EXPLICIT TEACHING OF QUESTIONING IN MATH METHODS COURSE: PRESERVICE TEACHERS' ATTEMPTS TO ASK PROBING QUESTIONS

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After an explicit unit of core activities on questioning, preservice teachers (PTs) completed an assignment to select a problem-solving task, anticipate student solutions, and plan probing questions. After analyzing PTs' work, we discovered that, although most PTs planned probing questions, many also planned questions focused on information or procedures. Next steps include exposing PTs to probing questions focused on meanings, context, or representations.

Keywords: Instructional activities and practices, Teacher Education- Preservice

According to National Council of Teachers of Mathematics (NCTM, 2014), effective teaching of mathematics requires asking "purposeful questions to assess and advance students' reasoning and sense making about important mathematical ideas and relationships" (p. 35). Although teacher questioning has long been viewed as a critical component of mathematics teaching, rigorous and challenging mathematics standards (Common Core State Standards for Mathematics [CCSSM], 2010) and NCTM's (2014) release of effective mathematics teaching practices brought attention back to teacher questioning in the U.S. Especially, given that teachers in the U.S. ask fewer probing questions that support the deep levels of student understanding than teachers in other high-achieving countries (Stigler & Hiebert, 2009a,b), it is critically important to put emphasis on the practice of asking purposeful questions in teacher preparation programs. The main reasons for asking purposeful questions are to surface the student's understanding and reasoning, to probe student thinking, and to gather more information related to the student's understanding of their problem-solving strategies, key mathematical ideas, and meaning inherent in representations (Huinker & Bill, 2017). In an attempt to foster preservice teachers' (PTs) ability to use such purposeful probing questions, we contemplated that an explicit teaching of questioning was needed, and we planned and implemented a series of core activities in a methods course for teaching mathematics in the elementary and middle grades. After PTs were explicitly taught questioning through the series of core activities, they completed an assignment in which they selected a problem-solving task, generated different anticipated student solutions to the task, and planned probing thinking questions for each of their anticipated student solutions. We analyzed PTs' planned questions in the assignment, in order to determine how our explicit teaching of questioning through a series of core activities helped them cultivate good questioning skills, and to identify next steps that we would either begin to address or continue to implement in our methods courses. The guiding question for this study is: What types of questions do elementary PTs propose in order to probe the thinking of their students?

Theoretical Framework

Teacher questioning in mathematics has been investigated in many studies with a focus on inservice teachers (e.g., Boaler & Brodie, 2004; Franke et al., 2009; Kawanaka & Stigler, 1999; Martino & Maher, 1999; Myhill & Dunkin, 2005; Shahrill, 2013; Sahin & Kulm, 2008; Wimer, et al., 2001); however, fewer studies have focused on PTs' questioning (e.g., Akkoç, 2015; Cakmak, 2009; Hähkiöniemi, 2017; Hollebrands & Lee, 2016; Moyer & Milewicz, 2002; Weiland, et al., 2014). Akkoc, Hollebrands and Lee, and Hähkiöniemi investigated PTs' questioning in relation to technology, in computerized environments, or with the use of dynamic software. Moyer and

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Milewicz observed PTs' assessment interviews with students, and found that they often asked questions with single answers in rapid succession, rather than probing for student thinking. Weiland et al.'s case study observed two PTs' assessment interviews in their field study; found an increase in their competent follow-up questions; and suggest that PTs can develop their questioning skills through rich field experiences. Cakmak reported that PTs often view the role of questioning as simply a way to motivate students or get their attention.

