The flows and scales of language when doing explanations in (second language) mathematics classrooms

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I develop the idea of sources of meaning by proposing the notions of scale and flow as a way to think about participation in mathematics classroom discourse. Flow emphasizes the dynamic nature of language use, while scale makes apparent its stratified and stratifying nature. Drawing on an ethnographic study of four second language mathematics classrooms in Canada, I examine the flow and scales arising in interaction in one 'language positive' classroom: a group of recently arrived immigrants to the province of Quebec. The analysis focuses on examples of the construction of mathematical explanations to illustrate the role of scale-jumping in the construction and stratification of mathematical meaning.

Keywords: Language diversity, second language learners, scale-jumping, social stratification, mathematics classrooms.

Introduction

The political role of language in mathematics classrooms has long been recognized in research in mathematics education. In particular, research has demonstrated the role of language in the reproduction of social structure. In the UK, Cooper and Dunne (2000), for example, showed how differences in children's interpretations of word problems were related to differential rates of success in solving such problems (where 'solving' refers to the production of responses that fit the conventional expectations of school mathematics). Cooper and Dunne showed that such differences were related to students' socio-economic backgrounds, such that students from working-class backgrounds were more likely to produce more 'realistic' responses, which were therefore often considered incorrect. Their work shows how language is not a neutral feature of mathematics classrooms, but contributes to the marginalization of some students (see also Zevenbergen, 2000). As a result, Morgan (2012) has argued for greater attention to social structure in the analysis of mathematics classroom discourse.

A political dimension has also arisen in research on language diversity in mathematics classrooms. This work has particularly focused on the perceived value of different languages as a way to explain how languages are positioned in mathematics classrooms in different contexts. Setati (2008), for example, showed how English was more valued as a language of instruction by parents and students in South Africa, since it was perceived as giving access to better jobs and education, despite making the learning of mathematics more challenging when students spoke other languages at home. In later work, Setati (now Phakeng) and others have argued for languages to be thought of as resources for learning, and that the use of language as a resource is mediated by the broader political landscape in which mathematics classrooms are embedded (Planas & Civil, 2013; Planas & Setati-Phakeng, 2014).

The above work points to the significance of the relationship between language, mathematics learning and marginalization. That is, we know that part of the explanation for differences in students' performance in school mathematics is their socio-economic background, including their racial or

linguistic background, although the relationship is not simple (see, for example, Secada, 1991, but also Clarkson, 2007). This relationship seems, in part, to be mediated by language. The work summarized in the first paragraph draws on sociology to understand this relationship, using concepts like linguistic capital, arguing that mathematics classroom interaction is shaped by much broader social structures. The work referred to in the second paragraph draws on discursive perspectives, using the concept of language as a resource which students and teachers can use to access desired parts of the social structure. But how does the relationship between language use and social structure play out in the moment-by-moment exchanges of a mathematics classroom? In this paper, I draw on the notion of scale to explore this question, with a particular focus on students' explanations.

Theoretical perspective: flows and scales

To think about the role of language in mathematics classrooms, I use the idea of sources of meaning, in which language is seen as a kind of flow. In participating in interaction, speakers navigate this flow, making use of parts of the current to make meaning with each other. In so doing, they also alter the flow, so that downstream, language is slightly different from what it was before. The flow of language has several general features (Barwell, 2018):

- *Meaning-making is relational* – there are no absolutes in language; meaning arises from the relations between multiple features of language, from phonemes to discourses to languages; these relations are always situated and depend on where speakers are in the flow;
- *Language is agentive* – in navigating the flow of language, speakers are pushed and pulled by language, so that multiple, often unintended meanings are possible; this dimension of language contrasts with ideas like languaging, which emphasize the agency of speakers;
- *Language is diverse* – the flow contains many currents, including strong 'mainstreams', as well as eddies and backwaters, all of which are constantly changing; all parts of the flow interact and shift, with new currents forming and existing currents dispersing over time.

Thinking about language in terms of flow highlights the dynamic, agentive nature of language, into which humans insert themselves as they interact. One of the drawbacks of this image, however, is that, as shown in the literature, the role of language in society and in education is not neutral. Blommaert (2007) argues that metaphors like flow therefore fall short, and proposes the metaphor of scale. Integrating this idea into the sources of meaning framework gives a fourth feature of language:

- *Language is stratified and stratifying* – language is "a system full of inequalities, in which people and actions develop on or across different scale-levels, and in which moves across such scale-levels are moves within a power regime" (Blommaert, 2007, p. 15). Working with some streams of language connects across wide scales, while others are locally located; forms of language are indicative of higher or lower status (institutional, political, educational, etc.) within a given milieu; higher status generally corresponds to wider scales.

