# Preservice Secondary Mathematics Teachers' Learning of Purposeful Questioning

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## Background

Currently, reformers and researchers in teacher education (e.g., McDonald, Kazemi, & Kavanagh, 2013) are advocating for teacher's professional coursework curricula to focus on core practices for teaching and that course activities be designed around pedagogies of practice. Grossman, Compton, Igra, Ronfeldt, Shahan, and Williamson's (2009) framework for pedagogies of practice – decomposition of practice, representations of practice, and approximations of practice – has gained traction in mathematics teacher educators design of methods course activities (e.g., Boerst, Sleep, Ball, & Bass, 2011; Ghousseini & Herbst, 2014; Tyminski, Zambak, Drake, & Land, 2014). In mathematics education, researchers and research-informed documents (NCTM, 2014) are explicating mathematics teaching practices to promote students' mathematical thinking. One such mathematics teaching practice is facilitating classroom mathematics discourse, which involves the key practice of purposeful questioning (e.g., asking assessing questions and advancing questions [Smith, Bill, & Hughes, 2008]). Scholars assert the importance for teacher education researchers, of which mathematics teacher educators are a subset, to examine both the design of professional coursework focused on these core practices and preservice teachers' learning as they engage in coursework designed around pedagogies of practice. While researchers (e.g., Boerst et al., 2011; Ghousseini & Herbst, 2014) have identified opportunities for mathematics PTs to learn about the components of facilitating meaningful classroom mathematics discourse and have characterized teacher education activities in methods courses grounded on pedagogies of practice, we know little about what preservice mathematics secondary mathematics teachers (PSMTs) actually learn during their participation in such courses.

This study builds on the work of these researchers by addressing the following question: *What* conceptions of purposeful questioning (e.g., assessing and advancing questions) did four secondary mathematics preservice teachers (PSMTs) construct while they were enrolled in a mathematics methods course focused on mathematics teaching practices and designed around pedagogies of practice.

## Methods

Two frameworks shaped the design of this study. First, assessing questions and advancing questions (Smith, et al., 2008) served as a decomposition of the mathematics teaching practice of purposeful questioning. These two types of questions framed the object of the PSMTs' learning. Second, a constructivist learning perspective (Von Glasersfeld, 1995) was used to model the PSMTs' learning of purposeful questioning. A key tenet of this perspective is that learning "is explained as a transformation and reorganization of the learner's conceptions (Simon, Tzur, Heinz, Kinzel, & Smith, 2000, p. 584).

The design of the study was informed by the interpretive research genre (Borko, Whitcomb, & Byrnes, 2008) and qualitative data collection and analysis techniques (Erickson, 1986) focused on four case studies of PSMTs' learning of assessing and advancing questions. The study setting was a 15-week secondary mathematics methods course at a Mid-Atlantic university in which the instructor (Dr. A) designed course activities around decompositions of practice, representations of practice, and approximations of practice. The remainder of this section reports the participants, methods of data collection, and analysis methods.

### Participants

This study sits within a larger research study designed to investigate a number of research questions. As such, the corpus of data includes data from seventeen PTs, of which four PTs

became case study participants. The PSMTs were all undergraduate students who were prospective middle-grades or secondary school mathematics teachers accepted into the university's secondary education/mathematics option certification program. I deliberately selected four PSMTs – Nick, Steve, Gretchen, and Leslie (all pseudonyms) - from the seventeen participants to be case studies of PSMTs' learning of purposeful questioning. I explain the selection process of the cases in the data analysis section.

**Data Collection**

The corpus of data for this study consisted of data collected in three different settings during the fall semester: (a) the Teaching Secondary Mathematics I course at the university; (b) the interviews with the PSMTs; and (c) the PSMTs' notebooks and assignments. While data was collected for all twenty-eight class sessions, only data from classroom observations in Classes 3 – 15 and Classes 23 – 28 were analyzed. Table 1 reports the class session number and corresponding data sources and collected class artifacts.

