Paper Title Preservice Teachers' Questioning and Students' Responses During Algebra Tutoring

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Abstract

Posing questions is a direct way for teachers to push students to verbalize justifications and make connections among ideas, but this skill is difficult to learn. We recruited four pre-service special education teachers to participate in a semester-long professional development focused on developing mathematics knowledge and asking questions, while concurrently providing 1-1 tutoring to students with learning disabilities. The pre-service teachers increased their frequency of questions overall and of questions that probed students' thinking or explored mathematical relationships. The pre-service teachers also developed strategies for shifting among different types of questions when students struggled. The findings of this study illustrate the potential for pre-service teachers to develop questioning routines that challenge students while scaffolding their progress towards new understanding.

Background and Objective

Novice teachers can benefit from teacher education efforts to develop core practices for teaching, including practices related to orchestrating discussions (Franke et al., 2007). Mathematics teachers facilitate conversations through a range of discourse moves including posing questions, telling information, rephrasing students' ideas, and asking students to rephrase one another's ideas (Chapin et al., 2009; Wells & Mejía Arauz, 2006). Posing questions, like other discourse moves, reflects a teacher's attempts to engage students' participation, share mathematical information, and distribute mathematical authority (Boaler & Brodie, 2004; Kazemi & Stipek, 2001). The ways pre-service teachers (PSTs) learn to pose questions is an important aspect of research and practice because questioning represents the clearest interface of teachers' and students' contributions to mathematical discourse.

The purpose of this study is to document how special education PSTs changed their questioning practices through their participation in a 15-week extracurricular professional development (PD) focused on algebra content, posing questions, and using gestures to support students' learning. Concurrently with the PD, PSTs provided 1-1 tutoring to high school students with LD taking Algebra 1. Our research questions are as follows:

1. What types of questions did PSTs pose, and how did the complexity of their questions change over time?
2. When PSTs posed questions of higher complexity, how did students respond?
3. When PSTs posed higher-complexity questions that received incorrect or incomplete response from students, how did the PSTs follow up?

Theoretical Framework

Questioning is one aspect of a teacher's classroom practice that allows a teacher to guide students' mathematical activity. Questioning, like other forms of classroom discourse, serves multiple interrelated purposes at once. The content of a teacher's questions directs the mathematics content that students are likely to consider. At the same time, the types of questions a teacher poses inform the type of discourse community present within a classroom (Kazemi & Stipek, 2001). Because posing questions is the most direct way for teachers to elicit students' participation in classroom discourse, the questions a teacher poses have the most straightforward impact on how students' participation. Thus, the types of questions that teachers pose, and how they engage students, needs to be made clear.

Traditional mathematics instruction—where teachers present concepts and procedures for students to learn and, in turn, practice—has been characterized by the initiation-response-evaluation/feedback (IRE/F) pattern of interaction (e.g., Cazden, 2001). Although the ideals of math education have largely moved beyond the use of triadic dialogue, these types of interactions are still relevant to classroom discourse and the types of questions teachers pose. Initiation questions have been characterized in various literature as surface, convergent, factual, leading, or recall questions (Fazio, 2019). Most studies of PST discourse practices find that the majority of questions PSTs pose fall into these related categories, in full-class lessons (Diaz et al., 2013; Kaya & Cevic, 2017), in 1-1 settings with students (Kilic, 2018; Moyer & Milewicz, 2002; van den Kieboom et al., 2014), and in written planning (Akkoç, 2015). Special education PSTs, like math education PSTs, tend to pose mostly initiation-style questions (Griffin et al., 2009).

Part of the work of moving beyond more traditional forms of teacher-student interaction has been to document the different types of questions that teachers can use to engage students in mathematical activity. Probing questions can be defined as questions that explore students' mathematics understanding and engage students in clarifying their ideas and explanations for claims (Franke et al., 2009; Sahin & Kulm, 2008). A teacher's use of probing questions can facilitate students' construction of correct explanations and conceptual learning (Franke et al., 2009). PSTs working in 1-1 tutoring or diagnostic settings often struggle to pose probing questions (Moyer & Milewicz, 2002), although this skill can be improved alongside improved noticing of students' thinking (Weiland et al., 2014) or improved content knowledge (van den Kieboom et al., 2014).

Data Sources and Methods

This study comes from a larger effort to prepare pre-service special education teachers to tutor students with LD in Algebra 1. We recruited four second-year special education majors that had chosen math as their subject of focus. We met approximately weekly with the PSTs from December through mid-April. In all we conducted 15 training sessions lasting 45-60 minutes each. PSTs met as a group with the first and second author at the school where they provided tutoring. The PSTs began tutoring in January, so each week they attended a training session and tutored on the same day.

The tutor training had three primary foci. The first was to develop the PSTs' algebra knowledge, specifically related to linear functions and solving systems of two equations. The second focus was the use of gestures to support students' processing of information and their attention on key problem elements and connections between problem elements. The third focus was on developing questioning techniques that would give PSTs insight into students' thinking and also help them move student thinking forward.

For the purpose of this analysis we selected three tutoring sessions for each PST—one at the beginning of our tutor training program, one near the end of our program, and one in the year following. The authors, as well as a research assistant, coded the transcripts using Boaler and Brodie's (2004) categories of teacher questions. After coding the PSTs' questions, the next step was to document how students responded to each question. Following each question we coded the student's next comment (or, lack of comment) in one of five ways: "correct short answer," "correct explanation," "incorrect or incomplete response," "no response," or "PST did not leave time for response."