Overall, therefore, the sources of meaning framework emphasizes the dynamic, contingent nature of language in use, as well as the way language is ordered across different scales. The notions of flow and scale link the individual moments of language to broader social structure.

Background to the study

The data for this paper comes from an ethnography of four second-language mathematics classrooms in Canada, a country with two official languages, English and French. Data including observations, audio-recordings, interviews and students' work were collected in four different classrooms featuring

second-language learners: a mainstream anglophone class in which some students were learners of English as a second language (class A1); an anglophone class specifically for learners of English as a second language, all of whom were of Indigenous Cree background for most of the year (class A2); a francophone 'welcome class' for new immigrants who were all learners of French as a second language (class B); and a French-immersion class in which most of the curriculum was taught in French to students who did not speak French at home, so that they would become proficient in that language (class C). Classes A1, A2 and B were of grades 5-6, while class C was of grade 3.

In recent analysis of the full dataset, I developed a distinction grouping these classes into two: I characterized classes A1 and A2 as *language neutral mathematics classrooms* and classes B and C as *language positive mathematics classrooms*. This distinction was on the basis of a detailed analysis of how students in each class appear to be socialized into the discourse of mathematics as well as the medium of instruction. Language diversity was present in both types of classroom. In language positive mathematics classrooms, this diversity was explicitly recognized and incorporated into discussion of mathematics in different ways. In language neutral mathematics classrooms, language diversity was more implicit and tended to be skirted around in classroom interaction. (For a detailed account of this work, see Barwell, 2020). This analysis, however, did not explicitly examine the stratified and stratifying nature of language in mathematics classrooms. In this paper, therefore, I present a preliminary analysis of language flow and language scales in a language positive classroom (class B), and offer a brief comparison with these aspects of interaction in the language neutral classrooms, with a specific focus on students' mathematical explanations.

The analysis is organized around the idea of scale-jumping, which designates moments in which participants indicate a scalar shift in language use or their interpretation of an utterance (Blommaert, 2007). Scale-jumping can involve participants marking shifts "from the individual to the collective, the temporally situated to the transtemporal, the unique to the common, […] the specific to the general" (p. 4). Here is an example of scale-jumping from class A1 (language neutral, observed 10 December 2008):

Teacher L: number two Darryl, where does it [the decimal point] go?

Darryl: (indicates where)

Teacher L: how do you know Darryl?

Darryl: I just know

Teacher L: you know what if you write that on your exam, what do you get?

Whereas Darryl's response may be locally acceptable (e.g., to himself, to his classmates), the teacher introduces a wider scale, institutional reading of his response. Exams are widely used (in this case, the teacher is referring to provincial exams) and impose wide-scale mathematical discourses, including with respect to explanations. The teacher's framing is therefore bound up with the measurement and performance of students, in which 'success' involves particular kinds of discourses.

For this paper, I selected an example of students in class B (language positive) participating in mathematical explanations, which had been recognized in previous work as significant in terms of students' participation in mathematics (Barwell, 2020). I examined the transcript for examples of

scale-jumping, which were then unpacked in terms of the other aspects of the sources of meaning framework. In the last part of the paper, I briefly compare the results of this analysis with those from a previously published analysis of interaction in an episode from class A2 (Barwell, 2016).

Scale-jumping in mathematical explanations in class B

This notion of scale is highly applicable to (second language) mathematics classrooms, since the goal is to introduce widely scaled mathematical discourses, as well as an educated variety of the medium of instruction. The following extract comes from a series of lessons on geometry, in which the students, all newcomers to Canada and learners of French, were introduced to various geometric forms and their properties. The teacher used a variety of activities and styles, including group work, student-generated ideas, worksheets with various tasks and whole class interaction. In this extract, the teacher is reviewing some different geometric forms and encouraging the students to think about similarities and differences and find ways to articulate them.[1]

Teacher N:	ok E5 est-ce que tu peux m'expliquer la **diff**érence entre un ovale et un cercle ? {*ok E5 can you explain to me the **diff**erence between an oval and a circle?*}
E5:	uhm ok
Teacher N:	explique moi la [difference {*explain the difference*}
E5:	[ah le cercle il fait la troue comme ça et le ovale il est comme ça (.) pas de lignes mais il est comme drette ici (.) pas tout ça comme ça {*ah the circle it does the hole like that and the oval is like that (.) no lines but it's like straight here (.) not all like that*}
Teacher N:	o:k: et si je fais ça comme ça ? qu'est que c'est ? {*o:k and if I do this like that? what's that?*}
E5:	c'est un ovale {*it's an oval*}
Teacher N:	pourquoi ? {*why*}
E5:	parce que il est comme ça ici (.) un cercle est tout comme ça ici {*because it's like that here (.) a circle is all like that here*}
Teacher N:	ok est-ce que quelqu'un est capable de t'as la bonne réponse E5 ? quelqu'un qui serait capable de l'expliquer plus précisément ? {*ok can someone you have the right answer E5 someone wuo could explain more precisely?*}
E6:	c'est comme que c'est un cercle mais c'est comme tu fais un cercle comme ça et fait comme ça {*it's like that it's a circle but it's like you do a circle like that and do like that*}
Teacher N:	c'est comme si tu pousses sur le cercle ? {*it's as if you push on the circle?*}
E7:	**ouais (.)** {***yes***}

