Using Online Simulations to Support Elementary Preservice Teachers' Questioning Practices in Mathematics Classrooms

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Abstract: Posing questions is central to teaching; however, more work is needed to understand how to support preservice teachers (PSTs) in developing this skill. This study describes the instructional principles used in a design experiment that aimed to develop elementary PSTs' ability to ask effective questions in response to students' mathematical thinking. Preliminary analysis revealed an overall decrease in PSTs' preference for teacher-directed and funneling questions and an increase preference for both general and specific elicit questions.

Keywords: teacher education-preservice, instructional activities and practices, design-based research

Introduction

Asking questions that support student learning is both complex and unnatural (Ball & Forzani, 2009). Unlike in everyday situations, teachers routinely ask students questions they already know the answer to and probe student ideas instead of assuming they know what the student means. In order to ask questions that allow students to develop their own understanding, teachers need to learn how to pose questions that "make mathematical thinking visible" and "build on, but do not take over or funnel, student thinking" (National Council of Teachers of Mathematics, 2014, p. 41). Given the complexity of asking effective questions, research is needed to better understand how to support preservice teachers in developing this skill. The purpose of this study was to implement and refine an instructional sequence to develop elementary preservice teachers' (PSTs) ability to pose and select high-leverage questions in response to elementary students' mathematical thinking.

Literature review and theoretical framework

Not all questions result in equal opportunities for students to reflect on their work and develop understanding of important concepts. For example, Franke and colleagues (2009) found that asking a probing sequence of specific questions is more likely to result in the student producing a correct, complete answer than asking a single specific or general question. Other high-leverage questions include ones that ask students to explain and justify their solutions, or make connections between representations rather than just focusing on a procedure (Kazemi & Stipek, 2001). In contrast, low-leverage questions include those that invalidate student thinking, funnel students to a specific response, or follow the initiate-respond-evaluate (IRE) questioning pattern (Herbel-Eisenmann & Breyfogle, 2005). See Table 1 for a summary of the question types used in this study.

Table 1: Classification of questioning types

Question	Description	Examples
Specific, elicit (high-leverage)	Questions that elicit or build upon a specific aspect of a student's work	• Can you tell me more about how you were thinking about the 1/3rd? • What do you mean about the four squares? Can you show me how that would look?
General, elicit	Questions that broadly elicits more information from a student	• Can you tell me how you got the answer for part c? • You think Susan is wrong. Why do you think that?
Teacher-directed (low-leverage)	Questions where the teacher directs a student to solve a problem using a specific strategy	• What if you moved this block up here and combine them to make one shaded piece, and do the same with the unshaded pieces. Now that there's only two pieces, how many parts are shaded in the one I drew? • Why don't you try dividing each sub into three parts?
Funneling (low-leverage)	Questions that funnels a student to a specific answer or procedure; often binary (either/or, yes/no)	• What if you think about both brownies as the whole? How much is each piece of the whole two brownies? • In the problem it says that there are three fourths and three sixths. Are fourths the same as sixths?

The instructional sequence is based on the assumption that PSTs should develop their teaching knowledge and skills by engaging in experiences that approximate, to some extent, the practice of teaching (Grossman, Hammerness, & McDonald, 2009). Approximations of practice differ from regular classroom instruction in that they reduce the level of complexity of the situation, which slows down the teaching process and allows PSTs to focus on a particular aspect of the practice without additional distractions. Our study in particular utilizes cartoon representations of teaching, developed using the online program Lesson*Sketch,* which allows PSTs to view a student's work, choose a question to pose to a student, see their (pre-established) response, and then reflect on the impact of the question (Herbst, Chazan, Chen, Chieu, & Weiss, 2011).

Methods

Context

Drawing on design research methodology (The Design-Based Research Collective, 2003), we report preliminary results from the third iteration of an intervention to develop PSTs' questioning practices. There were 44 undergraduate juniors/seniors who participated in the study, all enrolled in one of two sections of a course on teaching math for elementary education majors at a public university in the Midwest United States. Both sections were taught by the first author and all components of the instructional sequence were completed as a part of the course. The instructional sequence was implemented over a four-week period alongside discussions of the *5 Practices for Orchestrating Mathematical Discourse* (Smith & Stein, 2011). Immediately prior to the study, PSTs learned about the principles of Cognitively Guided Instruction (Carpenter, Fennema, Franke, Levi, & Empson, 2014) and then interviewed a fourth or fifth grader to better understand their strategies for solving a sequence of word problems. As a result, PSTs had some prior experience unpacking students' mathematical thinking and were exposed to the importance of seeking to understand how the student was thinking about the problem. However, conversations prior to the design experiment did not focus on specific features of effective questions.

