*Jl. of Technology and Teacher Education* (2018) **26**(1), 127-147

# Using Technology in Representing Practice to Support Preservice Teachers' Quality Questioning: The Roles of Noticing in Improving Practice

JANET WALKOE AND DANIEL M. LEVIN
*University of Maryland, USA*
jwalkoe@umd.edu
dlevin2@umd.edu

Calls for a "practice-based" approach to teacher education have become common in scholarship on teacher education, and preservice-teaching (PST) mathematics programs are increasingly heeding this call. Practice-based teacher education (PBTE) moves beyond standard approaches to teacher education in which PSTs learn about teaching in ways they are then expected to apply in practice and toward an approach that provides PSTs opportunities to gain experience in particular core practices in ways that approximate enactment in the classroom. A growing body of research suggests that teachers' responses, including the questions they ask, can help students' develop content knowledge and proficiency in mathematics and science practices in the classroom. However, despite evidence that PSTs can notice students' thinking in various activities in their preparation programs, it is not clear that they are sufficiently well-prepared to propose quality responses before entering the classroom. In this paper, we describe two different approaches that we have taken to provide support for quality teacher questioning in the LessonSketch environment. From our results, we develop a hypothesis that a pedagogical approach that primes novices to notice model questioning can support a stance of focusing on the substance of students' thinking and probing rather than guiding students' thinking in their proposed questions.

## INTRODUCTION

Current theory and research in teacher education calls for a practice-based approach (Ball & Cohen, 1999; Matsko & Hammerness, 2014), and preservice teaching (PST) mathematics programs are increasingly taking up this approach (Ghousseni, 2009; Grosser-Clarkson, 2016; Kazemi, Lampert, & Franke, 2009). Practice-based teacher education (PBTE) moves beyond standard approaches to teacher education in which PSTs only learn about teaching and are expected to apply strategies in the classroom (Russ, Sherin, & Sherin, 2016) and toward an approach that provides PSTs opportunities to gain experience in particular core practices in ways that approximate enactment in the classroom (Ball & Forzani, 2009; Lampert, Beasley, Ghousseini, Kazemi, & Franke 2010; McDonald, Kazemi, & Kavanaugh, 2013). We use the term core practices, and this term is similar enough to other common terms used in the literature (such as "high-leverage" practices, e.g., Ball & Forzani, 2009) that our description of such practices would fit within these other formulations as well. While there is no set agreement on what constitutes a core practice, most formulations fit with Grossman, Hammerness, and McDonald's (2009b) proposal that core practices occur frequently in teaching, can be studied, practiced, and enacted in classrooms by novices, allow novices to learn about teaching, are research-based, and preserve the integrity of teaching.

Eliciting and responding to student thinking have been commonly discussed as core teaching practices (Neel, 2015; Robertson, Scherr, & Hammer, 2016; Singer-Gabella, Stengel, Shahan, & Kim, 2016; Windschitl & Calabrese Barton, 2016; TeachingWorks, 2017). A growing body of research suggests that teachers' responses, after eliciting students' ideas (Ball, 1993), can help students develop content knowledge and proficiency in mathematics and science practices in the classroom (Hammer, Goldberg, & Fargason, 2012; Pierson, 2008; Robertson, et al., 2016). Our focus on this paper is primarily on responding to students' thinking with questions, and eliciting not in the sense of launching a new task (Neel, 2015), but instead in the sense of probing students' ideas in moment-to- moment interactions with the intent of uncovering students' thinking.

With many events vying for a teacher's attention in the classroom, effective responding depends on teachers noticing substantive ideas and interpreting them in the context of how they connect to the discipline (Levin, Hammer, & Coffey, 2009; Neel, 2015; Robertson et al., 2016; Sherin & van Es, 2009). Noticing has been discussed in the mathematics and science education literatures as a key aspect of teacher knowledge (Sherin et al., 2011).