Table 1: Classroom Observation Data

| **Class Session #** | **Data Source** |
|---|---|
| Class 3 | Audio-recordings, Audio-recording of Dr.A (course instructor), video-recording, photos of whiteboard, |
| Class 4 | Audio-recordings, Audio-recording of Dr.A, video-recording, photos of whiteboard, |
| Class 5 | Audio-recordings, Audio-recording of Dr.A, video-recording, photos of whiteboard, StudioCode Timelines |
| Class 6 | Audio-recording, StudioCode Timeline, Digital scans of the PSMTs response sheets, Notebooks, Video-recordings |
| Class 7 | Audio-recordings,<br>Audio-recording of Dr. A, Video-recording, Photos of the White Board |
| Class 7 | Video-recording, Audio-recording of Dr. A, Audio-recordings, TTLP in Word |

| | |
|---|---|
| Class 9 | Video-recordings, Audio-Recordings, Digital Scans of Observation Sheets (Not many of the PSMTs included their names on their observation sheets) |
| Class 10 | Audio-recording, StudioCode Timelines |
| Class 11 | Audio-recordings, Video-recording, Audio-recording of Dr. A |
| Class 12 | Notebooks, audio-recording, Video-Recording<br>Audio-recording of Instructor, Notebooks |
| Class 13 | Video-recording, photos, audio-recording of Dr. A, Notebooks, Audio-recordings, Notebooks, TTLPs in Word |
| Class 25 | Audio-recordings, Digital Scans of Student Work |
| Class 26 | StudioCode Timelines, Audio-recordings |

At the end of the semester, I collected electronic files (docx and PDF files) of all PSMTs' assignments and the PSMTs' notebooks. The PSMTs' notebooks included the PSMTs' hand written notes, assignments with instructor feedback, responses to in-class writing prompts, and narrative cases that included the PSMTs' markings.

I conducted three rounds of individual interviews with each of the seventeen participants. The first interview with each participant was a semi-structured interview that occurred during the first week of the course. The interview focused on the PSMTs' background in secondary mathematics as well as their visions of mathematics instruction. The second round of interviews occurred mid-semester. These interviews focused on each PSMTs' understanding of purposeful questioning and the course activities that may have supported their learning of purposeful questioning. I conducted a final interview with each participant after the course had ended so that I could collect data on each participants' understanding of purposeful questioning at a temporal distance from the end of the course. The third interview protocol consisted of questions

about course activities along with a card-sort activity in which the participants categorized question types (Boaler & Brodie, 2004) as either assessing questions or advancing questions.

**Data Analysis**

I conducted the data analysis in four stages. First, my ongoing analysis of data during the fall semester identified four participants for the case studies. The ongoing analysis involved reviewing all data sources and writing brief summaries of each participants' descriptions of assessing questions and advancing questions. I selected these four participants using criteria I established through my ongoing analysis of the data such as:

- The PSMTs were not absent for more than two class lessons
- The PSMTs' were representative of other representative of other participants insofar as the conceptions of other participants were similar to one or more of the selected cases
- The selected PSMTs exhibited qualitative differences among each other in their descriptions of assessing questions and advancing questions in data sources across the semester.

During the second stage, I identified and coded relevant data sources using an *a priori* coding scheme. Table 2 presents a portion of my coding scheme and code dictionary, which was based on the assessing questions and advancing questions framework. Using this coding scheme, I coded all the data sources for a single case in chronological order before moving onto a second case. For each coded instance, I wrote low inference analysis memos that included: lesson number or assignment title, excerpts from the transcript or document, referents in the conversation.

Table 2: Coding scheme and dictionary

| Code | Rationale |
|---|---|
| Assessing Questions | Data was coded as an Assessing Questions: (a) When object of the PSMTs' and/or Dr.A's verbal statements in a conversation is an Assessing Question(s); (b) when the object of the PT's written assignment or StudioCode Timeline was an Assessing Question; and (c) when the object of the PT's verbal or written response is one of the 9QTs that the PT had categorized as an Assessing Question. |
| Advancing Questions | Data was coded as an Advancing Questions: (a) When object of the PSMTs' and/or Dr.A's verbal statements in a conversation is an Assessing Question(s); (b) when the object of the PT's written assignment or StudioCode Timeline was an Advancing Question; and (c) when the object of the PT's verbal or written response is one of the 9QTs that the PT had categorized as an Advancing Question. |

The next stage of analysis was based on constant comparative analyses (Strauss & Corbin, 1990) in order to search for patterns and themes among the coded instances for each of my cases. My constant comparative analysis of the coded instances involved two main passes of the coded instances for each participant's collection of assessing codes and advancing codes. During my first pass of the data for each PSMT's collection of assessing codes and advancing codes, I began to sort the data into clusters, which were groups of the coded instances that exhibited common feature(s). As these clusters began to form, I interpreted the data in the clusters as indicators of a component of the PSMT's conception of assessing questions and advancing questions, which I call a *feature.* These passes enabled me to search for and identify commonalities, differences, and patterns in the data so that I could model components of each PSMT's conception of assessing questions and advancing questions. The outcome of this stage was the development of the cases of the PSMTs' conceptions of assessing questions and advancing questions.

