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FORMATIVE ASSESSMENT *FOR* MATHEMATICAL PRACTICES

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This case study investigated preservice secondary mathematics teachers' (PSMTs') developing understanding of formative assessment as a way to leverage mathematical practices for student learning. Qualitative data came from PSMTs' responses to a learning sequence designed to help them develop nuanced and disciplinary-specific understandings of formative assessment. Analyses suggest a trajectory for PSMTs learning to use formative assessment in problem-solving environments, but also shows how the orientation of one PSMT continued to obstruct her progress. The results suggest that mathematics teacher educators must themselves use formative assessment that supports PMSTs' developing orientations to currently suggested ways of teaching.

INTRODUCTION

At ICME 13, Deborah Ball argued that "although progress has been made in understanding "mathematical knowledge for teaching," more study is needed to understand interactive mathematical work of teaching and to orient teachers' professional education to this dynamic and performative mathematical fluency and activity" (Ball, 2017, p. 11). The interactive and flexible mathematical knowledge for teaching (MKT) Ball referred to becomes essential in light of current recommendations for teaching and learning mathematics, described as responsive teaching, in which instructional decisions are based on teachers' interpretations of student thinking (Dyer & Sherin, 2016). Current recommendations suggest that students develop mathematical practices such as problem solving, reasoning, and communicating as a way to construct deeper and more connected understandings of the mathematics (National Council of Teachers of Mathematics, 2014). Thus, PSMTs must learn to understand and respond to students' mathematical reasoning, problem-solving approaches, and use of mathematical tools such as graphs, tables, symbols, and procedures.

Teaching that provides students these opportunities is challenging, especially for PSMTs, and is mediated through their orientations about mathematics and about teaching (Crawford, 2007; Foster, 2013). This paper reports on a portion of a design study taking place at a public university in the northwest United States that received an NSF Robert Noyce grant designed to increase the number of secondary science, technology, engineering, and mathematics (STEM) teachers well-prepared to teach in high-need schools. We seek to understand the nature of MKT that allows PSMTs to identify and capitalize on students' mathematical practices as they formulate questions and listen to students' responses, and how PSMTs develop this MKT.

CONCEPTUAL FRAMEWORK

Teaching in a problem solving environment involves posing tasks so that students build on or revise their current mathematical understandings into more advanced and precise understandings as a result of grappling with problematic aspects of the tasks. Responsive teaching in a problem solving environment necessitates the teacher's attention to student thinking and ability to respond in ways that maintain the problematic aspects while also supporting students' problem-solving abilities. We use one aspect of responsive teaching, formative assessment (FA), since that is the language PSMTs use in their foundation coursework in our program. FA involves both teacher and student activities that clarify expectations for learning, elicit student understanding, and provide feedback which supports new learning (Black & Wiliam, 2009). While FA has been widely lauded by the education establishment as effective, some researchers have articulated concerns (Dunn & Mulvenon, 2009). In particular, Coffey, Hammer, Levin, and Grant (2011) criticized major studies of FA that generalized strategies across disciplines. Illustrating with excerpts from these studies, they demonstrated the field's lack of attention to the disciplinary substance of student thinking and portrayed content merely as a body of correct information. They further criticized distinguishing FA strategies from the teaching and learning process, rather than as responding to students' ideas "as a seamless part of teaching. Strategies should be in the service of that attention" (Coffey et al., p. 1112). This disciplinary-specific view of FA emphasizes the importance of the teachers' pedagogical content knowledge (PCK) in that teachers must engage with the disciplinary substance of their students' ideas. Teachers must identify where students may have the beginnings of use of mathematical practices and help them build on those, or understand students' ideas as they relate to concepts, or know when they can help students advance an idea. PCK, in the way it is used here, involves unpacking content to understand how mathematical ideas are related, and integrating that knowledge with students' potential thinking about the content. This PCK involves being able to devise questions to elicit students' current understandings, and imagine ways to advance students' mathematical practices and understandings. PCK is an important resource for teachers in their use of FA and can also help them build their PCK (Falk, 2012). But PCK is developed through filters of teacher orientations, context, and prior knowledge (Gess-Newsome, 2015).