Despite evidence that PSTs can notice students' thinking in various activities in their preparation programs (e.g., Levin & Richards, 2011; Star & Strickland, 2008), it is not clear that they are sufficiently well-prepared to propose quality responses (e.g., Jacobs, Lamb, & Philipp, 2010), largely in the form of questions (Pierson, 2008), before entering the classroom. More work is needed to understand how we can productively support PSTs, using pedagogies of PBTE, to improve the quality of their proposed questions in response to evidence of student thinking.

In this paper, we describe the design of a practice-based teacher learning experience, using the Lesson*Sketch* (www.lessonsketch.org) environment, that leverages the construct of noticing to support teachers' practice of responding to student thinking in the form of questions. In prior work teacher noticing has been discussed as an important construct in teacher cognition that can support responsive practice (Sherin, Jacobs, & Phillip, 2011). At the same time PBTE has been discussed as a pedagogical approach to support core teaching practices (Grossman et al., 2009b; McDonald et al., 2013). Little work has been done to to link the two bodies of literature (c.f. Benedict-Chambers, 2016). Our work contributes to the emerging connection between these research strands. We propose a theoretical framework that illustrates how noticing, together with practice-based pedagogies, can support PSTs in their efforts to enact core practices (responding, and questioning in particular). We analyze a small set of data that illustrates this relationship, to strengthen and ground the proposed framework.

## PRACTICE BASED TEACHER EDUCATION

In discussing various conceptualizations of "practice" in the teacher education literature, Lampert (2010) highlighted the active verb form of practice as the repeated and continued doing of some exercise for the purpose of reaching proficiency. This idea is not new, Lampert pointed out, referring to Berliner's (1985) claim that it is absurd to teach teaching techniques without creating opportunities for novices to practice them, such as on a smaller scale, or through simulations. Citing work demonstrating that teachers generally become more effective with greater experience, Lampert suggested that practicing "in the sense of repeated efforts to do the same thing" (p. 28) could lead to greater proficiency in whatever it is that is important for teachers to learn.

This active form of practice is central to PBTE and has led to the development of a set of pedagogies. Examining pedagogical approaches in the

preparation of professionals in "relational" professions including the clergy, clinical psychology, and teaching, Grossman, Compton, Igra, Ronfeldt, Shahan, & Williamson (2009a) identified three key concepts for understanding pedagogies of practice in professional education: representations of practice, decomposition of practice, and approximations of practice. In teacher education, representations of practice are forms that teacher educators use to depict aspects of practice, such as video recordings of classrooms, samples of student work, or more intentionally designed depictions of classroom interactions, such as those created in the Lesson*Sketch* platform. Later theory included instructors' modeling as a form of representation (McDonald et al., 2013). These representations can then be "decomposed," that is, by "identifying components that are integral to practice and that can be improved through targeted instructions" (Grossman et al., 2009b, p. 2069). The teacher educator guides PSTs through the decomposition, helping them to identify the discrete parts in order to make them easier to practice and learn. Finally, approximations of practice refer to opportunities for novices to rehearse particular core practices in a safe setting, which Grossman et al. compare to "learning to kayak on calm waters" (p. 2076). In elaborating on Grossman et al.'s pedagogies, McDonald and colleagues included pedagogies that occur in the more authentic setting of the classroom, where teacher educators guide PSTs in enacting core practices with students, and PSTs reflect on their enactment (McDonald et al., 2013). In this paper, we report on an online teacher learning experience we developed that leveraged teacher noticing, and a representation of practice to support PSTs' enactment of core practices. Before describing the development and use of the experience, we discuss the theoretical constructs that underlie the approach to teacher learning embedded in the design.

## TEACHER NOTICING

Teacher noticing has been identified as an important construct in teacher cognition, specifically in service of supporting teachers' responding to students' ideas (Sherin et al., 2011). Sherin and van Es (2009) define noticing as consisting of two processes, attending and interpreting. Attending refers to the moments that grab a teacher's attention. Interpreting refers to how the teacher makes sense of that moment. Jacobs et al. (2010) include responding or intended responding in the definition of teacher noticing.

