SECONDARY TEACHERS' TALK ABOUT THE MATHEMATICS REGISTER

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The mathematics register refers to the forms of meaning and styles of communication characteristic to the mathematics disciplinary community. An important role of teachers is to support students in developing facility with the mathematics register in order to support students' learning. This study focuses on the ways in which a group of secondary mathematics teachers talked about the mathematics register over the course of a year-long study group. In particular, we analyze their discourse to identify themes and shifts in the ways they collectively made sense of the mathematics register. We found that the teachers came to discuss the mathematics register as more than specialized vocabulary, and we anticipate that their understanding of the mathematics register will continue to deepen as they use this academic idea in the context of their own teaching practice.

Keywords: Classroom Discourse, Teacher Education-Inservice/Professional Development

Researchers in mathematics education have become increasingly interested in mathematics discourse and classroom discourse (Ryve, 2011). In particular, the idea of the "mathematics register" has become central to this research. Michael Halliday (1978), a sociolinguist, introduced this idea and defined it as:

> A register is a set of meanings that is appropriate to a particular function of language, together with the words and structures which express these meanings. We can refer to a 'mathematics register', in the sense of the meanings that belong to the language of mathematics (the mathematical use of natural language, that is: not mathematics itself), and that a language must express if it is being used for mathematical purposes. (p. 175)

Our review of literature utilizing the mathematics register (MR) has shown that the number of articles using this idea has more than quadrupled from the 1980s to the 2000s. The use of MR, however, seems to have stayed primarily in the mathematics education *research* community, which raises the question of how it might be taken up by mathematics *teachers*.

In this article, we build upon the existing literature to investigate how teachers, who were involved in a year-long study group focused on secondary mathematics classroom discourse, talked about and made sense of the "mathematics register." In order to make theoretical ideas useful to practice, we would argue, it is imperative to better understand how people who might use the ideas with students in classrooms talk about and make sense of the ideas. In fact, some research has suggested that teachers' implicit understandings of mathematical discourse (and the values that go along with those understandings) shape teachers' assessment practices (Morgan, 1998). Thus, it seems important to understand these implicit understandings in order to capitalize on them in work with teachers in contexts like study groups. Although we restrict our focus to how the teachers talked about the MR in the study group and not what they did with it in their

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classrooms, we would argue that this remains an important step toward informed work on how the MR is taken up in the context of classroom practice, especially since the activities of the study group were grounded in artifacts of practice.

Theoretical Perspectives

Our overarching framing of this work is sociocultural and sociolinguistic. We see learning as being related to participation in discourse practices of a community (Lave & Wenger, 1991). Because participation and context are central to learning, we draw on the tools of systemic functional linguistics (SFL) in our analysis. SFL assumes that language learning is intimately related to the cultural and situational context in which the learning takes place (Halliday & Matthiessen, 2003). Halliday, who introduced the MR, was a pioneer in SFL.

Pimm (1987) elaborated on Halliday's beginning definition of MR provided earlier, pointing out that Halliday was not only talking about how mathematical terms are used but also saying that there are characteristic phrases and certain modes that are acceptable for processes such as argumentation. These modes of argument, for example, should be precise, brief, and mathematically logical (Forman, McCormick, & Donato, 1997). O'Halloran (2005) provided a detailed description of the MR by focusing on the processes, representations, symbolism, and so forth. O'Halloran highlighted, in particular, the important role that this range of meaning systems plays in construing mathematical meaning.

Schleppegrell (2007) delineated many grammatical patterns used to construe the MR, beginning with aspects related to mathematical vocabulary, such as the fact that certain terms may take on different or more precise meanings in the MR than they do in other contexts. Beyond mathematics vocabulary, Schleppegrell also described how dense noun phrases, nominalizations, logical connectors, and verbs can be challenging for students. With regard to dense noun phrases, when contrasted with students' out-of-school experiences, relatively short written and spoken phrases in mathematics may hold a great deal of meaning in very few words. Moreover, within the mathematics register, complicated processes are turned into nouns—called nominalizations—so that we can do new things with these processes. Examples of nominalizations in mathematics include "rotate the triangle 90 degrees in the plane" becoming "the rotation" and "taking the limit of a difference quotient" becoming "the derivative." In some cases the nominalization involves a new form of the original verb (as in rotation), but in other cases a new noun is introduced (as in derivative). A result of nominalization is that the human participants are removed from the statement, giving agency to mathematical objects and processes rather than to the people who are doing the mathematics. Even the verbs tend to be different in the MR. In other domains, there tends to be a prevalence of doing or thinking verbs, for example. In the MR, however, relational verbs like *be*, *have*, and *means* are more often used to express relationships between objects and processes.

