PRE-SERVICE TEACHERS' PATTERNS OF QUESTIONING WHILE TUTORING STUDENTS WITH LEARNING DISABILITIES IN ALGEBRA 1

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This study documented changes in the types of questions posed by pre-service teachers (PSTs) who participated in a semester-long professional development (PD) program focused on questioning in algebra. PSTs who participated in the PD—who were conducting 1-1 tutoring for students with learning disabilities during the same time—showed positive changes in the types of questions they posed. PSTs reduced their frequency of closed, leading questions to lead students through solution methods, and they increased their frequency of questions to probe students' thinking, to focus attention on important mathematical ideas, and to establish mathematical relationships.

Keywords: Algebra and Algebraic Thinking, Teacher Education – Preservice, Classroom Discourse, Special Education

The development of positive, productive classroom discourse practices is a challenging component of learning to teach mathematics. Posing questions is one way for teachers to scaffold students' mathematical learning, giving a teacher insight into students' thinking while promoting student autonomy and sense making (Anghileri, 2006). However, posing questions is a complex skill (Hufferd-Ackles et al., 2004; Imm & Stylianou, 2012; Kazemi & Stipek, 2001). For pre-service teachers (PSTs) to pose questions that probe students' thinking, help students focus on important mathematical ideas, and make necessary connections, they likely need consistent, ongoing professional development (PD) and opportunities for reflection. This is especially important for future special educators who may have less training in mathematics content and discipline-specific practices for teaching math.

The purpose of this study was to document changes in the types of questions posed by PSTs who participated in a semester-long PD program focused on questioning in algebra. We worked with four PSTs who were special education majors with a content emphasis in mathematics. We facilitated weekly training sessions, concurrently with which the PSTs tutored students with LD in 1-1 settings. We found that the PSTs became better throughout the PD at asking questions to probe students' thinking and make mathematical ideas explicit.

Research Perspectives

Teacher questioning is one aspect of classroom mathematical activity, and it is difficult to isolate teacher questioning from other aspects of teaching and learning. However, characterizations of the different types of questions that teachers pose—for example, leading (closed) questions, probing questions, or (open) questions to extend students' thinking—have been useful to document features of existing classroom practice (Boaler & Brodie, 2004; Hufferd-Ackles et al., 2004; Moyer & Milewicz, 2002) and to support teachers in improving their questioning practices (Aydogan et al., 2018; Di Teodoro et al., 2012; Piccolo et al., 2008). Boaler and Brodie (2004), for example, established a set of nine categories of teacher questions that shares features with other frameworks. The types of questions that mathematics teachers pose include categories like "leading students through a method," "exploring mathematical meanings," and "orienting and focusing."

Research has shown across multiple contexts that PSTs across grade levels especially struggle with questioning, primarily posing lower-order questions focused on the recall of facts or the steps of a procedure (Diaz et al., 2013; Kaya & Ceviz, 2017; Purdum-Cassidy et al., 2015). It can be difficult

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for PSTs to anticipate how they might pursue extended sequences of questions to probe student thinking (Kilic, 2018; Weston et al., 2018). However, there is some evidence that sustained and supported reflection on the part of PSTs can support improvement in questioning practices, in particular when PSTs work in 1-1 settings with students, and when attention to questioning is integrated with the development of content knowledge and professional noticing (van den Kieboom et al., 2014; Weiland et al., 2014). Thus, it is reasonable to expect that PSTs can benefit from sustained PD in the area of questioning and consistent opportunities to practice questioning in controlled settings.

Data and Methods

Participants

Four PSTs participated in this project for three semesters during a teacher preparation program at a large university. Although the PSTs were special education majors, they had all selected math as their area of focus and were recruited from a mathematics methods course based on their achievement and engagement in the course. In the first year of the project, the PSTs met with the two authors on approximately a weekly basis, for a total of 15 sessions. Most of the time in our sessions was spent developing the PSTs' algebra content knowledge and questioning. Concurrently with our tutor training, PSTs tutored on a weekly basis. The students they tutored were all identified as having LD, and they were enrolled in the first year of a 2-year remedial algebra sequence at a large suburban high school.

Tutor PD

The math content of our PD sessions with the PSTs was primarily related to linear functions and solving systems of equations, because this was the content covered in the associated algebra course for most of the year. Our discussions of questioning proceeded along a trajectory:

- Distinctions between *funneling* sequences (i.e., a sequence of closed questions to lead students towards a solution) and *focusing* sequence (questions that build upon students' contributions and help to focus on key mathematical ideas) (Herbel-Eisenmann & Breyfogle, 2005; Wood, 1998).
- "Buying time" questions, intended for PSTs to slow the pace of conversation and have time to react to student thinking.
- The use of probing questions and how teachers have used probing questions to help students generate correct explanations (e.g., Franke et al., 2009).
- Distinctions between asking and telling, and considerations of when "telling" might be a more appropriate practice than asking closed questions (Baxter & Williams, 2010).

