols, words, material objects and other ways of representing mathematical concepts. This notion emphasises that relationships between representations and concepts are mediated by the "reference context", including the previous knowledge and experiences of the students. This theoretical notion is taken up by Gellert (this issue) to analyse the different conceptualisations of mathematical problem situations by students and teachers interacting in small groups.

4.2 Understanding the shaping of mathematical activity

Another approach to the issue of the development of mathematical knowledge makes use of the Vygotskian notion of tool mediation. From this perspective, verbal language and other semiotic systems are conceived of as psychological tools that shape the nature of human activity. This framework has been used to analyse the effects of particular tools (whether specific words or other forms of representation or more extensive semiotic systems) on the development of mathematical activity. For example, when students are engaged in mathematical expository writing, the cognitive processes required to give clear explanations have been seen to encourage deeper mathematical thinking and understanding (Craig, 2011; Misfeldt, 2007).

From a different tradition, current theories of language use and discourse tend to focus on what utterances achieve rather than treating them as a means of accessing inner thought or objective reality. Within mathematics education, this perspective has been developed further by Anna Sfard (2008) in her communicational theory. Here no distinction is made between speaking/writing/communicating in mathematical forms and doing mathematics/thinking mathematically. Detailed characterisation of the nature of mathematical language thus provides a means of describing the ways in which learners are engaging in mathematical activity.

Studies of mathematics classroom language using Systemic Functional Linguistics and other tools that implicate the development of ideas and of human relationships within language practices help us see where students, who carry their conceptions into adulthood, get their conceptions of mathematics (e.g. Chapman, 2003). These conceptions often position people as powerless in relation to mathematics or in relation to others doing mathematics, emphasizing the importance of considering how people may be empowered with mathematics through attention to language (e.g. Wagner, 2007) or through particular language practices. In this issue, Wagner & Herbel-Eisenmann model a linguistic-based framework for understanding the development of authority in mathematics classrooms. Furthermore, as shown in the article by Planas and Phakeng, the role of language in positioning students with and in relation to power is exacerbated by the politics of multilingual settings.

4.3 Understanding processes of teaching and learning in social interactions

Developments in the study of language in mathematics education are closely related to developments in the wider field. The move to considering learning as a social or socially organised activity and the move from ideas of individual construction of meaning to considering meaning as something formed by individuals within social environments have opened up a space within which language oriented studies contribute to the overall project of understanding teaching, learning and doing mathematics (Christie, 1999; Kress & Selander, 2012; Mehan, 1979; Mercer, 1995). In this issue, for example, Barwell uses Bakhtin's theory of centripetal and centrifugal language forces for an analysis of a Cree-speaking second-language mathematics classroom. In this analysis he highlights three situations in which the tension between these forces is particularly salient: the students' use of Cree, the work on mathematical word problems and finally the production of mathematical explanations.

Many of the theoretical and methodological resources used by researchers into classroom interaction originate outside the field – in ethnomethodology, linguistics, pragmatics, semiotics, sociology, etc. – and have been developed to deal with general interactions. These ways of thinking recognise that there are patterns in any social interaction that are distinctive to particular practices and functional in shaping what gets done in the interaction. Recognising these patterns and what they achieve provides tools for analysing classroom processes and can also inform development of teaching practice. For example, the patterns of funnelling and focussing identified and discussed by Bauersfeld (1988) and Wood (1998) have proved a useful tool for working with teachers as well as a foundation for further work on identifying patterns of interaction and establishing their functions. More recent work adopting interactional approaches to interpretive education research has been produced among others by Krummheuer and Schütte (e.g. Krummheuer, 2012; Schütte & Krummheuer, 2013; Schütte, 2009).