The characteristics described here provide some insights about what makes the MR complex and potentially difficult for students. It also highlights the fact that the teacher's role as a "more knowledgeable other" is important in scaffolding students' facility with these meaning systems and grammatical characteristics. Yet, Morgan (1998) has provided evidence that teachers unknowingly evaluate students' work based on their differential use of characteristics of the MR. So, it is important for teachers to be aware of the particular ways in which mathematics is construed in language and to make these language choices more explicit to themselves and to students. As Schleppegrell (2007) pointed out, supporting students to develop facility with the MR takes time and serious consideration. Such consideration requires that teachers recognize

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these characteristics of the MR. Here we investigate how teachers talked about and made sense of this idea in the context of a study group about mathematics classroom discourse. In this way, we sought to answer the following questions: What kinds of discourse practices did the secondary mathematics teachers use to participate in discourse *about* the mathematics register? How did they talk about this idea over time? and Which characteristics of the mathematics register garnered the most attention?

Method

Setting

The participants in this study were middle school and high school mathematics teachers from three different school districts. The nine participating teachers had varying educational backgrounds, teaching experience, and classroom settings. Most of the teachers had little or no prior professional development (PD) experience focused explicitly on classroom discourse, though some had completed teacher preparation programs that included work on discourse-related ideas and one teacher was also certified to teach English. The teachers volunteered to participate in the pilot of a set of PD materials focused on classroom discourse (see Herbel-Eisenmann, Steele, & Cirillo, 2013), thus indicating at least some level of interest in classroom discourse and a potential desire to make changes in this area of their practice. The facilitation team comprised two faculty members and four graduate students. Almost all had classroom teaching experience and had worked with prospective and practicing teachers previously. The facilitation team was comprised of two men and four women and all facilitators were involved in writing and revising the PD materials that we were piloting.

The PD materials were designed to support teachers in becoming purposeful about developing productive and powerful discourse in their classrooms, where *productive* refers to discourse that supports students' access to mathematical content and ways of meaning and *powerful* refers to discourse that positions students as legitimate knowers and doers of mathematics. One particularly important idea from sociolinguistics that is explored throughout the materials is the mathematics register. The first unit focuses primarily on students and characteristics of mathematics classroom discourse. It launches an investigation of the mathematics register by looking at student written work and textbook pages. In the second unit, particular "teacher discourse moves" (TDMs) are introduced and teachers are encouraged to consider their use of TDMs with respect to developing productive and powerful discourse. The remaining units include a variety of activities, many of which directly involve the mathematics register as the teachers analyze and discuss their mathematics textbooks, cases of classroom discourse, and artifacts from their own teaching practice.

Data

Study group sessions were approximately three hours in duration and occurred every 2–3 weeks throughout an academic year. Project team members video recorded and took field notes at each session and collected teacher artifacts (e.g., written responses to discussion questions, notes on hand-outs). For this analysis, we identified study group activities that related directly to the mathematics register. These activities either involved the mathematics register by name after it had been introduced and defined or were from early sessions in which various ideas related to communication in mathematics classrooms were discussed. Through this process, fourteen activities were identified for further analysis spanning nearly the entirety of the PD pilot.

Analysis

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To analyze each of the fourteen PD activities related to the mathematics register, we employed a form of thematic discourse analysis (Herbel-Eisenmann & Otten, 2011; Lemke, 1990). First, we reviewed the videos and formed lexical chains that mapped the flow of the discussion over time. Second, we identified the segments of discussion from the lexical chains that involved the mathematics register most directly. For example, segments of the discussion pertaining to the characteristics that made one explanation "more mathematical" than another were marked for further analysis, whereas the segments from the same discussion in which the teachers talked about types of tasks that they had enacted in their classrooms were not. Third, with these focused segments, we generated thematic maps of the terms used by teachers and the semantic relations construed between the terms (Herbel-Eisenmann & Otten, 2011). This process illuminated the ideas that arose in the discourse related to the MR and also provided a representation of how teachers were making sense of those ideas in each particular interaction. Finally, we identified recurring themes in the ways that the teachers engaged in the discourse as they discussed the MR and also examined shifts in the content of the teachers' discourse related to the MR. Specifically, our analysis highlighted two particular discourse patterns that the teachers used to make meaning of the MR: providing particular examples of characteristics associated with the mathematics register and were sometimes able to connect these examples to broader categories (e.g., audience, who the actors were, dense phrases, use of logical connectors) associated with the MR; and utilizing comparison and contrast as a means for talking about what they noticed with respect to the mathematics register. In the findings, we illustrate these two meaning-making themes related to the language practices the teachers used to make sense of this idea.