Many of the studies have produced classifications for probing questions in mathematics. Sahin and Kulm classified teacher probing questions as ask students to (1) explain/elaborate their thinking, (2) use prior knowledge/apply, (3) justify/prove. Kawanaka and Stigler classified questions as requesting (1) analysis/synthesis/conjecture/evaluation, (2) how to proceed in solving a problem, (3) the methods that were used to solve a problem, (4) the reasons why something is true/why something works/why something is done, and (5) other information. Boaler and Brodie's classification was: (1) exploring mathematical meanings and/or relationships, (2) probing, getting students to explain their thinking, and (3) extending thinking. Moyer and Milewicz categorized PTs' questioning strategies as questioning of (1) only incorrect responses, (2) non-specific questioning that did not acknowledge an individual child's responses, and (3) competent questioning that attended to a child's responses and probed for more information. Hähkiöniemi (2017) divided PTs probing questions into categories as probing method, reasoning, cause, meaning, argument, extension, and unfocused probing.

In this study, we aim to explore the nature of elementary PTs' probing questions as a result of explicit teaching of questioning skills through a series of core activities, and in relation to implementing problem-solving tasks. Rather than using an existing classification, we explored the question types that emerged from our PTs, which would complement the previous studies, help us better understand the ways our elementary PTs attempt to ask probing questions, and aid us in redesigning our explicit teaching of questioning module based on the emerging types.

Methods

The sample consisted of 115 PTs in five sections of an elementary/middle math methods course for a mix of elementary and special education majors. In an attempt to foster PTs' ability to use purposeful probing questions, we designed and implemented an explicit questioning module involving a series of core activities, as recommended by Morrissey, et al. (2019).

First, PTs studied the four types of questions as gathering information, probing thinking, making the math visible, encouraging reflection and justification (NCTM, 2014), and the idea of assessing and advancing questions (Huinker & Bill, 2017) through descriptions, examples, and discussion. Then, they watched and analyzed classroom teaching episodes that demonstrate the teacher's use of purposeful questions, and examined excerpts from lesson transcripts for the types of questions posed by the teachers. They categorized teacher's questions by four types and also identified whether each question was assessing or advancing. Next, they examined lesson plans that include planned purposeful questions during implementation of problem-solving tasks. These lesson plans included teacher's planned questions for a variety of anticipated student solutions to a mathematical problem involving various degrees of mathematical sophistication and understanding. Last, they studied four different student works to a given problem-solving task, and created three (two assessing and one advancing type) purposeful probing questions for each of the four student work samples. Finally, they completed an assignment in which they selected a problem-solving task, generated a number of different anticipated student solutions to the task, and planned probing thinking questions for each of their anticipated student solutions. The assignment prompted PTs to ask questions about the anticipated student work in order to help students deepen their understanding, to probe into their reasoning, and/or to have them evaluate and judge their own work. We analyzed PTs' planned questions in order to explore PTs' competency in asking probing questions, as a result of explicit

teaching of questioning through a series of core activities. We used an open coding strategy (Strauss & Corbin, 1990) to categorize PTs' probing questions. One researcher analyzed the questions, and proposed initial categories with descriptions. Two other researchers reviewed a subgroup of the data, and agreed with the categories, and suggested revisions for the descriptions. Then, the three researchers, in collaboration, revised the descriptions to make them more subtle and accurate. After finalizing the categories and descriptions, one researcher coded the data; another researcher reviewed the codes and indicated their disagreements with the coding. The discrepancies were discussed, and the codes were revised, repeatedly, until 100% agreement was achieved.

Six categories of questions emerged: (1) focusing on information and/or procedures, which ask students to identify numbers, shapes, key words, and/or procedures to use to solve a problem; (2) focusing on context, which ask students to identify information given in a problem, think in the context of the problem, or connect their solution back to problem context; (3) focusing on meanings, which ask students to explain why something was done, interpret the meaning of given information, explain their reasoning, or interpret the meaning of the answer in terms of the context; (4) focusing on representations, which ask students to use different ways to represent a problem situation, such as draw a picture, write an equation, use manipulatives, etc., ask students about their current representation, or ask students to justify their representations; (5) general questions with no focus, which ask students to explain how they approached solving a problem with no reference to the context of a problem, or ask students general questions about the concepts involved in a problem - overall, this type of question can be used with any other problem students are asked to solve; and (6) other, in which the PT will show, explain, talk through, remind, give an alternative problem –in general, questions are not directed at students. The emerging categories showed that PTs were able to ask probing questions that focus on context, meanings, or representations. Yet, some question types that focus solely on information and procedures, and do not probe into student thinking also emerged, along with general questions and other comments/questions unrelated to students' current work and understanding.