The classroom is full of stimuli, all vying for a teacher's attention. In order for a teacher to respond to students' ideas, whether asking a follow-

up question or introducing a new idea, the teacher needs to sift through the many events occurring simultaneously and interpret those events in relation to the instructional context. The events a teacher attends to and the way she interprets them will inform how she responds. As noticing underlies practices of responding, many researchers in teacher education have focused on supporting teachers' abilities to notice students' disciplinary ideas and reasoning, in PST education, professional development, and in practice (Levin et al., 2009; Sherin & van Es, 2009; Star & Strickland, 2008; Walkoe, 2015). Some researchers have found that PSTs initially have difficulty noticing students' substantive thinking, but get better at it with practice watching videos of classroom discussions (e.g., Star & Strickland, 2008). Encouragingly, others have found that some PSTs are able to begin focusing on student thinking early in their coursework (Levin & Richards, 2011; Walkoe, 2015) and can do so in their student teaching (Kazemi, et al., 2009; Levin et al, 2009; Monte-Sano & Cochran, 2009) when the conditions allow. Jacobs et al. (2010), however, found that while PSTs can attend to and reason about student thinking, they still have difficulty creating substantive responses that are based in student thinking. In this paper, we discuss our efforts to design experiences with representations in the Lesson*Sketch* multimedia platform to help PSTs attend and respond to students' ideas. The Lesson*Sketch* experiences we designed provide pedagogical opportunities for PSTs to practice crafting quality responses, particularly probing student thinking.

We claim that noticing, as we discuss it, is not itself a core teaching practice but rather a set of cognitive processes that can support or underlie a number of core teaching practices, including eliciting, responding to, probing, and analyzing student thinking. Below we present an initial framework describing how noticing underlies the enactment of core teaching practices. The noticed aspects of the context, in this case teachers interacting with representations of practice, are shown in a dotted rectangle to indicate that they are cognitive processes that we cannot observe, but can infer. The enactment of core practices can be directly observed, thus are shown in a solid rectangle, and can help us infer what was noticed. Of course this relationship is part of a larger framework, which we present later, but what we represent here is that noticed moments inform a teacher's actions, and this link (represented by the arrow in Figure 1) can be strengthened intentionally within the context (represented by the yellow box in Figure 1) of practice-based teacher education.

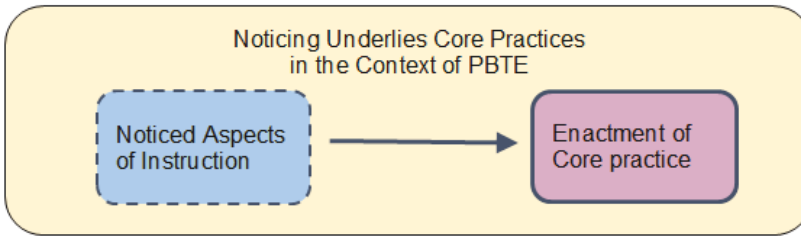


**Figure 1.** Framework of noticing and pedagogies of PBTE: Noticing underlies responding.

We argue that pedagogies of practice can work to leverage teacher noticing in the enactment of core practices. We now turn to the ways technological tools have been used to support pedagogies of practice.

## TECHNOLOGY USE IN PRACTICE BASED TEACHER EDUCATION

Technology has been used to support various aspects of practice-based teacher education (Herbst, Chazan, Chieu, Milewski, Kosko, & Aaron, 2016). Studies have explored virtual classroom environments to give PSTs practice in approximating teaching. For example, Ma et al. (2014) used *Second Life,* an interactive multi-user virtual environment (Cunningham & Harrison, 2010), to provide prospective teachers with practice in teaching algebra to diverse learners. In recent collaboration with colleagues, we have used a virtual classroom with avatars developed at the University of Central Florida (Dieker, Hynes, Hughes, Hardin, & Becht, 2015) for PSTs to approximate leading discussion about the causes of scientific phenomena (Levin, Chumbley, Jardine, Grosser-Clarkson, & Elby, in press).

