Learning Mathematics and Language at the Same Time: An Initial Theorisation

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There is a growing body of research into mathematics education in multilingual or plurilingual classrooms. The attention of this work is firmly on the learning and teaching of mathematics in such settings. Researchers have generally avoided any consideration of language learning, despite the widespread expectations of students, communities and states that language learning take place in mathematics. If language learning is to be taken into account, however, a theorisation of mathematics-and-language learning is necessary. This paper draws on language socialization research to sketch such a theorisation. The ideas are illustrated with data from an ethnographic study in a second language mathematics classroom in Canada.

Keywords: Mathematics and language, Mathematics and multilingualism, Language socialisation

Introduction

How do school students learn mathematics when the language used in class is a language they are also learning? Although this kind of situation is increasingly widespread, it has only recently been the focus of research in mathematics education. There is now, however, a growing body of research into the teaching and learning of mathematics in multilingual or plurilingual settings, including second or additional language classrooms. This work examines a range of different issues, including students' attainment in mathematics, the nature of students' participation and the nature of the challenge faced by teachers (for a review, see Barwell, 2009). How students learn mathematics through a second or additional language is, however, only partly the focus of this paper. For the question has an antithesis: how do school students learn a second or additional language when the subject they are learning is mathematics? This question has been almost entirely ignored by researchers in mathematics education. Of course mathematics educators are not specialists in language learning so it is perhaps understandable that they should pay little attention to such a question. Nevertheless, the first point I want to make is that mathematics educators should give some thought to language learning. Why? Setati's (2008) research has highlighted the link between the politics of language and mathematics education in her native South Africa. Her work has highlighted a tension between, roughly speaking, languages that may be comprehensible to students and languages that may be more valued by students. In the case of South Africa, most schools adopt English as the language of learning and teaching for mathematics and other subjects. Most students, however, are in some sense learners of English (though arguably what is meant by English here is 'schooled English' or 'mathematical English'). Such students would certainly find mathematics more comprehensible if it were taught in their home languages although such an approach is not without its challenges. Despite a constitutional right to such a move, the students and teachers in Setati's research often express a preference for learning or teaching mathematics in English. Setati's research attributes this desire to a combination of mutually reinforcing perceptions: that English is the language of mathematics; and that English is the language needed to get on in the world. What this perception means is that many students and teachers implicitly assume that learning and teaching mathematics in English will also entail learning English.

Although Setati's research has not been replicated elsewhere in the world, the situation she describes is likely to be similar or at least analogous to many others. In some cases, it is the state that assumes that students will learn a national language even through their mathematics classes, such as in the UK, where learners of English as an additional language are expected to integrate into mainstream classes from the day they arrive in the school system. In other cases, the impetus comes more from home or community such as in countries where many languages are routinely spoken and intermingled, but some are more valued than others (e.g. India, Pakistan, South Africa). So my first answer to the question of why mathematics educators should pay more attention to language learning is that education systems, communities, parents, teachers and students expect language to be learned in mathematics classrooms. Indeed given this expectation, it is curious that researchers in mathematics education have paid so little attention to language learning.

There is, however, a second answer to the 'why' question. Simply put, mathematics learning and language learning are

inseparable. This point has not, however, been clearly made in studies of mathematics learning in multilingual or plurilingual settings. The most significant recent studies all subscribe to a view of language as social practice. Moschkovich (2008, 2009), for example, analyses the practices involved in situated meaning-making by Spanish-English bilingual students in Grade 8 mathematics classes in the United States. She argues that students' "multiple interpretations can serve as resources for instruction in bilingual classrooms" (Moschkovich, 2009). Writing in the context of the United States, where bilingualism is still often seen in deficit terms, she goes on to argue that:

> *This positive perspective on multiple interpretations is particularly important for bilingual classrooms. This mathematical discussion [analysed in the chapter] shows that multiple interpretations need not be seen as obstacles but can be used as resources for explaining and using important mathematical concepts […] This positive perspective on multiple interpretations shifts the emphasis from asking what difficulties bilingual students encounter to how instruction can support students in participating in discussions (p. 95-96).*