The final stage of my analysis was the cross-case analysis of my four case studies – Leslie, Steve, Gretchen, and Nick. My cross-case analysis used a strategy Miles, Huberman, and Saldana (2013) called *stacking comparable cases* that incorporates both *case-oriented strategies*

and *variable-oriented strategies*. Specifically, I spent significant time analyzing each participant's conception of assessing questions and advancing questions in depth, I incorporated a tenet of the *variable oriented strategy* by looking for "themes [that] cut across cases" (Miles et al., 2013, p.103). In the next section, I report my findings generated by the data analysis.

## Findings

Over the course of the semester, the PSMTs constructed conceptions of assessing and advancing questions included different features that addressed both qualities and functions for each type of question. Many of these functions were similar among the PSMTs' conceptions and were oriented towards focusing on and promoting students' mathematical thinking. While a number of the PSMTs' conceptions of assessing and advancing questions similar features, there were nuances among the features of the PSMTs' conceptions.

In this section, I will first report the features of the PSMTs' conceptions of assessing questions that focus on students' mathematical thinking. Then, I will share the features of the PSMTs' conceptions of advancing questions that focus on and promote students' mathematical thinking. I conclude with ways in which the nuances among the features of the PSMTs' conceptions.

### Assessing Questions

The PSMTs' conceptions of assessing questions included features that addressed three ways in which the questions focus on determining students' mathematical thinking: (a) determine students' approaches or rationales for work as they engage in a task; (b) determine students' rationales for answers to a mathematical task; and (c) gauge students' mathematical understanding and/or capabilities. I use the cases of Nick and Steve to illustrate the nature of these three features.

Early in the semester, Nick's descriptions of assessing questions addressed both determining students' approaches as they engage in a tasks and gauging students' understanding. Nick wrote, "[assessing questions] find out what students have come up with through their exploration and to see what they understand after they give their explanation. Whether it's they understand nothing or have complete understanding or have partial understanding". Also, in a planning session prior to instructing a lesson, Nick stated to his peers the following about assessing questions,

> The first thing we are going to do when we get up there is ask them, 'So what do you have so far?' … So we are going to have to say, 'What do you have? How did you get there?' And have them explain their reasoning to us".

Steve's description of assessing questions mid-semester addressed both determining students' rationales for answers and gauging students' understanding. during the second interview, Steve was asked to review his Second Rehearsal assessing question, "How'd you get expression 4k + 4?" and explain his thinking for asking the question. Steve stated:

> That's assessing as well. I know what she did. She added the two numbers together, but can she explain to me what she did? Or will she say, "I think it's this." And that was the only reason why I was asking this question - does she know what she did here to get this expression.

In addition to determining students' mathematical thinking, the PSMTs' constructed features of their conceptions that addressed several other functions of assessing questions. These features include: (a) informing teachers' subsequent instruction; (b) supporting students' reflection; and (c) promoting classroom mathematics discourse. I use the cases of Leslie and Gretchen to illustrate the nature of these features.

Leslie's description of assessing questions mid-semester addressed using the questions to inform her subsequent use of advancing questions. During Leslie's second interview, Leslie stated, "So, I think these *[referent is questioning]* are definitely ways to gain the students' full understanding and have them work through the problems and me just trying to use assessing questions to figure out where they are. Then, based on that, use the advancing questions."

Gretchen's description of assessing questions mid-semester addressed the way in which assessing questions supports student's in reflecting on their approach to a task. During the second interview, Gretchen was asked how "context" may influence whether a teacher's question or statement is a certain type of teacher talk, to which she responded, "They're assessing still, because they know that the student knows more about what they did and they're just getting them to verbalize it and think about what they did and everything."

After the course, Gretchen's descriptions of assessing questions addressed using the questions to support student-to-student interaction. During the card sort activity in the third interview, Gretchen was asked to categorize the "generating discussion" question type from Boaler and Brodie (2004), to which Gretchen stated,

> I think a lot of times when you're generating discussion you might already know what the student has written for you know certain students have the right or wrong answer and you need them to share those answers with the class or with their group for the benefit of others.