### Technology to explore teacher noticing

Technological tools have also been used to support teacher practice and teacher noticing, in particular. Video tagging and annotation tools allow users to identify and comment on moments teachers notice. van Es and Sherin (2002) used the Video Analysis Support Tool (VAST) to support preservice teachers' analysis of video clips of classroom practice. The tool allowed teachers to highlight moments in a video and guided them to attend to certain aspects of practice depicted in the moment, such as student thinking,

teachers' roles, discourse, or content. Tagging tools have also been used to explore change in teacher noticing. Walkoe (2015) explored PSTs' attention to the details of student algebraic thinking as evidenced through their video tagging. Rich and Hannafin (2009) present a review of annotation and tagging tools and how they have been used in teacher education.

Animations as depictions of practice have also been used to explore teacher noticing. de Araujo et al. (2015) explored PSTs' creation of animations as a way to gain insight into what PSTs noticed when observing a classroom video clip. They found that the animations provided affordances over written recollections, such as supporting the recall of specific details. The authors hypothesized that these affordances may have been a result of the closer approximation of practice provided by the animations over written descriptions.

In this study, we used the Lesson*Sketch* platform to help guide PSTs' noticing of student thinking and to support PSTs' questioning techniques. The Lesson*Sketch* platform is an online environment in which experiences can be created to engage participants with core teaching practices (Herbst, Aaron, & Chieu, 2013). Experiences are self-contained PD modules that can include representations of teaching practice such as cartoon depictions, video clips, or audio clips all embedded in the Lesson*Sketch* environment. These artifacts can be included along with question or comment prompts, video tagging features, and/or forum discussions to allow PSTs to engage with the representations in an interactive way. In this study, we represented student thinking by embedding specific video clips of interviews to draw PSTs' attention to the richness of student thinking with the aim of supporting the development of quality questions for students. We then created space for teachers to approximate questioning techniques based on the thinking they observe.

Rather than conducting an empirical study and providing data to answer a research question, in this exploratory paper, we take a theoretical approach and articulate it through data. We developed two different experiences in Lesson*Sketch* and explored how our theoretical position on the relationship between noticing and practice-based teacher education helps us articulate how representations of practice can support noticing in the service of the improvement of PSTs' questions.

## METHOD

### Context

The data for this study come from a pair of online experiences (the "Lemonade" experience and the "Paint" experience) created for middle school PSTs. The PSTs were all undergraduate students enrolled in the academic major "Middle School Mathematics and Science Teaching" at a large public Mid-Atlantic university. The program leads to certification in both mathematics and science teaching in grades 4-9. The PSTs completed the experiences in a senior year "integrated middle school methods" course, before entering their student teaching. One cohort of 15 PSTs completed the "Lemonade" experience described below in 2016; the other group, of 12 PSTs, completed the "Paint" experience in 2017. Both experiences were completed in the same methods course, one year apart, with different cohorts.

We used the Lesson*Sketch* platform to create these experiences for PSTs; the experiences were specifically designed to use student thinking interviews to inform and support PSTs' attention to student thinking and ultimately the practice of responsive questioning. The experiences in this study both were based on student thinking interviews focused on proportional reasoning tasks, though there was one subtle difference in how the two experiences were designed. We begin by outlining commonalities between the experiences and then introduce the key difference.