Findings

Table 1 summarizes the frequencies with which each of the four PSTs posed the different types of questions across the three tutoring sessions. All of the PSTs increased the overall percentage of questions they posed and reduced the percentage of gathering information and leading questions following session 1. Overall, PSTs posed more probing questions, and their use of probing questions persisted beyond the conclusion of the tutor training program. This was also true in most cases for questions related to exploring mathematical meanings, hereon referred to as "exploring" questions. PSTs' use of orienting questions seemed to drop off in many cases after the conclusion of our work together.

Table 2 summarizes the types of responses the PSTs received from students when posing probing, exploring, and orienting questions. In the case of probing and exploring questions, students gave incorrect, incomplete, or non-responses only slightly more often than they provided correct short answers or explanations. Orienting questions were the most difficult for students to answer (and more difficult for PSTs to pose), and this may be because these questions required students to anticipate some aspect of a task rather than to reflect on something they had already done.

In Table 3 we summarize how the PSTs reacted when students gave incorrect or incomplete answers to probing, exploring, or orienting questions. PSTs most often posed less complex questions or corrected a student who provided an incorrect or incomplete answer to a question of greater complexity. In only a few cases did a PST persist in posing an equivalent or higher-complexity question following an incorrect or incomplete answer. The relatively low percentages of questions of higher complexity in Table 2 can be explained, at least in part, by the fact that PSTs often abandoned these types of questions when they received insufficient responses from students. Additionally, however, by reducing the complexity of their questions following incorrect or incomplete responses allowed the PSTs to continue making progress with students when they struggled to answer a more complex question.

Scholarly Significance

It is clear that pre-service and in-service teachers can learn to pose higher-complexity questions, especially when they learn about different types of questions in coordination with developing their content knowledge or noticing of students' thinking (Aydogan et al., 2018; Ong et al., 2010; van den Kieboom et al., 2014; Weiland et al., 2014). However, such outcomes are not guaranteed, and for the sake of improving PSTs' questioning practices, it is not enough to treat the questions that teachers pose as independent events. Some researchers have illuminated how individual utterances are almost inseparable from the broader participation and norms in math discourse communities (Hufferd-Ackles et al., 2004; Imm & Stylianou, 2012; Kazemi & Stipek, 2001), although such broad units can present a challenge for teacher education. Teaching PSTs how to respond to insufficient responses from a student is a necessary complement to teaching them to pose better questions in the first place.

In working to increase the frequency with which PSTs pose more complex questions that give students more opportunity to engage in mathematical meaning making, it is also necessary to recognize that there is no universally appropriate balance of question types. We saw that PSTs could use gathering information questions, or other less complex questions, to scaffold students towards mathematical explanations. Especially for students with LD, who are more likely to struggle with mathematics or experience anxiety around doing math, a teacher's work to help a

student make progress and stay engaged in a task can be a necessary step to make more complex questions viable (Author, Date; Nelson & Harwood, 2011).

Table 1
A Summary of PSTs' Questioning Frequency

	Alice			Brittany			Linda			Sandy		
Session	1	2	3	1	2	3	1	2	3	1	2	3
Total # Turns	142	154	59	137	209	40	165	191	101	246	259	121
Total # Questions	33	47	32	36	106	16	21	78	41	56	68	22
Questions as a % of turns	23%	31%	54%	26%	51%	40%	13%	41%	41%	23%	26%	18%
Gathering/ Leading	97%	38%	66%	92%	54%	62%	81%	62%	37%	84%	66%	91%
Inserting Terminology	0%	11%	9%	0%	8%	0%	0%	1%	5%	11%	1%	0%
Linking	0%	11%	3%	0%	7%	0%	0%	3%	0%	5%	6%	0%
Connecting to Context	0%	17%	9%	0%	9%	19%	0%	4%	29%	0%	4%	0%
Probing	0%	8%	3%	0%	7%	6%	5%	10%	12%	0%	16%	9%
Exploring math meanings	3%	6%	9%	6%	7%	6%	5%	12%	17%	0%	3%	0%
Orienting and Focusing	0%	8%	0%	3%	5%	6%	9%	9%	0%	0%	3%	0%
Extending Thinking	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%

Table 2
A Summary of Student Responses to PSTs' More Complex Questions

	Total Number Posed	Correct Short Answer	Correct Explanation	Incorrect or Incomplete	No response	PST Left No Time for Response

Probing	41	2 (5%)	16 (39%)	15 (37%)	7 (17%)	1 (2%)
Exploring	36	9 (25%)	7 (19%)	14 (39%)	4 (11%)	2 (6%)
Orienting	22	1 (5%)	1 (5%)	14 (64%)	4 (18%)	2 (9%)

Table 3
PSTs' Next Moves When Students Provided Incomplete or Incorrect Responses

	Posed the Same or More Complex Question	Posed a Less Complex Question	Corrected the Student or Told Information	Other
Probing	3 (20%)	7 (47%)	4 (27%)	1 (7%)
Exploring	5 (36%)	4 (29%)	5 (36%)	0
Orienting	1 (7%)	7 (50%)	6 (43%)	0

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