Findings

The two salient themes that emerged from the teachers' talk about the MR were comparison and contrast (comparison/contrast) as a meaning-making device in the discourse and the use of examples to highlight broader categories related to the MR (examples/categories). We use these two discourse patterns to organize our presentation of the findings of how the teachers' discourse about the MR shifted over time. We thus organize the examples chronologically and highlight only a few representative excerpts in each section below to illustrate some of these themes and to show some of the subtle differences we saw over the course of the PD.

Early Professional Development Sessions

Several times across the sessions, teachers identified specific mathematics terminology or vocabulary as examples related to the MR. They provided examples of these words and also named it by the category "math terminology" or "vocabulary." In early sessions, they sometimes used the category label of "language" to be synonymous with vocabulary. An early excerpt from the PD, in which the teachers identified the category of "math verbs" and listed examples, is given below. The teacher here was sharing aspects of her definition of discourse. The other teachers then added their own examples.

Kelly: Using and just understanding the other math verbs appropriately. Calculate, justify, analyze.
Xander: Construct, draw.
Diedre: Describe.
Kelly: Estimate.
Diedre: [laughing] Find, solve.

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Generally speaking, we found that the participants often focused on mathematical terminology. In another example, a participant described how her students were using the "right vocabulary" and she listed "perimeter," area," and "angles" as examples of this vocabulary. We noticed that this emphasis on mathematical terminology persisted across the sessions, but it tended to be a sole focus in the early sessions.

In this next excerpt, both meaning-making themes (example/category and comparison/contrast) are illustrated. After each participant said something about his or her own definition of discourse (shown in the previous example), the group began to discuss their definitions and a reading they had just completed about the definition of discourse underlying the PD materials:

> *Diedre:* I kind of like the paragraph here [in the reading], where it said, you know--, it's related to the fact that students are studying *math* and what we use in our connections and our words have totally different meanings than when they come in and out of other classes. And that's really hard to get across to other people that are coming in and watching, you know, there is a specific meaning to "if-then", you know, and it means something very different and not just, well, that *and* that.
>
> *Xander:* But then there is also showing the similarities that there are. Like, you know, when you have a word like intercept, showing them that it's not just some new math word. OK, what does intercept mean in the real world when you are talking, when you say that word intercept a pass in football or intercept your path? OK, it means the same thing in math, just on a graph context. So, yeah, some are different, but some are the same and having that discussion of where you see these words and where we get them in math.

In this excerpt, Diedre stated that connections and words in mathematics contexts have different meanings than in other contexts. The category Diedre exemplified may be characterized as "connections and words with different meanings in math" and she provided the example of if-then. Xander provided another example, intercept, but shifted the category to similarities in meaning and in doing so drew a contrast with Diedre's example, marked with the word "but" in the first and last sentences of his turn.

We see Xander's contribution as illuminating an issue of theory and practice at play. Xander is someone who tried to develop meaning for mathematical ideas by building on students' prior knowledge from outside of the classroom to make aspects of mathematical language and communication meaningful. These connections can be valuable in a practical sense and are important with respect to developing classroom discourse, yet these connections also emphasize similarities between different contexts rather than differences that help to illuminate particularities of the MR. Having access to such nuances are important for students, especially students who have been historically underrepresented in mathematics classrooms (e.g., see Moschkovich, 2007).

Later Professional Development Sessions

In an interaction two PD sessions later, teachers discussed excerpts from mathematics textbooks related the ideas of area and perimeter. Whereas the previous (and earlier) excerpts showed the teachers focusing primarily on mathematical terminology rather than other particular characteristics of the MR, this excerpt contains the beginning of a more nuanced understanding of the MR. In this case, however, one of the facilitators, Beth, played a central role in the interaction by asking the teachers to reflect on uses of the word *is* in the textbooks they were examining. The uses of *is* in the excerpt is readily articulated by Diedre and other teachers'

contributions indicate that this information is new to them. The topic, however, is not taken up further by the group or elaborated on:

Beth: I was noticing in what you [Diedre] just read [from the textbook], "the base is changed to twice its current measure." And then the other one in the upper right hand, "line segment BF is the perpendicular bisector." How is *is* being used differently in those two [sentences]?
Diedre: Yeah, one's being equal and one's an attribute.
Beth: So they're indicating different relationships between the noun, or what is before *is* and what follows it, which I think could make it [the meaning of *is*] confusing, too.
Xander: That's true.
Beth: Because if I thought base *is* change, that those two [phrases] are the same thing.
Xander: I always preach that *is* means equals.
Donna: I do too.
Maggie: That's very confusing.