METHODS

This investigation included four PSMTs in a 10-week secondary math methods course in their last year of their program; the course emphasized teaching responsively through problem solving. All participants had taken an upper-division mathematics problem-solving seminar for prospective secondary mathematics teachers and foundation courses in the education program, and were concurrently in their field placements. The instructor/ researcher hypothesized a trajectory of learning to teach responsively through problem-solving based on the PSMTs conjectured prior knowledge of teaching through problem solving and of FA. This trajectory included in-class activities and discussions, and seven assignments.

Because of space we only use artifacts from the first three assignments as data sources: PSMT written reflections on two assignments and one lesson plan they revised to apply their growing understanding of FA. Analyses focused on PSMTs' understanding of and ability to apply FA to improve student learning.

The sequence of assignments were intended to build on teacher candidates' prior knowledge on formative assessment through awareness, then exploration and application. How do they envision the purpose of questioning students?

The first assignment, given on the first day of class asked PSMTs to share their current understanding of FA with examples, and what they still wanted to know. The purpose of this was to identify their current conceptions of FA. The second assignment was for them to read Coffey et al. (2011), and to identify any changes in their understandings while also providing examples. The purpose of this was to hone their conceptions of FA as engaging with students' ideas and to see FA as integrated seamlessly throughout a lesson. Coffey et al. (2011) includes transcripts and explanations of those transcripts emphasizing important points about the disciplinary-specific nature of effective FA. Since PSMTs could read the article at their own pace, and read the authors' analyses, the researcher hypothesized that this reading would be more effective than watching videos where they would likely attend to other factors in the lessons. Thus, the article was chosen specifically for PSMTs to focus on the idea of FA as attention to disciplinary substance and valuing and using students' ideas. Later classroom discussion and another article focused on students' engagement in mathematical practices to learn the concepts and procedures. The third assignment asked them to revise a lesson plan they had taught. The purpose of this was to provide PSMTs with an opportunity to apply their new understandings of FA to a lesson and to receive feedback. Analyses focused on the nature of the formative assessment PSMTs used: To what extent was it integrated with the lesson? To what extent could it elicit student thinking that PSMTs could use to improve their lesson? To what extent did it target conceptual understanding and reasoning central to the lesson goals?

Within-case displays ((Miles & Huberman, 1994) provided analysis of how PSMTs' ideas about FA changed throughout the assignments and to what they attributed that change. It also highlighted aspects of PCK and PSMTs' orientation to teaching mathematics (e.g. are they trying to get students to know facts or trying to get them to reason and build mathematical ideas that make sense?);

RESULTS

Due to space, we discuss only two themes. A longer paper currently in preparation will provide a more thorough analysis of the entire sequence with connections among the themes.

Theme 1: Three of the PSMTs' understanding of formative assessment shifted from general strategies to mathematics-specific strategies that enabled them to identify students' current understandings in relation to the intended learning, and to make instructional decisions that could benefit particular groups in their classes. Their first assignments demonstrated only general strategies consisting of students' self-reports. For example, using strategies such as asking students to rank themselves on a scale of 1-4 on how they feel about the content covered in the previous day's lesson. However, after the second assignment, PSMTs' examples emphasized using discussion for FA and listening for students' reasoning to help them decide next instructional steps for particular groups based on their reasoning. By the third assignment, three of the PSMTs changed their lesson plans to incorporate open-ended but strategically-designed FA. For example, Mark replaced his thumbs-up/thumbs-down FA to an open-ended prompt after he anticipated that students might not have a strong conception of volume:

> one key question I will need to ask students is how they went from their formulas for area to formulas for volume because this is a key concept they need to understand. When going from circles and rectangles to cylinders and rectangular prisms, many students will just "add" a height to their formula in the form of multiplication because we are adding a new dimension to the object. Many will just multiply by height because it "makes sense" to them.

These PSMTs also anticipated students' likely prior conceptions so they could ask questions that would net students' ideas.

The fourth PSMT focused on whether students 'get' what the teacher is teaching or not, and showed evidence of thinking of mathematics learning as disconnected objectives rather than as a progression of learning. While responding to the Coffey article, she focused on discussion as a way to find correctness: "From what I learned from this article, …I would instead ask multiple other students what they think until I get the correct answer.

Theme 2: None of the four PSMTs yet valued student contributions as learning resources for the entire class, nor were they designing lessons and integrating FA in ways that support students' developing proficiencies in mathematical practices to improve understanding (e.g. reasoning and critiquing others' reasoning).

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