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Teaching the language of mathematics: What the research tells us teachers need to know and do

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ABSTRACT

The focus of this paper is on what research suggests primary school teachers need to know about the specialized language of mathematics teaching and learning: the mathematics register. When teachers act effectively on this knowledge, students have multiple opportunities to construct mathematical understandings and to demonstrate what they know in the variety of tasks that are required by formal schooling. First, the national and policy context within which mathematics is taught and learned is considered. Secondly, the mathematics register is defined, followed by a consideration the significance for teaching, learning, and assessment in school; examples are provided. The educational implications of these analyses include guidelines for what teachers need to know and to do, so that their students appropriately utilize the mathematics register in the classroom. In so doing, students are provided with optimal circumstances to learn, where they may deploy all of their cognitive-linguistic resources to the particular mathematics tasks at hand.

1. Overview

Teaching primary level mathematics is a complex process. Teachers are required to know and apply their many understandings about mathematics, including their knowledge of the language and communication challenges inherent to mathematics learning. This paper addresses what teachers need to know and do, so that their students attain mastery of the academic language used in mathematics, the mathematics register.

Mathematical processes of thinking, discovery, and problem solving are at the center of the processes of identifying mathematical patterns, creating mathematical insights, and also in applying mathematics in real-world contexts. Via communications with others, learners explore, offer conjectures, find patterns; these learners then construct conceptual and procedural understandings of mathematics. The Core Curriculum Content Standards in Mathematics (Common Core State Standards Initiative, 2010) specified for the field, the mathematical practices that all learners must develop, which include the following: "make sense of problems and persevere in solving them," "construct viable arguments and critique the reasoning of others," "model with mathematics," and "use appropriate tools strategically."

The perspective taken here is that teachers should focus on students' developing mathematical understandings at the same time that they are learning the specialized language of mathematics (Wilkinson, 2015; Bailey et al., 2018b). Mathematical understanding refers to students' ability to make connections among mathematical ideas, concepts, and procedures (Maher & Martino, 2000). In developing understanding, students engage in meaningful discourse with each other and with their teachers. Teaching through problem solving requires tasks designed to engage students in constructing their own knowledge and also engage them in dialogue with other students. Students grapple with challenging tasks and are able to construct meaningful mathematical understandings. In this case, problems are used both as a means for learning concepts as a means for learning the specialized use of language in

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mathematics (Bailey, Maher, & Wilkinson, 2018a).

Mathematics learning and teaching involves mediating the complex relationships among linguistic, symbolic, visual forms of representation of mathematical knowledge. These relationships are interwoven and evolve throughout schooling. Students must be encouraged and supported directly in their efforts to learn to speak, read, and write mathematics (Moschkovich, 2015; Wilkinson, 2015). Furthermore, for students to succeed in school, they must demonstrate what they know in a variety of school tasks, including performance on standardized tests which include dense texts, such as complex word problems (Cheuk et al., 2018; Martiniello, 2009; Wylie et al., 2018).

What do teachers need to know about and do with the particular language forms and content used in mathematics learning? The overarching issues for teachers are: Do students readily understand mathematics textbooks and individual test items? Do teachers provide students with both the opportunities and assistance to engage with mathematics in ways that are supported through classroom talk? Do teachers extend this process to include reading and writing texts as well as creating and comprehending representations? How do teachers teach students the mathematics register and its' application to texts and tests? Do the language challenges built into test items attenuate students 'opportunities to demonstrate what they know about the mathematics assessed by these instruments? Do students know the mathematics content but are unable to formulate and demonstrate their knowledge as required by the test items? Perhaps students do not understand what the test item requires because they do not possess the linguistic, cultural, and background knowledge required by the test. How prepared are teachers to assist students as they grapple with understanding how to interpret such texts and tests? Do teachers model the mathematics register? Are there specialized challenges in working with students for whom the language of instruction in is not students' first language (Bailey et al., 2015)?

This paper offers a point of view about what primary school teachers need to know about the mathematics register, and how they may act on this knowledge in their own classrooms, so that students learn mathematics and demonstrate what they know in the variety of tasks required by schooling. There are specific guidelines for what teachers need to know and to do so that their students appropriately use the mathematics register. In so doing, students are afforded multiple opportunities to deploy all of their cognitive-linguistic resources to the particular mathematics tasks at hand. The first section references this discussion within the context of national policies and standards for mathematics achievement. The second section defines the mathematics register and discusses current perspectives for successful participation in the language of instruction. The third section discusses the significance of the mathematics register for teaching, learning, and assessment in primary school. Three examples are given, one from a problem-solving situation; and two from international standardized assessments. Finally, some observations about the educational implications of this work are offered.

2. The Context of Standards: Mathematics Achievement and National Policies

We are cognizant that this discussion about mathematics learning and the salience of language issues, takes place in a context for the United States, and world-wide, where there are dramatic, demographic shifts of multilingual youth and adults worldwide. This is a time of enormous human migration. These population shifts result in significant consequences for students in schools, where the language of instruction is not likely to be their first or even second language. For example, in the U.S. approximately 21% of the population speaks a language other than English in the home (Ryan, 2013). These families represent a variety of ethnic groups who "bring with them a diverse set of values, practices, and resources" (McCabe et al., 2013, p. 4).

Linguistic diversity, while a rich classroom resource, can also create challenges for teachers, who are responsible for educating students in disciplinary content, including the various, disciplinary languages (e.g., the language of mathematics, science, history). This teaching challenge is further magnified by findings that multilingual students in the U. S., after six years, continued to struggle academically (Olsen, 2010). From a worldwide perspective, the literature on multilingual students and their educational achievement is limited with regard to the language demands of schooling.

With regard to standards, countries specify what students need to learn for different disciplines. For the U.S., the standards include mathematics practices (e.g., perseverance, reasoning, and communication skills), which are key to mathematics achievement in school (National Council of Teachers of Mathematics, 1989; Common Core State Standards [CCSS], National Conference of State Legislatures, 2016). In the case of mathematics, the U.S. standards emphasize "general, cross-disciplinary literacy expectations that must be met by the time students graduate from high school to be prepared to enter college and workforce training programs ready to succeed" (Common Core State Standards Initiative, 2010, p. 4). Standards-based reform has been taking place at the same time as the evolving composition of the student population in the U.S., with English learner students showing the fastest growing cohort (National Clearinghouse for English Language Acquisition, 2018). Throughout their schooling in the U.S., the standardized achievement scores of these children and youth are significantly below their peers (Bailey et al., 2018a),

3. What is the Mathematics Register?

Each academic discipline is defined by a specific kind of language that is distinct from everyday natural language. A register refers to any language variation that is socially shaped by the participants 'interactional engagement and is distinguished by the co-occurrence of particular linguistic features in that situation; consequently, a register serves a singular interactional purpose. As Biber and Conrad (2001) note: "Register variation is inherent in human language: a single speaker will make systematic choices in pronunciation, morphology, word choice and grammar reflecting a range of non-linguistic factors" (p. 4).