### The experiences

The student thinking in the interviews is represented in two ways in the Lesson*Sketch* experiences discussed in this study. The first is through a short cartoon depiction of a classroom scene. The fictional scene depicts the focus student working with classmates on the problem. The second representation includes two short video clips chosen from the student thinking interview, that are embedded in experiences to illustrate levels of the focus student's thinking that extend and go beyond what is visible in the cartoon depiction of classroom interaction, thus representing what the student in the classroom might have been thinking. When the experiences begin, PSTs are allowed time to work on the proportional reasoning problem discussed in the student thinking interviews. Next they are shown the fictional cartoon depiction of the classroom in which students (including the focus student) are working in groups on the problem. Recall, this depiction is fictional but

based on actual thinking displayed in the interview. After viewing the depiction, PSTs are asked a short series of questions, including "How is [the student in the depiction] thinking about the problem? What do you think [the student] understands? What misconceptions do you think [the student] has? Do you think [the student] would know how to 'scale up' or 'scale down'?" Each question includes a text box in which the PSTs' responses are logged.

When the PSTs have answered these preliminary questions, they are shown one of the two short student thinking interview clips that flesh out the student's thinking. PSTs are again asked to answer questions about the student's thinking. We included the interview clips for two purposes. First, the interviews allowed windows into the student's thinking that went beyond what was visible in the classroom. Allowing PSTs to see this depth and demonstration of the richness of student thinking could support PSTs in developing deeper, more relevant questions for students.

Second, an affordance of the Lesson*Sketch* platform was that it allowed us, the designers, to choose how the student's thinking was presented and revealed to the PSTs in a way that was more intentional than simply showing videos of student thinking. We were able to extract early ideas and display them in the cartoon depiction. We could then reveal more and more of the student's thinking by introducing short clips from the interview, which show the interviewer working to uncover deeper and deeper levels of the student's thinking. By using this technology to represent the student's thinking in multiple ways and revealing small pieces at a time, we could draw PSTs' attention to certain aspects of the student's thought processes. We hoped to support the PSTs in using what they noticed about student thinking to craft quality responses. Thus, instead of exploring what PSTs noticed and how they responded, we hoped to influence what they noticed to support their proposed responses.

After watching the student thinking interview clip, PSTs are asked a series of questions about the student's thinking and asked for examples of questions they would want to ask the student to probe his or her thinking further.

To summarize, the structure that the two experiences shared was as follows:

I. PSTs work on a proportional reasoning problem
II. PSTs view a fictional cartoon depiction showing what the focus student might do while working on the same problem in a classroom setting
III. PSTs are prompted to discuss observed student thinking and propose questions to ask the focus student to probe his or her thinking

IV. PSTs watch two short interview clips (taken from the actual student thinking interview with the focus student) in which more and more of the student's thinking is revealed
V. After each short interview clip, PSTs are prompted to discuss observed student thinking
VI. After the series of two interview clips, PSTs are prompted to suggest questions they would want to ask the student to better understand the student's reasoning

Figure 2 illustrates how the experiences designed in this way allow opportunities for representing and approximating practice. The LessonSketch experiences provide the representations of practice, namely representations of student thinking a teacher might come across in practice. The dotted rectangles describe what is available for the teacher to notice in these representations. In this framework, we can see how the events the PST noticed can influence core teaching practices such as asking quality questions. By prompting teachers to craft questions they would ask a student, the experiences create opportunities for approximating asking probing questions.