Implicit in Moschkovich's remarks is the idea that students are learning language as well as mathematics and indeed that teachers have a role to play – supporting students to participate in discussions is arguably a form of language teaching. Moreover, this social practice perspective implies that language learning and mathematics learning go together. Barwell (2005) has gone further in this direction in focusing explicitly on both mathematics learning and language learning in interaction between two Year 5 students in the UK who were identified by their school as learners of English as an additional language. The students were both from Pakistani backgrounds and spoke Urdu, Punjabi and English. Based on his analysis, Barwell highlights the reflexive relationship between mathematics learning and language learning, showing how the two students' attention shifted between mathematical and linguistic aspects of their task. The students' overall meaning-making drew on both dimensions, with negotiation of linguistic elements contributing to more developed mathematical meanings and negotiation of mathematical aspects leading to a more developed understanding of language features such as verb tense, spelling and genre. This work suggests that if we are to better understand students' learning of mathematics in such situations, we must pay attention to their learning of language, since language learning is not a separate process that has no impact on mathematics learning.

Why, then, should mathematics educators pay more attention to language learning? I have set out two related reasons. First, language learning is often an expected outcome of mathematics education and second, there is evidence that language learning and mathematics learning are intimately related. What is needed, therefore, is a more clearly articulated theorisation of the relationship between mathematics learning and language learning. In the rest of this paper, I sketch out and illustrate one possible theorisation of this relationship. To do so, I draw on research in a domain of applied linguistics known as language socialisation research.

Language Socialisation and Mathematics Learning

There has been a good deal of research on the role of language in mathematics classrooms or the relationship pective (O'Halloran, 2005; Pimm, 1987). The work in this paper builds on the discursive, practice-based perspective developed by Moschkovich, Barwell and others. Such work provides a way of conceptualising the interaction that takes place at particular moments in the course of a mathematics lesson. Learning, however, emerges over time. This process can also be understood in terms of practices, through the notion of *socialisation*, a notion that has been developed both in language learning research and in mathematics education. In the introduction to *Language Socialization Across Cultures*, (Ochs, 1986, a widely cited chapter) defines and discusses socialisation as follows:

> *…an interactional display (covert or overt) to a novice of expected ways of thinking, feeling and acting […] social interactions are themselves socio-cultural environments and that through their participations in social interactions, children come to internalize and gain performance competence in these socio-cultural [sic] defined contexts. They learn to recognize and construct (with others) contexts and to relate contexts (and elements within contexts) to one another. We do not consider children to be passive participants in the process of socialization. First […] we see children and other novices as actively organizing socio-cultural information that is conveyed through the form and context of actions of others…Second, children are active socializers of others…Even infants and small children have a hand in socializing other members of their family […] (p. 2, references omitted).*

In the case of learning mathematics, various processes are involved in facilitating the development of students' (i.e. novices') entry into a mathematical discourse community; i.e. the development of their proficient use of the discursive practices of mathematics (see Lerman, 2001). In the context of the mathematics classroom, the teacher plays a particularly important role in the socialisation process, through their influence in shaping the nature of classroom discourse (Cobb & Bauersfeld, 1995). Students' interaction with each other is also, however, an important site of socialisation into mathematical thinking and discourse (Zack & Graves, 2001). This discursive, practice-based perspective, well established in mathematics education, conceptualises mathematics learning as, in effect, a process of socialisation into the discursive practices of mathematics – albeit a particular kind of mathematics institutionally organised by schools, curricula, etc. (Lave, 1990).

Learning a subject like mathematics through a second or additional language involves socialisation into both mathematics and language:

> *[Second language] students' participation in activities such as discussions – perhaps peripherally at first, through observation, and then more actively – becomes instrumental in their becoming fully fledged, more proficient members of a classroom [...] Their participation, in turn, allows them to both reveal and develop aspects of their [...] linguistic and content-area knowledge (Duff, 2002).*

From this perspective, second language learners, as participants in a mathematics classroom community, are seen as learning mathematics and the language of mathematics through their gradual adoption of the mathematical, linguistic and social practices of that classroom and the wider school. Learning mathematics entails students adopting practices of mathematical meaning-making like conjecturing, with their use of these practices becoming more proficient over time. As Ochs (1986) suggests, however, students should not be seen as passive subjects of the socialisation process. Each student's contribution to classroom activity serves to reproduce the practices of the discourse communities into which they are being socialised, gradually changing these practices in the process. In addition to the teacher, the students are agents in the socialisation process, so that there is a reflexive relationship between the learning of individuals and the learning of the class as a whole. What is powerful about this perspective, as Duff (2002) illustrates, is that it makes possible the exploration of learning of both mathematics and of language. Again, this relationship must be seen as reflexive in nature: there is no clear separation between learning mathematics and learning the language of instruction. Students' developing mathematical practices and developing linguistic practices are two sides of the same coin (Barwell, 2005).