Data collection

The study data included PSTs' written work on all activities in the instructional sequence as well as their responses on a pre- and post-assessment scenario-based survey. Our preliminary analysis focused on two sets of questions posed on the surveys: PSTs' rankings of provided questions in response to three students' mathematical work and their selection of the one question PSTs thought would be the most effective to ask each student. After analyzing each student's work on a task and composing their own question to ask the student, PSTs were shown a list of questions and asked which ones they would prefer to ask. For each of the provided questions, PSTs selected from "definitely ask", "maybe ask", "probably wouldn't ask", to "definitely wouldn't ask" for each of 4-6 provided questions. Next, they were asked to identify the question they thought would be the best to ask each student.

Instructional design and implementation

Drawing on findings from previous iterations of the instructional design (Webel & Conner, 2017; Webel, Conner, & Zhao, 2018), we developed a 4-week module that targeted three learning goals:

- **Goal 1**: PSTs select and pose questions that elicit student thinking instead of suggesting a teacher-driven strategy or telling students what to do.
- **Goal 2**: PSTs select and pose questions that elicit student thinking based on specific features of their work instead of selecting/posing general questions that elicit student thinking.
- **Goal 3:** PSTs pose questions that elicit student thinking based on specific features of their work instead of asking questions that funnel them to a specific response.

For each goal, we aimed to perturb PSTs' beliefs about effective questions by contrasting two types of questions. We viewed the third goal as a more nuanced version of the first goal based on prior findings that PSTs tended to prefer funneling questions even after similar interventions (Webel, Conner, & Zhao, 2018). In order to achieve these learning goals, we designed an instructional sequence that utilized three key design components (see Table 2). First, we placed all tasks within the context of fractions to maintain some uniformity across experiences. We centered the instruction around approximations of practice. Second, these approximations of practice provided space for reflective decision-making without the time constraints and contextual variability of a real interaction. Third, we asked PSTs to contrast pairs of questions with different features in order to expose the benefits of certain question types and limitations of others (Webel & Conner, 2017). The Lesson*Sketch* simulations allowed PSTs to follow multiple pre-established paths and "go back in time" to view the simulated student's response to two teacher questions. The instructional sequence consisted of four Lesson*Sketch* simulations (LS) with follow-up

classroom discussions, two video-based homework assignments (V) that served as formative assessments, and a final project where PSTs reflected on their questioning practice after working individually with a 4th or 5th grader.

Table 2: Summary of design components and how they were embedded into the instructional sequence

Design Component	Component Embedded within Instructional Activities
Mathematical context varied within the category of fractions	• identifying ½ (LS1) • equal sharing problems (LS2, V2) • labeling fractions based on identification of whole (LS3) • subtracting fractions with unlike denominators (V1) • adding fractions with unlike denominators (LS4)
Experiences centered around a single student's work within an approximation of practice	• student written work (pre/post assessment) • Lesson*Sketch* simulations (4; see next design component) • video clips used for formative assessment (2) • one-on-one interview with 4th/5th grade student (final project)
PSTs contrasted pairs of questions that were similar across one dimension but differed across a second dimension	• LS Scenario 1, identifying ½: contrasted general elicit question with a teacher-directed telling question. Neither question resolved the student's misconception. • LS Scenario 2, equal sharing: contrasted specific eliciting question with general eliciting question. • LS Scenarios 3 & 4, labeling fractions, adding fractions: contrasted specific elicit question and funneling question. Both questions were specific to the student's work.

Our preliminary analysis focused on PSTs' ratings for each of the questions as well as the questions they thought was the "best" one to ask based on three elementary students' written work on the pre- and post-assessments. We chose to combine the teacher-directed and funnel questions into a single category since they were both low-leverage questions. Although we also analyzed the questioning preferences for individual students' work to look for differences in responses, we only report the aggregate ratings across the student work below.