Data Collection and Analysis

In addition to the PD, PSTs provided 1-1 tutoring weekly for approximately 45 minutes per session. Each tutoring session was recorded using a document camera that captured the conversations as any written work produced on the table. We selected three sessions from each tutor to focus our analysis: one session each from the beginning and end of the first year, and one session from the second year of tutoring. For consistency in our sample of data, we selected sessions in which linear functions were the main topic of focus of students' work.

A research assistant transcribed the selected sessions, and we adapted Boaler and Brodie's (2004) categories of questions to code the PSTs' questions across the sessions (Table 1). First, both authors as well as the research assistant coded two transcripts and compared our initial coding. This allowed us to clarify coding criteria. At this stage we also shared our initial coding with an external advisor to get feedback on our coding criteria and improve the validity of our codes. After clarifying our definitions and distinctions between the question types, we each coded two more transcripts to test

our reliability. Having achieved sufficient reliability, we divided the remaining transcripts to code. In this final phase, we each highlighted sections that seemed to be edge cases so that we could resolve such cases via discussion and consensus.

Table 1: Types of Teacher Questions, Adapted from Boaler and Brodie (2004)

Question Type	Description
Leading Through a Solution	Questions requiring short answers on the part of the student, generally focused on the steps of a solution.
Exploring Mathematical Meanings	Questions requiring students to establish connections between mathematical ideas.
Probing	Questions that ask students to explain why a particular solution was valid or reasonable.
Orienting and Focusing	Questions that ask students about important elements of a task, to help focus students' attention.
Connecting to Context	Questions about a real-world context, either the given context of a task or introducing a new context.

Results

Table 2 summarizes the PSTs' questions in semester 1 of year 1 in semester 2 of year 1. These two sessions occurred near the very beginning and, respectively, near the very end of our tutor training. (Results from year 2, during which PSTs continued tutoring but no longer received training, will be added prior to PMENA 2020.) Several outcomes are notable in Table 2. First, and most importantly, PSTs substantially reduced their use of "leading" questions with students from the beginning to the end of the tutor training program. Leading questions are those that roughly correspond to initiation (I) questions in an IRE sequence and are generally defined by the fact that they require very short (1-3 word) answers to move a student through a solution procedure.

Table 2: Changes in Tutors' Questions Over Time

	Year 1 Semester 1	Year 1 Semester 2
Leading Through a Solution	86%	68%
Exploring Mathematical Meanings	7%	8%
Probing	4%	15%
Orienting and Focusing	4%	6%
Connecting to Context	0%	2%

With the reduction in "leading" questions, PSTs asked many more questions to explore mathematical meanings, to probe students' thinking, and to focus students on important mathematical ideas. It is notable that, even by the end of the 15-week PD, over two-thirds of PSTs' questions were still leading questions. This is partly explained by the fact that leading questions—by their very definition—typically come in condensed sequences, for example with a tutor posing 3-4 such questions to lead a student through one task or part of a task. Other types of questions are less predictable in nature and create more opportunity for students to direct the discussion.

An Example of PST Questioning

We share one example, from a conversation between Linda (a PST) and a student, Mia, to illustrate the use of questions that went beyond leading questions. This example came from a year 1 semester 2 session. Linda and Mia were together looking at a "worked example," a task in which two linear

functions had been graphed (incorrectly) to identify a point of intersection, and Mia needed to determine whether the solution was correct.

Linda: Okay, so did the student graph these correctly? (*leading through a solution*)
Mia: No.
Linda: What did they do wrong? (*probing*)
Mia: For the blue one they went up, well like they went up the *y*-axis correctly, but they went up-right instead of up-left when they graphed the -3.
Linda: Oh okay so, what did they do with the 3, like what did they do wrong with the 3? (*probing*)
Mia: They went to the right instead of to the left.
Linda: What does it mean when they go to the right? (*exploring mathematical meanings*)
Mia: It is a negative slope.
Linda: When they go to the right? (*leading through a solution*)
Mia: Oh wait no, it's a positive slope when you go to the right.
Linda: Oh okay, so they just forgot the negative.

One phenomenon that is illustrated in this conversation between Linda and Mia was the way in which different questioning types seemed to have a snowball effect. By posing two probing questions, Linda was able to draw enough information out of Mia that she could then use that information to establish more general connections. Just as "leading" questions tend to reproduce themselves, more open-ended questions also beget further open-ended discussion.

Discussion and Conclusion

Prior research has shown how challenging it can be for PSTs to develop productive questioning practices. This work has shown that pre-service special educators can learn to pose more questions that probe and extend the mathematical thinking of students with LD. Even so, leading questions may continue to serve a purpose in 1-1 tutoring sessions as a form of emotional scaffolding (Hord et al., 2018) to maintain students' engagement in their work. While there is not clearly an ideal ratio for the different types of questions tutors should pose during 1-1 work with students, it is promising to see tutors expand their range of questioning in ways that give students opportunities to engage in deep mathematical discussions.

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