Ochs (1986), referring to language socialisation research (i.e. not generally classroom-based) summarises some of the discourse practices that "assist children in understanding what is going on an /or helping them to perform" (p. 6):

— Prompting the child to use an appropriate practice (e.g. 'say please').

— Announcing what is about to occur, is not occurring, or should be occurring or should not be occurring.

— Simplifying meaning or structure of prompts, announcements, directives etc.

— Repeating utterances or activities with the child as participant or observer.

— Expanding the child's utterance into an appropriate contribution (all from Ochs, 1986, p. 6).

Ochs points out that the use of these practices varies across cultures, although prompting seems to be widespread. Some of these practices have been observed in some form or in similar form in mathematics classrooms e.g. reformulation, repetition.

There are relatively few examples of studies of language socialisation in mainstream subject classrooms in which some or all learners are second language learners, perhaps because such studies tend to be broadly ethnographic in nature and thus very time consuming. Zuengler and Cole (2005) identified just ten classroom-based studies, most of which examined language rather than content classrooms (He, 2003; Kanagy, 1999; Willett, 1995) or focused on general classroom processes, particularly those relating to discourse roles and identity construction (Harklau, 2003). Key findings from this work include:

— an understanding of socialisation in the binary terms of experts and novices is simplistic: it is not always easy to identify who is an expert and who is a novice;

— language socialisation should not be understood as an exclusively consensual process: resistance and marginalisation, for example, have also been observed;

— issues of identity are as much a part of second language socialisation as learning vocabulary or correct grammatical forms;

— interactional routines are a valuable focus for tracing language socialisation over time.

The work discussed above provides a valuable starting point for an integrated theorisation of language learning and content learning. Language socialisation offers a detailed, language-focused view of language and mathematics learning, while mathematics education provides equally detailed accounts of the discursive practices associated with mathematical thinking. I have drawn on this combined perspective in an ongoing research study designed to examine second language learners in mathematics classrooms in Canada. In the next section I illustrate the theoretical ideas summarise above, drawing on some preliminary data from the study.

Learning Mathematics and Language in a Mathematics Classroom in Canada

During the current academic year, I have been visiting an Anglophone elementary school in Canada. A sizable proportion of the schools' students are second language learners of English, including several from Cree-speaking backgrounds. The Cree-speaking students are from Cree communities in northern Quebec, where most have, at some stage, attended Cree School Board schools. The early years of Cree School Board schools use Cree medium as a language of instruction. In the 2009-2010 academic year, an 'ESL' mathematics class ran for students in Grades 5 and 6 felt to be needing additional support in English. While the class included both Cree students

and students from immigrant language backgrounds, the majority were Cree. These students speak Cree with each other regularly in school, including during mathematics class. The number of students in the class has fluctuated between 7 and 10. The teacher is a White English-speaking woman in her fourth year of teaching.

The extracts below come from transcripts of a recording of the class engaging in what I have labelled the mystery number game (although the participants do not appear to have a name for this activity). The activity consists of the teacher choosing a number and then either giving a series of clues or inviting questions from the students. The students' task was to identify the number, either based on the teacher's clues or on her responses to their questions. The class have played some version of the mystery number game on several occasions, of which I have observed five. I first observed the game on 8 December 2009; most recently in March 2010.

When the class did this activity on 2 February 2010, the teacher provided clues for the five students who were present. Work on the first number to be identified began as shown in the transcript extract below. In the transcript, the teacher is TA and students are indicated by S (other transcript conventions are provided in[1]).