Results and Discussion

All but eight PTs proposed more than one type of question. The assignment required PTs to only ask questions that probe into student reasoning in their current solution, and that help them deepen their understanding. However, 88% of the PTs asked at least one question related to information and procedures, which do not consider the underlying conceptual understanding of the student, and do not probe into student thinking as required. It is worrisome that the majority of the PTs believed that questions related to information and procedures are probing thinking questions. For example, "Why did you solve for the smaller numbers instead of doing it as a large number?" is a question that is not linked to underlying meanings, problem context, or meanings inherent to representations. Frequently, the questions in this category focused on numbers, procedures, or notations, as in "Why did you use an equal sign instead of any other sign?" and "Could you use any other number and get the same result?"

Most (72%) of the PTs asked questions that focus on the meanings. This is an important component of questioning, as requiring students to explain the meaning of their solutions serves to reveal underlying gaps in students' conceptual understanding. Sample questions coded in this category are when PTs asked questions about the meanings of the numbers or operations involved in the solution, such as "What does 159 represent [in your solution]?" "Why do we add 1 to Fred's equation?" "Why did you use multiplication?" and "What does the graph tell you?"

About 35% of the PTs asked questions that focus on the representations, which also require students to explain their reasoning as they justify their representations. These types of questions provide the strong base of conceptual understanding that is necessary for building procedural fluency (NCTM,

2014). Sample questions coded in this category are: "How did you show in your picture that Johnny gave away to Tina?" "How could you represent this with pictures?" "What if they added two more bow colors, how would your drawing and equation change?" and "How could you show your circles using a number sentence?"

Although making connections between the solution and the problem context is also an important part of mathematics proficiency, as recommended in the CCSSM, only 14% of the PTs planned questions asking students to relate their solution to the problem context. For example: "What does your equation have to do with the lights Garrett wants to buy?" and "What relationship does doubling the savings have to do with the price of the shirts [in the problem]?"

Thirty-four percent of the PTs planned general questions with no relationship to the context of the problem, which did not assist students in evaluating their solutions and moving forward in solving a problem. For example, "How did you get your answer?" or "What strategy did you use to solve this problem?" were coded as general questions, because they are not specific to the student's current understanding, and can be asked for any type of student work. When PTs ask how students got their answers, students in most cases would simply go through the steps of their solutions. Another most frequent general question was, "Have you thought of another way this could be done?" which is not related to a student's work and understanding. Other general questions asked about general facts without connection to a student's work or problem, such as "How many minutes are there in an hour?" "What is the formula for area?" etc.

In a few cases, PTs either planned to show, explain, or talk through the problem and solution, instead of asking probing questions, or planned to tell students to check their work. Further analyses of question types in the future will consider variability across content and grade level.

Implications

The high percentage of PTs who planned to ask probing questions indicated that explicit teaching of questioning through core activities helped cultivate PTs questioning skills. Nevertheless, the low percentage of PTs who proposed questions relating student solutions to problem context will be addressed in future methods courses, as authors focus specifically on planning questions that move students forward and are related to meaning, representations, and context of solutions rather than general or procedural questions. The emerged categories of probing questions, as focusing on meanings, context, or representations, will be used as a guide for potential types of probing questions that can be asked specifically to probe into students' conceptual understanding. PTs will be asked to analyze teaching episodes and lesson plans in relation to these three probing question categories and create assessing questions focusing on meanings, context, and representations. The other two categories, general questions or focus on information/procedures, will be used as non-examples of probing thinking questions. PTs will also be asked to analyze teaching episodes and lesson transcripts to look for these two categories. The five categories of PTs' questions, and three categories of PTs' probing questions, complement the existing question classifications in the reviewed literature. In particular, the emerged categories provided subcategories for a combination of Boaler and Brodie's and Moyer and Milewicz's classifications.

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