[1] bold shows emphasis, timed pauses are in ( ), = shows latching, ? for rising intonation, : shows vowel extension, overlaps are shown with aligned [, my English translation given in { }.

Teacher N: un cercle=hein quand tu regardes le milieu (.) le milieu (.) si on regard à n'importe [quel côté ça va être la **même** longueur bon alors moi mon cercle il n'est pas parfait (.) mais un ovale (.) il n'a pas la même longueur (.) c'est comme si on avait pesé sur le cercle {*a circle=eh when you look at the middle (.) the middle (.) if you look at any side it'll be the **same** length (.) it's like someone had pushed on the circle*}

E8: [et là il va partout {*and there it goes everywhere*}

This extract concerns the difference between an oval and a circle and most of the exchange is devoted to constructing an acceptable explanation of this difference. The students' contributions are notable for their use of deixis: locally specific forms of reference, such as 'this' or 'there', as well as physical gestures. In the first half of the exchange, both students and teacher make repeated use of several deictic forms, including 'like that', 'here', and 'this'. These formulations are not somehow limited, imprecise, or deficient forms of mathematical discourse; it seems clear that the participants are able to follow each other's utterances. More generally, we see several formulations and reformulations that appear to concern the same general idea. There is, however, one example of scale-jumping: in the teacher's 5th turn, she acknowledges that E5's formulations have responded to the question, but then asks if anyone can explain 'more precisely'. E5's initial formulations are acknowledged as answering the question, but a revision is necessary. The problem with E5's formulations, framed in terms of precision, is that they are only locally meaningful. The heavy use of deixis all but guarantees that E5's explanation is locally constrained. His interaction with the teacher is in a part of the flow of language that involves French and some mathematics, as well as deixis, gestures and words like 'hole' that are not typically considered part of mathematical discourse. The teacher's request for precision, then, is really a request for a formulation with a wider scale of utility: she is calling for a shift to a more standard form of mathematical discourse as might be recognizable to mathematically knowledgable speakers elsewhere. E6 attempts to respond, largely drawing again on deixis and gesture. This response does not appear to meet the explicit request for precision, or the implicit request for a wider scale discourse, since the teacher provides her own more elaborated explanation.

The teacher's version does not simply involve a more sophisticated vocabulary or syntax – she uses 'middle', 'side' and 'length', and the construction 'as if' among other things. It also introduces a mathematical principle of a wider scale discourse: the idea of constant radius. Wider scale does not necessarily mean more frequently used; rather, it means used across a wider range of space and time. The idea of constant radius would be recognized by mathematically educated people in many places, in a way in which the exact words of the students can only easily be interpreted in the immediate location of their utterance. Interestingly, the teacher links this principle back to the students' versions by talking about 'pushing' again. The scale-jump was in this instance only temporarily effected, since the discussion returns to a more local scale immediately afterwards. The teacher's use of scale-jumping nevertheless serves a valuable pedagogical purpose: it introduces a distinction (labelled with the word 'precise') between local, informal, proximal mathematical discourses and wider scale, formal, distal mathematical discourses. The difference between them is neither absolute, nor inherent in the language; it emerges from the relation between the forms now marked as different.

A similar pattern can be observed in the next extract, which immediately follows the previous one:

Teacher N: ok **E13** explique moi la différence entre un **rec**tangle et un **car**ré {*ok E13 explain to me the difference between a **rec**tangle and a **squa**re*}

E13: il n'est pas il est comme (.) umm il a comme il a hhmm [(.) non ? il est carré c'est u peu haut petit petit {*it isn't it's like (.) umm it's got like it has hmmm (.) no? it's square it's a bit high little little*}

E14: [égal {*equal*}

Teacher N: donc le rectangle il est **long** (.) ok (.) alors si je fais ça (2.5) ça est-ce que c'est long ? (.) {*so the rectangle it's **long** (.) ok (.) so if I do that (2.5) is that long? (.)*}

E13: le gros carré normal petite (.) c'est long (.) mais carré petit comme tu le fais c'est petit comme ça mais petit mais c'est la même le même {*the big square normal small (.) it's long (.) but square small like you do it it's small like that but small but it's the same the same*}