**Advancing Questions**

The features of PSMTs' conceptions of advancing questions addressed three ways in which students' mathematical thinking can be extended by advancing questions. This includes supporting students in: (a) applying a mathematical idea to a different situation; (b) identifying

relationships among mathematical ideas; and (c) connecting mathematical representations. The cases of Nick and Steve are used to illustrate these features of the PSMTs' conceptions of advancing questions.

Mid-semester, Nick's descriptions of advancing questions addressed the ways in which the questions supported students using a mathematical idea in a different situation and making connections among ideas. Nick wrote,

> Advancing question can move a student who does have a mathematical understanding of a formula he/she produced to a new level of thinking such as if this formula would work in a different situation or context. Advancing questions help the students to make connections across mathematics and between mathematics and real world situations.

Also at mid-semester, Steve's description of advancing questions addressed the ways in which the questions supported students thinking about mathematical relationships. During the analysis of a peer's mathematics instruction, Steve stated, "Generate a relationship between the table and the graph … It's advancing because we want him to develop good relationships. And the purpose is to see if he understands the relationships."

In addition, the PSMTs' conceptions included other features that addressed functions advancing questions, such as: (a) the questions aim students towards the mathematical goal of the lesson; (b) the questions to focus on students' mathematical thinking; and (c) the questions guide students' mathematical thinking. The cases of Gretchen and Nick are used to illustrate these features.

At mid-semester, Gretchen described advancing questions as aiming students towards the mathematical goal of the lesson. Gretchen wrote in an assignment, "The instructional purpose of advancing questions is to discover new links and relationships between concepts and to extend

student thinking and understanding towards the mathematical goals of the lesson". At the end of the semester, Nick's description of advancing questions addressed the importance for the questions to focus on students' mathematical thinking. Nick stated, "[advancing questions] are dependent on what you are doing in the class, depending on what your students are doing, and where they're at". Also at the end of the semester, Nick described advancing questions as a way to direct, orient, and/or focus students to particular mathematical ideas and elements of a task that supports the students in their mathematical thinking. During the card sort activity in the third interview, Nick was asked to categorize the "orienting and focusing" question type from Boaler and Brodie (2004), to which he responded, "Orienting and focusing, probably I would put it in advancing. Because it's kind of getting the students to think about key elements, but you're doing that in order for students to solve the problem getting started".

It is important to note, while Leslie's conception of advancing questions also included guiding students' mathematical thinking, this feature of her conception was different than Nick's. In the next section, I focus on this feature of the two PSMTs' conceptions of advancing questions to illustrate the nuances among the similar features of the PSMTs' conceptions.

**Nuances Among the Features**

While the PSMTs' constructed similar features in their conceptions for the types of questions, the PSMTs differed in how their conceptions addressed the relationship between the type of questioning and students' mathematical thinking and learning. For example, the PSMTs' conceptions of advancing questions addressed guiding students' mathematical thinking. However, there was a difference among the way in which the PSMTs characterized teacher's guiding.

As reported in the previous section, this feature of Nick's conception addressed advancing questions as a way to direct, orient, and/or focus students to particular mathematical ideas and elements of a task that supports the students in their mathematical thinking. This is in contrast to Leslie, who characterized the action of guiding as a series of questions that funneled students through a task. During the second interview, Leslie was asked to talk about a series of questions in which she asked the student to determine the difference in the distance traveled between hours 0 and 1, 1 and 2, 2 and 3. Leslie stated,

> But during this part I think I was just advancing, essentially getting them to think outside their current thinking pattern … I think I almost use a series of assessing questions … And putting those assessing questions together is considered advancing because I'm getting them to the next box through a series of assessing questions … I definitely think my main goal was to find the pattern. Actually going and finding a pattern is more advancing than asking them maybe what they see at this moment. (Second Interview, audio-recording)

One could argue that using a series of questions that direct students through steps for carrying out a task limits the amount of thinking on the part of the students. Hence, the feature of Leslie's conception addressed guiding as a use of questioning that may constrain students' mathematical thinking. Where as the feature of Nick's conception addressed guiding as questioning that may promote students' mathematical thinking.