It is important, however, to ask what are the specifically mathematical issues that arise in studying interaction in mathematics classrooms. Why should mathematics educators be concerned? Indeed, some studies located in mathematics classrooms analyse interactions in ways that seem not to address the teaching and learning of mathematics directly. Such studies certainly illuminate important issues, for example, how knowledge is produced in interaction or how students may be positioned differently by classroom discourse. These issues are of concern both theoretically and in practice but as a researcher in mathematics education it is not enough to say simply that these studies are located in mathematics classrooms. Researchers in the field want to know what any study has to say about mathematics and about the teaching and learning of mathematics. Studies of interaction that engage strongly with mathematical aspects of interaction include those using the notion of socio-mathematical norms (Yackel & Cobb, 1996) as well as studies of specifically mathematical forms of interaction such as argumentation (Krummheuer, 1998; Planas & Morera, 2011) or group problem solving. In this issue, Andrea Gellert addresses the emergence and maintenance of contention in small group discussions as students and teachers struggle to establish meanings with respect to mathematical problem situations. Her analysis highlights the significant role played by the mathematical situation itself and the difficulties for students and teachers in sustaining forms of interaction that appear to be productive for mathematical learning.

Detailed analysis of interaction is also a feature of the article by Johansson, Lange, Meaney, Riesbeck and Wemberg. This study is set in a pre-school context where the young

children's linguistic skills are limited, thus necessitating a multi-semiotic approach to investigating their communication. The authors make use of the notion of semiotic bundles (Arzarello et al., 2009) to construct an account of how the children use combinations of words, gestures and interactions with artefacts in order to form explanations about similarities and differences of size and shape.

In a world in which new communication technologies provide new opportunities for interaction, it seems important to develop our understanding of how technologies may affect pedagogic and mathematical communication. This is especially pertinent as funding bodies encourage the development of internet-based tools and on-line collaboration. At this time, these studies of technologically mediated communication are still relatively isolated, focusing on the features of specific special contexts. This is an area that offers many opportunities for both empirical research and theoretical development as the use of communication technologies becomes more widespread in mathematics education.

Of course, new technologies are changing our ways of communicating, not only introducing new semiotic resources, notably dynamic, manipulable, and multiply linked representations (Yerushalmy, 2005), but also new forms of human interaction, both asynchronous as is generally the case through email, discussion boards, blogs, podcasts etc., and potentially synchronous as in chat rooms, instant messaging, video conferencing. The potentialities of these new forms disrupt our established understandings of, for example, differences between spoken and written language. There is as yet only a small amount of research in mathematics education looking at these new forms of interaction in mathematics education (e.g. Pratt & Back, 2009; Schreiber, 2013). Again, research in mathematics education needs to be informed by the developing field of research in on-line and mobile communication while maintaining a distinct focus on aspects of communication that are unique to mathematics contexts.

4.4 Multilingual Contexts

Multilingual classrooms, especially ones in which learners are studying mathematics using a language different from their mother tongue/first language, represent contexts where some of the above considerations of teaching and learning are significantly more obvious and acute. For example, the challenges students face when their language repertoires do not align with the language of instruction are most extreme when the students are simultaneously learning that language in a wider context than just the classroom. In such contexts there is a need to produce meaningful theories on the learning of mathematics, as well as to develop curricular elements that provide multilingual children with diverse opportunities to learn mathematics (Schütte & Kaiser, 2011). The distinctions drawn by Cummins (2006), which describe the competencies that children growing up in multilingual contexts lack, do not appear to be adequate in this regard. Pedagogic approaches that draw on Cummins tend to focus on deficits. In this way, not only do children's existing language skills go largely unacknowledged, but a kind of linguistic 'target register' is propagated. By focusing on this target register, the notion is lost that mathematics is a discursive activity which can be carried out in a range of different registers.

While there undoubtedly exists an interactional relationship between mathematics and language, addressing language challenges directly in multilingual classrooms can be

less useful than anticipated. Drawing on two studies of children learning mathematics in a multilingual context, in primary school and kindergarten, Schütte (this issue) argues that subject-related learning is best supported by educating teachers to be sensitive to diversity in context framing and interpretation. By acknowledging that a lack of linguistic ability is not necessarily the only cause of language-related learning difficulties encountered by second-language pupils, mathematical learning can be promoted more readily. Ji (this issue) expands on this theme to examine the problems encountered by Korean native speakers returning to a Korean environment after time spent immersed in another culture. For this purpose, Ji adapts Cummins' Quadrants Model and Sheltered Instruction Observation Protocol, originally developed to be used for English language learners, to the Korean language setting.