58	TA	sh: this is a (.) **two:** digit number (.) the first thing you
59		should do is write down (.) a line cause you know it's
60		**two:** digits (2.0) ^okay^ (2.0) **this** numbe:r **i::s** and **don't**
61		**scre:am** it out if you know it just write it down (.) this
62		number i::s an **o::dd** number which means that it's (.)
63		o:ne (.) three: (.) fi:ve (.) what comes next?
64	S1	don't know
65	Ss	^(*laugh*)^
66	Ss	[seven (.) nine
67	TA	[seve:n (.) ni:ne [(.) so it's an o:dd number not even
68		number o::dd number you don't have to write that down
69		just remember it o:dd number
70	S	[odd number

The teacher begins with the statement: 'this is a two digit number', with stress on 'two'. She also shows the students on the blackboard that they could write down two dashes, an iconic representation of an unknown two-digit number. Subsequently she states: 'this number is an odd number', and then attends to the meaning of 'odd number'. She glosses this word by examples, explicitly asking the students to complete the sequence and then contrasting it with 'even number'. The students contribute by completing the sequence of odd numbers. One student also echoes 'odd number'. These forms of participation potentially contribute to students' socialisation in relation to *odd number*. Completing the sequence of odd numbers socialises the students into its meaning of *odd number*; the contrast pair 'odd number/ even number' relates odd number with its antonym, although there is no direct evidence that the students take this up in this case; and the echoing (line 70) simply reproduces the key term. These practices contribute to students' language socialisation, in the form of the meaning and use of terms like *odd number* and *two digits*. The students are also participating in mathematical practices through their use of this language, completing a common sequence of numbers. A similar pattern is apparent in a later exchange:

87	TA	^get this down^ (1.0) okay this number and=this is the
88		la:st clue you're getting this is the la:st clue you're getting
89		this number is **ha:lf** (.) of fifty
90	S3	half of f[ifty
91	TA	[**ha:lf** of fifty(.) so think fifty (.) what's **ha:lf** of
92		fifty this number is **ha:lf** of fifty half of fifty (.) what's
93		half of fifty
94	S1	(…)
95	TA	what's ha:lf of fifty
96	S3	fifty divide by two
97	S1	three
98	TA	ha:lf of fifty
99	S3	no[(...)

The teacher's 'clue' (line 87) is responded to by a student who repeats the information. The teacher takes it as an opening to expand the statement, although in this case, she simply reformulates it as a question: 'what's half of fifty', before restating the information once more. One student offers a definition of 'half of fifty' but it is not hearably taken up. A few seconds later, however, a student prompts some elaboration:

116	S1	what's a half?
117	TA	half half so if you take fifty you cut it in half I wonder
118		what number would it be when you cut it in half
119	S	^five^ (3.0)

In response, to S1's request, the teacher offers a couple of different reformulations of the idea of half, couched in terms of a hypothetical student's action "if you take fifty…" (line 117). In the discussion of this last clue, the meaning of 'half' is central. Practices contributing to students' language and mathematical socialisation include the repetition of the information and a direct request for elaboration, an important example of students contributing to socialisation, in line with Ochs' (1986) point that socialisation is multidirectional.

Discussion and Conclusions

A variety of discursive practices that are likely to contribute to students' socialisation into mathematics and English are apparent in the preceding analysis. These practices are redolent those identified by Ochs (1986, p. 6) and include: repetition by the teacher, stressing key words, elaborating on the meaning of words or statements, echoing by students, completions and direct requests. Beyond these practices, however, the students and their teacher are constructing and relating contexts and their roles within them (Ochs, 1986). These contexts include 'school', 'mathematics class' and the specific mystery number activity. The use of expressions like 'odd number' or 'half of fifty' is part of the construction of mathematical activity, yet the meaning of these terms arises from that same context. The expression 'odd number' is simultaneously part of English *and* part of mathematics. Learning how to do the mystery number game entails learning how to use the language of the mystery number game – with the emphasis on use. Mathematics learning and language learning emerge through changing participation in these contexts over time. For example, some time later, the class again played the mystery number game, but one of the student's took on the teacher's role of thinking of a number. Learning how to use mathematical language and learning to think mathematically in the context of the mystery number game amount to the same thing. And learning how to use mathematical language is part of students' broader learning of English.

While the analysis I have presented in this paper is of a short activity from one mathematics lesson among many, it serves to illustrate the value of language socialisation as a way of framing and examining mathematics learning in multilingual or plurilingual settings in such a way that mathematics learning and language learning are fully integrated. Attention to the discursive practices of mathematics classroom interaction highlights the micro-level mechanisms through which mathematics-and-language thinking and learning take place. Of course, the illustrative analysis presented above is from one classroom in one multilingual setting. The mechanisms used in different settings may well be different, or may be used in different ways. In some settings (including the classroom referred to in this paper, though not in the extracts shown above), for example, several languages may be used; in others, only one. Nevertheless, in all settings, students are learning mathematics and learning language. Further analyses are necessary to develop and refine the language socialisation approach. In particular, the kind of analysis shown above suggests that such an approach has the potential to account for learning at several levels, including detailed micro-level discursive practices, broader discursive patterns and their evolution over time, and the joint construction of knowing, thinking and learning in mathematics-and-language.