Preliminary findings

Analysis of PSTs' ranking of the selected questions on the pre- and post-assessment revealed a decrease in the number of PSTs who indicated they would "definitely ask" any of the provided questions (245 vs. 120), signaling a more critical general stance toward questions (Figure 1). Particularly, there was a pronounced downward shift in the number of teacher-directed or funnel questions they would definitely ask (from 107 to 28). The number of PSTs claiming that they "probably wouldn't ask" such questions rose from 41 to 82, and the number claiming that they "definitely wouldn't ask" such questions rose from 18 to 66. And while there was some shift from "definitely ask" to "maybe ask" for specific questions that elicited children's thinking, those questions remained relatively popular in contrast to the teacher-directed/funnel questions.

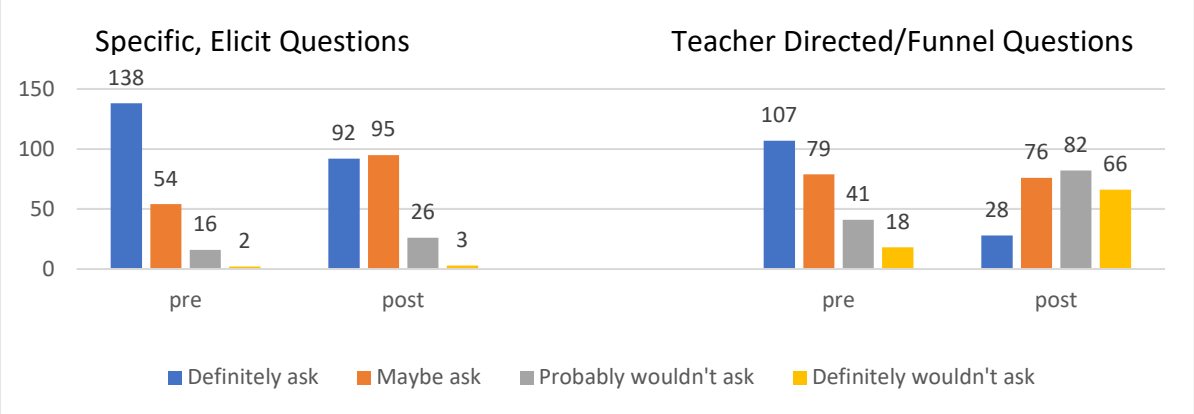

Figure 1. PSTs' ranking of high- and low-leverage questions on the pre- and post-assessments.

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When PSTs were asked to identify the one question they thought was the "best", we saw a decrease in the number of teacher directed/funneling questions, and a small increase in the number of specific/elicit questions. We also added, for two situations on the posttest, a "general eliciting" question, such as, "How did you get that?" which was selected 22% of the time. Of the 24 who selected a general question, 50% of them originally selected a high-leverage question and 42% selected a low-leverage question on the pre-assessment (2 PSTs did not take the pretest).

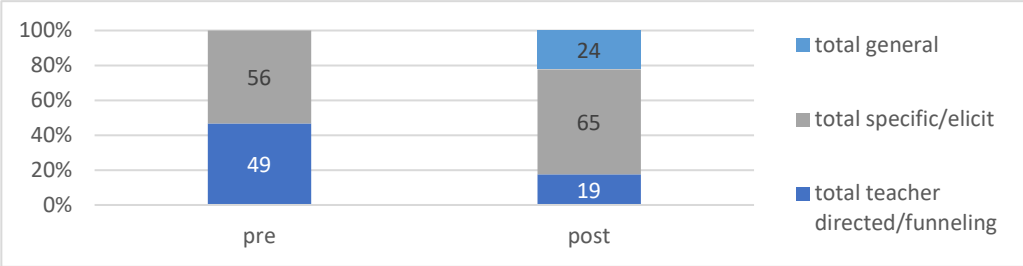

Figure 2. Question types PSTs thought were the "best" to ask each student on the pre- and post-assessment.

Implications and conclusion

The finding that PSTs were less likely to state they would "definitely ask" any of the question options could indicate an increased critical consciousness about the possible effects of questions, including an awareness of contextual reasons that might influence whether a question may or may not be effective. The contingent nature of teacher questioning in the context of a specific lesson was a consistent theme that was raised in the class discussions; for example, the PSTs questioned whether the students in the scenario were accustomed to sharing their strategies all the time, or only when they are wrong. This might influence, they believed, whether a particular question might convey that students were incorrect versus simply inquiring for more information. PSTs' attention to unknown contextual factors could help to explain their preference for general, elicit questions on the post-assessment despite being able to identify limitations of general questions during classroom discussions. Future analysis will investigate PSTs' open-response justifications on all of the written assignments in order to better understand how they interpreted each question and identify ways to continue refining the instructional sequence.

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