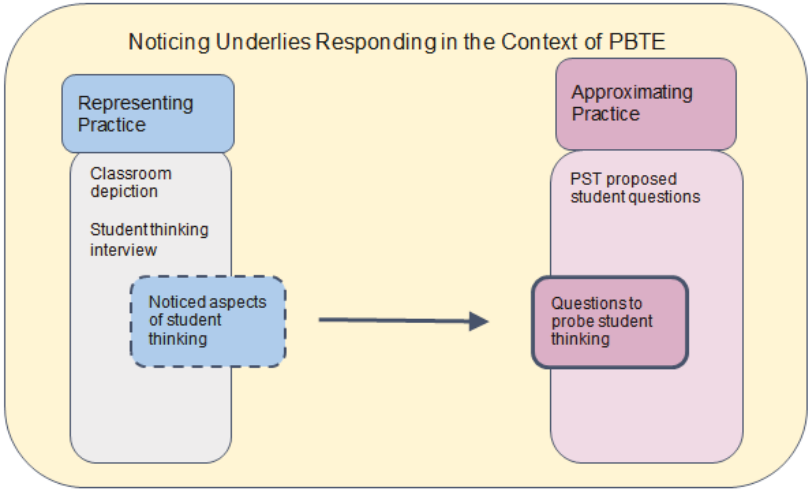


**Figure 2.** The LessonSketch Experiences support PST noticing for the purpose of crafting quality questions.

### A key difference in design

Based on a previous experience, not described here, we hypothesized that the interviewer's questions might be a resource for PSTs' development of skill in questioning. The Lemonade Experience directed PSTs to focus on student thinking, specifically, to inform the creation of questions to ask the student. We wondered how PSTs' questions might change if we directed them also to focus on the kinds of questions the interviewer asked the student. Thus we created the Paint Experience with this idea in mind. Before asking the PSTs what questions they would want to ask the student, we directed the PSTs to pay attention to what the interviewer asked, which was not done in the Lemonade experience. In this way the interviewer's questions were a more central part of the Paint experience. In addition, we were curious how PSTs' questioning might change between clips and not just after watching both clips. To explore this, we included the prompt for PSTs asking them to suggest questions to ask the student after each interview clip, rather than waiting until after viewing both clips, as in the Lemonade experience. (That is, Step VI was included with Step V in the Paint experience).

## DATA ANALYSIS

In exploratory analysis of our design choices, we were interested in how designed online Lesson*Sketch* experiences supported teachers in using student thinking to inform their proposed questions. In particular, we were interested in the connection between noticing and responding and how the Lesson*Sketch* experiences as designed supported PSTs' proposed questions by revealing specific segments of student thinking. We focused on the PSTs' questions written into the text box in the two similar Lesson*Sketch* experiences, Lemonade and Paint, as our unit of analysis. Recall, the question prompt was: "What questions would you want to ask [the student] to better understand his/her thinking?" We were interested in how this prompt would cue the PST to ask questions that would probe student thinking. In addition we were interested in the extent to which the questions were informed by the student thinking and the interviewers' responsive questions that were noticed in the interview. For this study, we used one set of responses from the Lemonade experience, collected after both interview segments were viewed, and two sets of responses from the Paint experience, one set collected after viewing Video Segment 1 and one collected after viewing Video Segment 2. We developed a coding scheme to capture data on PSTs' probing of stu-

dent thinking and on PSTs' attending to substance and coded each proposed question along these two dimensions.

### Dimension 1: Probing student thinking

Since we were interested in the practice of questioning as a way to probe and respond to student thinking, one coding dimension was the purpose of the question. Did the question serve the purpose of *probing student thinking* or did it serve to *lead or guide students* (Franke et al., 2009; Moyer & Milewicz, 2002; Sahin & Kulm, 2008) to a particular response? A question was coded as a probing question if it invited a student to explain or elaborate on an aspect of her thinking. A question was coded as guiding if its primary purpose was to lead the student down a particular path or to a particular solution. See examples in Table 1.

**Table 1**
Question types

| Question Type | Example |
|---|---|
| **Probing** student thinking (ST) | I would ask Raj to show step by step how he was able to get to his answer. I would also ask Raj how did he know that one paint had more value than the other and I would ask him to show numerical the actually difference in value. |
| **Guiding** student to specific idea or answer (G) | Does the amount of water affect how lemony the drink is? |

### Dimension 2: Attending to the substance of students' ideas

Another goal in the methods course, and in the Lesson*Sketch* experiences in particular, was to support teachers in attending to the substance of students' ideas. Thus, the questions were coded in terms of how closely they aligned with student thinking observed in the video. A question was assigned a code of low if the question did not connect to the student thinking observed in the depiction or the interview segments. A code of moderate was assigned if the question was connected to student thinking in general, but no specific details of student thinking were present, or if the PST's rationale for the question implied a judgment of the students' thinking as in-

correct. Finally, a question was coded high if it was explicitly connected to observed student thinking. See Table 2 for examples.