In summary, the PSMTs in this study constructed conceptions of assessing questions, and advancing questions that were oriented towards focusing on and promoting students' mathematical thinking. Tables 3 and 4 present the features of the PSMTs' conceptions in the right column and the initial description of the assessing and advancing questions as it appeared in

course materials in the left column. In addition, the table allows the reader to make comparisons among the definition of the question types with which the PSMTs' began and the constructed features of the PSMTs' conceptions of the question types at the end of the semester. Throughout the semester, the PSMTs' constructed multi-featured conceptions of assessing questions and advancing questions that addressed a number of qualities and functions that were not present in the initial description (see right hand columns of Table 3 and 4).

Table 3: Initial description and features of the conceptions of assessing questions

| Assessing questions: | Assessing questions: |
|---|---|
| • "Can assess what students understand about the problem (e.g., clarify what the student has done and what the student understands)" (Smith et al., 2008, p. 136) | • Determine students' approaches or rationales for work as they engage in a task<br>• Determine students' rationales for answers to a mathematical task<br>• Gauge students' mathematical understanding and/or capabilities<br>• Inform teachers' subsequent instruction<br>• Support students' reflection<br>• Role in whole class discussions |

Table 4: Initial description and features of the conceptions of advancing questions

| Advancing questions: | Advancing questions: |
|---|---|
| • "Help students advance towards the mathematical goals of the lesson. Teachers can extend student beyond their current thinking by pressing them to extend what they know to a new situation or think about something they are not currently thinking about" (Smith et al., 2008, p. 136) | • Support students' thinking about new or different situations<br>• Support students' thinking about a general case/idea<br>• Support students' thinking about new mathematical relationships and/or meanings<br>• Aim students' towards the mathematical goal of a lesson<br>• Build on students' mathematical understandings<br>• Guide students' mathematical thinking |

## Contributions

One contribution of this study is that the features of the PSMTs' conceptions of assessing questions and advancing questions provide the community with more technical definitions of assessing questions, advancing questions, and judicious telling that may be used in secondary mathematics teaching (see Table 5). The PSMTs in this study, although novices, are members of the secondary mathematics teaching community. Hence, their conceptions can support our community in further defining key teaching practices (e.g., purposeful questioning).

Table 5: Definitions of assessing and advancing questions.

| |
|---|
| **Assessing questions** enable teachers to elicit students' mathematical thinking and understanding during a lesson, which serves several functions for the teacher, such as: (a) determine students' mathematical thinking, understanding; (b) determine students' rationales for answers and approaches to mathematical tasks as well as students' progress on mathematical tasks; (b) gauge students' understandings of mathematical ideas and capabilities to engage in mathematical processes; and (c) enable teachers to purposefully position students in classroom mathematical discussions by supporting students' entry into the discussion and supporting student-to-student interaction focused on students' contributions. In addition, the understanding of students' thinking, understanding, progress on tasks, and capabilities informs teachers' subsequent instruction. Besides serving a function for teachers, assessing questions serve a function for students – assessing questions support students' reflecting on their approaches to mathematical tasks and reflecting on their thinking. |
| **Advancing questions** are questions that build on students' current mathematical thinking and/or understanding and aim students' towards the mathematical goal of a lesson by extending students' thinking in the following ways: (a) supporting students' thinking about new or different situations; and (b) support students thinking about new mathematical relationships and/or meanings. In addition, advancing questions orient and focus students on key mathematical ideas that aim students towards the mathematical goals of the lesson. |

In addition, the study findings build on those of Ghousseini and Herbst (2014) and Tyminski et al. (2014) in several ways. First, this study examined PSMTs' learning rather than preservice elementary teachers' learning. Also, while Ghousseini and Herbst (2014) reported PSMTs' opportunities to learn about practices that constitute facilitating mathematics discourse, this study identified *what* the PSMTs learned. The findings addressing the PSMTs' conceptions

of assessing and advancing questions are important for the field because it provides an initial understanding of what PSMTs, enrolled in methods courses designed around pedagogies of practice, learn about practices that constitute facilitating classroom discourse. Last, whereas Tyminski et al. found "many prospective elementary teachers were successful in writing clarifying and leading questions, there was a comparative dearth of questions providing students opportunity to make mathematical connections" (p.483), the PSMTs in this study constructed conceptions of advancing questions that addressed the way in which advancing questions can support students' opportunities make mathematical connections.

In conclusion, this study joins the work of other researchers in building a knowledge base that addresses what mathematics preservice teachers learn about mathematics teaching practices, specifically purposeful questioning, in a methods courses designed around pedagogies of practice.

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