Notes

[1] Transcriptions conventions: Bold indicates emphasis. (.) is a pause < second (2.0) is a timed pause > 2 secs. (...) indicates untranscribable. ? is for rising intonation. ^ ^ encloses whispered speech. Elongated vowels are shown with :: ( ) indicates transcription is uncertain. Vertically aligned square brackets [indicate overlapping speech.

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References

Barwell, R. (2005). Integrating language and content: Issues from the mathematics classroom. *Linguistics and Education,* 16(2), 205-218.

Barwell, R. (2009). Multilingualism in mathematics classrooms: An introductory discussion. In R. Barwell (Ed.), *Multilingualism in mathematics classrooms: Global perspectives*, 1-13. Bristol, UK: Multilingual Matters.

Cobb, P., & Bauersfeld, H. (Eds.). (1995). *The emergence of mathematical meaning: Interaction in classroom cultures*. Hillsdale, NJ: Lawrence Erlbaum.

Duff, P.A. (2002). The discursive co-construction of knowledge, identity and difference: An ethnography of communication in the high school mainstream. *Applied Linguistics,* 23(3), 289-322.

Harklau, L. (2003). Representational practices and multi-modal communication in US high schools: Implications for adolescent immigrants. In R. Bayley & S. R. Schecter (Eds.), *Language socialization in bilingual and multilingual societies*, 83-97. Clevedon: Multilingual Matters.

He, A.W. (2003). Novices and their speech roles in Chinese heritage language classes. In R. Bayley and S.R. Schecter (Eds.), *Language socialization in bilingual and multilingual societies*, 128-146. Clevedon: Multilingual Matters.

Kanagy, R. (1999). Interactional routines as a mechanism for L2 acquisition and socialization in an immersion context. *Journal of Pragmatics,* 31(11), 1267-1492.

Lave, J. (1990). The culture of acquisition and the practice of understanding. In J.W. Stigler, R.A. Shweder, & G. Herdt (Eds.), *Cultural psychology: Essays on comparative human development*, 309-327. Cambridge: Cambridge University Press.

Lerman, S. (2001). Cultural, discursive psychology: A socio-cultural approach to studying the teaching and learning of mathematics. *Educational Studies in Mathematics,* 46 (1-3), 87-113.

Moschkovich, J. (2008). "I went by twos, he went by one": Multiple interpretations of inscriptions as resources for mathematical discussions. *The Journal of the Learning Sciences,* 17(4), 551-587.

Moschkovich, J. (2009). How language and graphs support conversation in a bilingual mathematics classroom. In R. Barwell (Ed.), *Multilingualism in mathematics classrooms: Global perspectives*, 78-96. Bristol, UK: Multilingual Matters.

Ochs, E. (1986). Introduction. In B.B. Schieffelin & E. Ochs (Eds.), *Language socialization across cultures*, 1-13. Cambridge: Cambridge University Press.

O'Halloran, K.L. (2005). *Mathematical discourse: Language, symbolism and visual images*. London: Continuum.

Pimm, D. (1987). *Speaking mathematically: Communication in mathematics classrooms*. London: Routledge.

Setati, M. (2008). Access to mathematics versus access to the language of power: The struggle in multilingual mathematics classrooms. *South African Journal of Education,* 28(1), 103-116.

Willett, J. (1995). Becoming first graders in an L2: An ethnographic study of L2 socialization. *TESOL Quarterly,* 29(3), 473-503.

Zack, V., & Graves, B. (2001). Making mathematical meaning through dialogue: "Once you think of it, the Z minus three seems pretty weird". *Educational Studies in Mathematics,* 46, 229-271.

Zuengler, J., & Cole, K. (2005). Language socialization and second language learning. In E. Hinkel (Ed.), *Handbook of Research in Second Language Teaching and Learning*, p. 301-316. Mahwah, NJ: Lawrence Erlbaum.