**Table 2**
Attention to the substance of students' ideas

| **Attention to substance of students' ideas** | **Example** |
|---|---|
| Low | I would ask her to look at the original proportions as fractions and to compare the two fractions. |
| Moderate | I would ask her how her thought process from the beginning of the problem differs from her thought process now as she finished the problem.<br><br>Or<br><br>I would ask him to explain how he was comparing the two amounts, would it be part-to-part or part-to-whole because it doesn't seem like he is being consistent. |
| High | What do you mean by 'the value being too far apart?' |

The first author coded all of the proposed questions from the two experiences using this coding scheme. The second author coded one-third of the proposed questions separately and we reached 83% agreement on these codes. We discussed and resolved discrepancies.

## RESULTS

Results are summarized in Tables 3 and 4.

**Table 3**
Question type results

| | **Lemonade (n=15) Interview Clip 2** | **Paint (n=12) Interview Clip 1** | **Paint (n=12) Interview Clip 2** |
|---|---|---|---|
| **Probe** | 33% | 67% | 67% |
| **Guide** | 67% | 33% | 33% |

**Table 4**
Attention to substance results

| | **Lemonade (n=15) Interview Clip 2** | **Paint (n=12) Interview Clip 1** | **Paint (n=12) Interview Clip 2** |
|---|---|---|---|
| **Low** | 47% | 08% | 17% |
| **Moderate** | 40% | 25% | 08% |
| **High** | 13% | 67% | 75% |

Looking at the tables we can see that the majority (67%) of PSTs' questions in the Lemonade Experience focused on asking leading or guiding questions to direct students to an answer. However, the majority (67%) of PSTs' questions in the Paint Experience were used to probe and draw out the student's thinking. In addition, the majority of PSTs' questions in Lemonade were not based on specific student thinking they saw in the interview (47% were not connected to student thinking and an additional 40% were only mildly connected to the student thinking in the representation). In the Paint experience, however, 67% and 75% of the questions were strongly connected to represented student thinking after watching interview Segments 1 and 2, respectively. This was interesting in that this difference suggests that the design of the LessonSketch experience may have influenced how PSTs used the student thinking they noticed to guide the questions they formed. Below, we discuss why we think the PSTs used the thinking differently in the two experiences.

## DISCUSSION

Recall that in both experiences the PSTs were asked questions (specifically designed to draw their attention to the substance of the student's ideas) after viewing each interview segment. The key difference was that in the Paint experience, PSTs were asked a question about what the interviewer did to probe students' ideas before they were asked what questions they would want to ask the student. Thus, the results we saw in this study suggest that drawing PSTs' attention to the substance of the interviewer's questions may support high quality questions along the dimensions we observed, questions that probe student thinking and are highly responsive to observed student thinking. In the Paint experience, PSTs were asked to pro-

pose questions twice, once after watching Interview Segment 1 and once after watching Interview Segment 2. We can see that the percentage of probing questions versus guiding questions were high after the first segment and remained high (69% probing questions, 31% guiding questions) after the second.

We also point out that in the Lemonade experience, only 13% of the questions were strongly connected to observed student thinking. In the Paint module, 69% of the questions were strongly connected to student thinking after watching Segment 1 and grew to 77% after viewing Interview Segment 2. It is possible that not only does focusing attention on the interviewer support questioning that probes student thinking but that it also supports questioning that is highly responsive to student thinking. Notably, even the first prompt to notice the questioning of the clinical interviewer produced high quality questions along both coding dimensions, suggesting that a simple initial instruction can prime PSTs to attend to and emulate the interviewer's strategies.