Teacher N: t'es proche t'es proche {*you're close you're close*}

E13: je pense aussi ça fait un ligne c'est pas la même mais là le carré c'est le même longueur {*I think also it does a line it's not the same but there the square it's the same length*}

Teacher N: c'est ça si je prends un règle (.) le carré les **quatre** côtés vont mesurer la **même chose** (.) ça va être pareil (.) le rectangle il y en a deux qui peuvent être un peu plus petits que les deux autres qui sont plus longs tu comprends la différence ? {*that's right if I take a ruler (.) the square the **four** sides will measure the **same** (.) it'll be equal (.) the rectangle there are two that can be a bit smaller than the two others that are longer do you understand the difference?*}

Several: **oui:** {***yes***}

Once again, the students contribute highly localized explanations for the difference between a square and a rectangle. Their utterances are also grammatically, syntactically and phonologically unconventional. The teacher nevertheless participates in mathematical meaning making with these utterances, drawing out particular details such as 'long'. As in the previous extract, she scale-jumps, in this case by providing an elaborated formulation of key differences between the two geometric forms. The wider scale of this formulation is not just due to the use of more formal mathematical vocabulary, but also in the reasoning that is shared i.e. measuring and comparing lengths of sides. As with the previous extract, the teacher introduces a wider scale mathematical discourse.

Discussion

These two extracts give a sense of how the notions of flow and scale allow for a dynamic understanding of meaning making in (second language) mathematics classrooms, as well as a sense of how these processes are stratified and stratifying. In both the above extracts, students participate in the flow of language. They bring larger repertoires than that which is audible in the classroom; they all speak one or more other languages at home. Within the institutional context of the school, French is privileged. The students are buoyed by this flow in which, nevertheless, multiple sources

of meaning are available, including their non-standard French, deixis, gestures and the texts and diagrams found in worksheets and on the blackboard. I do not see the students as taking up resources to produce particular meanings, so much as hitching a ride on particular flows, forming them as best they can for their purposes, but having to accept what is already there in the stream.

There are, however, different scales of discourse available in this current. Deixis and gesture, and idiosyncratic pronunciation are local and proximal, while the teacher (in this case) offers formulations that draw on wider scale sources of meaning, both in the words and construction of her utterances, as well as in the forms of mathematical reasoning (as realized in her words) that she exemplifies. These different scales produce a clear stratification, with the teacher's 'precise' formulations drawing on higher status discourses that are connected to educational success, among other things. Students' utterances are positioned as of lower status; they are 'close' but not 'precise'. The broader institutional and political structures in which the class is embedded produce this ordering of discourses, from the official language policy, to the requirement for these children to attend a francophone school, to the mathematics curriculum and provincial assessment systems. To be successful in the school system, students must learn to produce the desired wide-scale mathematical discourses. As immigrants, however, they do not necessarily encounter the French language at home and may bring other discourses of educational success which do not map onto the mathematical and educational discourses of their new home. Students therefore begin in a relatively marginalized position.

In this language positive classroom, the teacher mediates students' engagement with mathematical and educational discourses. Much of the time, she focuses on students' mathematical thinking and meaning-making (rather than their pronunciation, for example), and makes connections between the different discourses. For example, she takes up students' suggestions of ovals being squashed circles, talking about 'pushing' circles into oval shape. She introduces wider-scale discourses but sets them in explicit dialogue with the students' local formulations. This kind of connecting is in contrast to the language neutral classrooms, where students encountered wider scale discourses as rather alien. For example, in earlier work, I showed how two Indigenous students worked on a word problem that referred to a situation and used a way of seeing the world that was alien to the students' experiences and worldview (Barwell, 2016). In this classroom, the students were expected to acquire a new discourse with less opportunity to connect it with their own. Moreover, these mathematical discourses were embedded in institutional and political structures that were linked to a history of oppression.

Conclusions

The political role of language in (second language) mathematics classrooms has been acknowledged for some time. In research on language diversity in mathematics classrooms, the focus has mostly been on students' choice of language. In the second language classrooms in my study, this choice was already made for students. Other aspects of language are, however, implicated in the stratification of mathematics classroom interaction. This stratification is related to broader social structures, but not in a simple way. The idea of language as flow emphasizes how language is dynamic and how students must navigate these flows to make mathematical meaning. The notion of scale emphasizes how classroom discourses are ordered, such that some forms of expression are considered less valuable, precisely because they are not widely recognized. From this perspective, succeeding in mathematics means learning to navigate the flow of language, to shape it to one's intentions, and to be able to shift

levels within the prevailing order. My analysis of examples from a language positive classroom suggests that teachers can support the learning process by connecting discourses of different scales so that students can learn to make these shifts in their own mathematical meaning-making.

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