Multilingual learning contexts have been a concern for many years. Indeed, current understanding of the nature of mathematical language as a whole owes much to a paper by the linguist Michael Halliday that was originally presented as part of a UNESCO symposium addressing the issue of education in post-colonial countries (Halliday, 1974). In many of these countries the colonial language was still used as the language of instruction but there was increasing interest and political desire to make use of local languages. In many cases a mathematical register did not exist in the local languages, raising serious questions for the development of mathematics education.

Some of the challenges related to developing mathematical registers are identified by Trinick, Meaney and Fairhall. Much of the work of these authors in the past has focused on the development of register for students learning mathematics in the Māori medium. However, in their contribution to this issue, they take a new direction by considering the unique challenges faced by the teachers who have to learn a developing and under-resourced mathematics and mathematics education register. The context of their work is one in which aspects of colonialism are being resisted, but in many parts of the world colonial languages still dominate.

Mathematics educators (and others) are still grappling with challenges arising from colonialism; challenges which are political as well as linguistic. On the one hand, questions about which language should be used for teaching and learning mathematics and about the effects on learning of using one language rather than another have been addressed by studying the affordances of a language and the issues that arise for learners. For example, Kazima (2007) identified issues in the learning of probability concepts in Malawi due to structural differences between the local language, Chichewa, and English, the language of instruction in secondary schools. Barton (2008) provides a fascinating discussion of relationships between the characteristics of a language and the kinds of mathematical thinking that may develop through using it. His theorisation of the relationships between mathematics and languages opens up a rich field of study.

However, the practical questions about which language to use in the classroom cannot be answered fully without addressing the wider socio-political role of language. The challenges presented by multilingual contexts are not only cognitive. Relational aspects of discourse are also strongly implicated when learners have different language backgrounds. This is due to the power relations associated with language differences, which are always political, and due to cultural differences, which often align with linguistic differences. Setati's work in the context of multilingual South Africa raises an important distinction between what she calls the epistemological access to mathematical ideas that may be

enabled by teaching and learning in a student's home language and the access to social, economic and political advancement enabled by developing higher levels of fluency in a world language such as English (Setati, 2005). In this issue, the article by Planas and Setati-Phakeng draws on the legacy of Setati-Phakeng's work in the South African context and Planas' work in Catalan contexts to recognize the power relations at work and suggest an approach to addressing them productively. They show how language can be viewed as a right, a problem, or a resource, and suggest the importance of viewing language practices as negotiable.

Increasingly educators around the world are faced with multilingual classrooms as global mobility of populations increases. However, the contexts vary considerably – culturally, linguistically and economically. Alongside issues of language, many of these contexts also involve complex issues of social deprivation, social and political exclusion and cultural differences and diversity. The learners in South African classrooms, in Catalonia and elsewhere in the world are not only learners of mathematics but are also becoming citizens of their own countries and of the world. The significant roles of language in both these domains cannot be ignored or resolved easily. As might be expected in a maturing field, considerable work is being done to map out the scope and develop a coherent understanding of the theoretical diversity brought to work in this area, yet there is room for further intercommunication.

5. A methodological issue: the multilingual global context

A common element throughout the wide scope of research relating to language and communication in mathematics teaching and learning contexts is the use of language-based forms of data. We identify here a methodological issue for such research, whether it is explicitly focused on language or merely using language as data.

In editing this issue and participating in other international research contexts, we are very aware of the privileged position accorded to contributors who are native speakers of English. Where international conferences and journals use English as the primary language for communicating scientific studies, many researchers experience the pressure of expectations to present their work, including the data and its analysis, entirely in English. This is not just a social and political issue but also a methodological concern.

Once we recognise that the words we use and the ways in which they are combined grammatically play a constitutive role in the construction of mathematical thinking, we also need to be aware of how this role may be different depending on the specific (national) language that is being used. However, it is rare to find examples in the international English language literature that present data or analysis in other languages except in studies whose main focus is on the distinct characteristics of the (national) language of the learners. By publishing only translated versions of interactional data, subtle yet important aspects of the functioning of language may be lost. Moreover, readers of translated data are likely to form their own interpretations based on the translated words – interpretations that may have no basis in the words of the original data. Recognising this methodological problem has implications for the production of research reports that need to be grasped and addressed by authors, editors and publishers.