We drew on noticing as a cognitive framework for this study. In prior work on teacher noticing and responsive teaching, guiding teachers' attention to the disciplinary substance of student thinking has been the main emphasis. In fact, some work has specifically sought to focus teachers' attention on student thinking above other available stimuli, such as teacher pedagogical moves (e.g., Sherin & Han, 2004). In learning any practice, however, a learner does not only focus on the objects (i.e., the students), but also on the model practitioner they are learning from, as our findings suggest. For example, in Goodwin's (1994) description of the subtleties that novice archaeologists learn to notice, he focuses on the objects (i.e., the particular rubrics used to classify dirt). Undiscussed is the way in which novice archaeologists notice how more experienced archaeologists notice, interpret, and use these rubrics. This focus is consistent Grossman et al.'s (2009a) "cross-professional perspective" and with Lave and Wenger's (1991) description of how apprentices become gradually greater participants in a practice, first by taking on simple aspects of the practice and observing practices of the craftsperson.

The results of our exploratory study suggest that drawing PSTs' attention to student thinking and to teachers' responsive questions may be more effective for supporting teachers in the practice of questioning than focusing on student thinking alone. Our conceptual framework of the relationship between noticing, representations of practice, and the practice of questioning is now expanded to include the idea that noticing the questioning strategies of the interviewer plays a role in the quality of proposed questions (See Figure 3).

## Future research

As we discussed above, when learning a practice, not only is the learner attending to the object of the practice but they are also attending to how experts do the practice. In this case, we have evidence to suggest that focusing PSTs' attention on the substance of teacher questioning may support PSTs' asking of high-quality questions. The interviewers in this study were both veteran teachers, coming from years of facilitating instruction in reform-oriented, student-centered classrooms. The questions the interviewers asked to probe student thinking were open-ended invitations for students to articulate their thinking, rather than questions that aimed to guide students to a specific response. Asking PSTs to think about what the interviewers did to probe student thinking may have primed them to take a similar stance when formulating questions themselves. Thus, we propose a priming hypothesis: asking PSTs to pay attention to the questions an interviewer asks may prime them to ask similar high-quality questions as their responses to student thinking.

In conclusion, we suggest that noticing is a set of cognitive processes that underlies responding. As discussed, much of the literature on teacher noticing focuses on noticing of student thinking, in particular. Our observations indicate that noticing other aspects of instruction, in this case the interviewers' moves, might also impact teacher responses. We intend to explore this idea and our priming hypothesis further in future work by designing studies to investigate ways we can support PTSs' responses, such as crafting high-quality questions, by drawing their attention to the practices of expert teachers. In other pedagogical activities in our middle school certification program, we draw PSTs' attention first to the student thinking evident in representations and then ask PSTs to propose possible instructional responses that a teacher could make, in the form of a "menu of possibilities" to respond to student thinking (Hammer & van Zee, 2006). We are currently investigating the quality of responses that PSTs propose when their attention is drawn to different instructional approaches.

## Acknowledgment

This work is supported in part by a grant from the National Science Foundation "Improving Undergraduate STEM Education (IUSE)" program and by funds to the first author (Janet Walkoe) as a LessonSketch Research and Development fellow on the National Science Foundation Grant DRL-1316241. In addition, the graphics used in these images are © 2017 The

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## APPENDIX

### The Lemonade Problem

Question: Maria and Janelle are making lemonade by mixing lemon juice and water. Maria used 2 cups of lemon juice and 3 cups of water. Janelle uses 3 cups of lemon juice and 4 cups of water. Whose lemonade tastes more lemony or are they the same?

### The Paint Problem

Jess and Quinn are decorators and are mixing pink paint using a combination of white and red paints. The one adds more red paint to a pink mixture, the mixture will be a darker shade of pink. Quinn mixed 3 liters of red paint with 4 liters of white paint. Jess mixed 2 liters of red paint with 3 liters of white paint.

Question #1

How much red and white paint are needed to make just 1 liter of Quinn's mixture? (Remember that Quinn used 3 liters of red paint and 4 liters of white.)

Question #2

I want to make 70 liters of Jess' mixture to paint all the walls in a large house. How much red and white paint will I need? (Remember that Jess used 2 liters of red paint and 3 liters of white.)