Here, Beth pushed participating teachers to consider an example of a characteristic of the MR by re-reading two lines from the textbook a teacher had just read and drawing a contrast between the two. In these lines, there are differences in the uses of the word *is* that are common in the mathematics register but often go unnoticed. Diedre quickly identified the functions for these two uses, but did not quite provide a category for this instance. Beth pointed out that these are "different relationships" between "the noun" and "what follows it," locating the example as being about relational verbs (e.g., *being* and *having* verbs). Such a category might also include the fact that relational verbs are typically more common in the MR than in other kinds of texts. For example, many non-mathematical texts would describe what people are doing, thinking, or talking about, rather than indicating abstract relations between objects, which is common in the MR. Although the teachers did not name the category in this interaction, we see the instance as representing a shift in attention to characteristics of the MR beyond mathematical vocabulary.

Three sessions later, the teachers were asked to analyze new textbook excerpts, following an activity in which they examined textbooks from their own classrooms. They were given a set of questions about the text to consider. Xander reported back to the group by sharing what he noticed about his mathematics textbook. In particular, he compared what his experience was like reading a mathematics textbook as compared to when he reads a novel.

Xander: The interesting thing for me when I was going through my textbook is how I read a novel versus how I read a textbook and then incorporating that with how I teach. When I read a book--, when I'm reading a novel, the narrator's talking to me like I'm having a conversation with the narrator. You know, I'm hearing what they're saying. So when I read a textbook it's almost like you associate it as the teacher's voice saying what you're reading, you know what I mean? Because you could talk to somebody in class but when you read it in a textbook at home and you're trying to think about, what did the teacher say to relate it to? But when I teach stuff up at the board I say a lot of, "You do this," "We do this," "What do we do next." And it's a lot of you's and we's in it. And in the textbook it's none of that. It's all commandments at you. [others laugh] And it's because in the textbook they don't get responses back. And so the textbook is just, "Simplify this," "Next this." It never says "you do this" or "we do this." It doesn't relate it in with the subject like I do when I read a novel, that it relates it back to the characters and in me. Because you do associate the reading. When I read this, I want to have my teacher--, I want to connect it to what my teacher said in class. And I kind of expect that same kind of language, and when I have my teacher saying things

like "you" and "we" and "us" and all of a sudden there's none of that in the textbook, I kind of see how there's a disconnect there.

In this excerpt, Xander draws both comparisons (i.e., between reading a novel and talking with people such as teachers and students) and contrasts (i.e., between reading a novel or talking with people and reading a mathematics textbook) as he makes sense of certain features of the MR. He also has moved beyond vocabulary to issues of voice in mathematical discourse. Although Xander did not mention the MR by name, he articulated the distanced and authoritative voice described in some other analyses of mathematics textbooks (e.g., Herbel-Eisenmann, 2007). Xander provided specific examples of the grammatical features that contribute to this voice, for example the bald imperatives (*simplify this* versus *we do this*) and lack of human actors that occur in mathematics textbooks. This excerpt provides evidence of an expanding attention to the construct of the MR as a genre rather than particular attention primarily on mathematics vocabulary, as in many of the early PD sessions.

Discussion

In this paper, we extended the exploration of the MR in the context of mathematics classroom discourse and written work to an investigation of how teachers make sense of the idea in the context of a study group focused on mathematics discourse. We do so to set the stage for informed work with teachers on this idea. We found that the process of unpacking the MR was mutually constructed through two particular discourse patterns: providing examples and (sometimes) locating them in categories associated with characteristics of the mathematics register; and comparison and contrast. Each of these discourse patterns appeared throughout the study group and teachers used them to unpack the idea of MR throughout the study group. As they engaged in these discourse practices, we have evidence that the teachers moved from focusing almost exclusively on mathematics vocabulary or terminology to describing and engaging with more nuanced characteristics of the MR.

Although we did not follow the mathematics teachers into their practice to see how they took up the MR ideas, we see this kind of investigation as providing background knowledge for teacher educators in order to work with teachers as they support students in developing facility with the MR. As designers of PD, we have learned about how the teachers made sense of the MR and then interpreted the MR in the context of talking about their practice. In fact, we have revised parts of the PD materials to shape them in terms of these meaning-making themes. For example, we described the kinds of examples and categories teachers might suggest when they first look at student work and suggest ways in which a facilitator may use examples and categories to probe for more nuanced noticings. We have also reflected, through this analysis (e.g., the *is* excerpt and pushing for more nuance), on our roles as facilitators in a discourse community of teachers, which is in many ways analogous to the roles of teachers as they support students with respect to the mathematics register.

As Gibbons (2009) argued, when teachers attend to the mathematics register explicitly and carefully consider how they scaffold language learning, they can provide access to every student because the 'rules' of the game are made apparent to everyone. As teachers engage with ideas from discourse literature, we have found that the ideas shift and change as they then try them out in their classroom (Herbel-Eisenmann, Drake, & Cirillo, 2009). Thus, it is important, as a next step, to continue this investigation by building on the meaning-making discourse patterns the teachers employed as they talked about the MR in order to support their exploration of how to best use ideas from the MR to scaffold their students' learning.

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