Considering the wider impact of our developing understanding about language, we must also recognise that language choices impact theory, meaning, epistemology, etc. We

observe that theories and interpretive traditions that are strongly developed and shared by researchers with a common non-English linguistic background often have little impact on the work of those who do not share the language. This is clearly due in part to lack of access to publications in the original language. However, it is also the case that publications that are translated or written in a language other than that in which the original thinking was developed may function in ways that are different from communications in the original language. It is important for researchers, especially those who are in positions of influence and power within the field, to be aware of the problems inherent in communication across languages and to be intentional about learning from theories and interpretive traditions from non-English language communities.

6. Conclusion

In this issue of ZDM, the contributing authors present research oriented towards development of students' mathematics and towards understanding mathematics and teaching practices through scrutiny of connections within and between contexts. The papers are at once diverse, across theoretical resources and methodological approaches, and cohesive, agreeing as they do on the central role of language and communication in mathematical teaching and learning.

A range of theoretical and analytical tools can support our attention to language and communication in mathematical learning contexts; several are represented in this volume. These theories have often been developed originally within disciplines with priorities that differ from education scholarship and thus we encourage care in using them. On the other hand, when new theoretical tools are developed specifically to address mathematics education contexts and problems, it seems important to consider how they might be informed by existing and on-going work in other disciplines. It can also be warranted to develop theory and conceptual tools to address the differences in perspectives that impact the cross-fertilization of disciplines.

In some sense almost all studies involving language and communication in mathematics education also address other significant issues – learning, teaching, affect, identity, curriculum, assessment, etc. At the same time, it could be argued that, as most studies addressing such issues also make use of some form of textual data and communication between researchers and the participants in the research, the findings and theoretical developments related to language and communication are likely to have very broad implications.

We distinguish two orientations to the aims of research in mathematics education. On the one hand, researchers in mathematics education generally aim to produce knowledge that will in one way or another support the development of students' mathematics. On the other hand, researchers also aim to understand what happens in mathematics classrooms and other mathematics education contexts and to account for the development of the mathematical and pedagogic practices found in these contexts. We contend that both these aims strongly implicate issues of language and communication.

From the perspective of the first orientation, development of students' mathematics may be seen to be closely related to their development of linguistic competencies. This relationship is a consequence of the semiotic nature of our experience of mathematics, whether one accepts Sfard's identification of mathematical thinking with communicating or

holds to the independent existence of mathematical objects. There is widespread recognition of the difficulty that many learners have with mathematical language and the importance of language in learning mathematics. However much less attention has been paid to the question of how children learn to speak or write mathematically or to what kinds of mathematical-linguistic competence may be developed in the home, in pre-school settings and in other non-school settings. Detailed studies of classroom interactions sometimes demonstrate student acquisition of particular signs or ways of communicating during classroom mathematical activity (e.g. Temple & Doerr, 2012). However, the focus tends to be on how language use contributes to learning specific mathematical constructs. Little attention has been given to the more general issue of the acquisition of mathematical ways of speaking or writing that may be applicable and acceptable in a wide range of areas of mathematics. We suggest three areas of concern in which, while some work has been started, there is a need for more substantial and coordinated research effort.

- What are the linguistic competences and knowledge required for participation in mathematical practices?
- How do students develop linguistic competence and knowledge in subject-specific learning?
- What knowledge and skills might teachers need and use in order to support the development of students' linguistic mathematical competence?

From the point of view of research oriented towards understanding mathematics classrooms and other learning contexts, the role of language goes even wider – beyond the development of mathematical cognition to consideration of how language shapes and is shaped by the whole human experience. In addition to the importance of mapping the development of linguistic competences and the pedagogical needs that support this development, there is also a need for attention to the language choices made by teachers and students in the mathematics learning moment and to the connections between these choices and the social contexts, which both underwrite and are shaped by these choices. We also note that efforts to support language acquisition are examples of unique linguistic contexts. The particularities of these contexts are shaped by the language choices of people in power in those contexts and are artefacts of the power relations. For example, we have discussed the dominance of English in academic publications; this dominance is a reflection of colonialist histories, but also sustains those histories. Consideration of the shaping force of language choices enables us to see the possibilities for change. As mathematics education researchers develop understanding of mathematics education contexts through analysing how language operates in them, we are afforded the opportunity to change those contexts and to disrupt power relations in ways that may benefit mathematical learning.

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