Transitions in Prospective Mathematics Teacher Noticing

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Student-centered instruction (Ball and Cohen 1999; Feiman-Nemser 2001; National Council of Teachers of Mathematics (NCTM) 2000; Sherin 2002) requires that teachers carefully attend to, assess the potential of, and respond to student ideas during instruction. To support such instruction, one important transition that prospective teachers (PTs) need to make is in the way classroom instruction is viewed—transitioning from viewing it as a student concerned with his or her own learning, to viewing it as a teacher attentive to student learning.

One venue where this transition might occur is in school-based field experiences, which have long been advocated as an important component of teacher education programs (Ishler and Kay 1981; Myers 1996). Such experiences have been criticized, however, for failing to provide a structure that allows PTs to learn about teaching in significant ways (Feiman-Nemser 2001; Leatham and Peterson 2010a; Philipp et al. 2007). It has been found, for example, that many PTs lack the skills to meaningfully observe and make sense of classroom interactions during field experiences (Masingila and Doerr 2002; Orland-Barak and Leshem 2009). Furthermore, the goals of field experiences are often not well articulated, resulting in the experience having little focus on mathematical content or students' understanding of it (Leatham and Peterson 2010a, 2010b). Thus, it has been suggested that substantial teacher educator involvement, including collaborative viewing and discussion of instances of practice, might be critical to supporting meaningful learning from field experiences (Masingila and Doerr 2002; Oliveira and Hannula 2008).

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Central to the transition from viewing the classroom as a student to viewing it as a teacher is the construct of *teacher noticing* (Sherin et al. 2011; Sherin and van Es 2005). Underlying this construct is the notion that some events that occur during instruction are more productive for a teacher to attend to because of their potential to be used to support student learning. Although experienced teachers might intuitively recognize and respond to productive moments that arise during a lesson, novices often fail to notice or respond to these same instances (Peterson and Leatham 2010; Stockero and Van Zoest 2013). In fact, a major difference between expert and novice teachers' practices has been found to be their ability to attend to and capitalize on important instructional events (Berliner 2001; Mason 1998). Although targeted noticing is not something that adults automatically know how to do (Jacobs et al. 2010), the results of numerous studies suggest that it is a skill that can be learned (Jacobs et al. 2010; Santagata et al. 2007; Sherin et al. 2011).

Accumulating evidence suggests that structured viewing of video recordings of classroom lessons is one effective method of supporting both prospective (Santagata et al. 2007; Star et al. 2011; Stockero 2008a, 2008b) and practicing (Jacobs et al. 2011; Sherin and van Es 2009; van Es and Sherin 2008) teachers' ability to notice important events that occur during instruction. By slowing down practice and eliminating a need to immediately react to classroom situations (Sherin 2004), the structured analysis of video has been found to help teachers develop a stronger focus on students and their learning of mathematics (Sherin and van Es 2005; Stockero 2008a, 2008b) and increasingly consider the impact of teacher decisions on student learning (Santagata and Guarino 2011). Teachers have also been found to become more specific in their description of classroom events (Santagata and Guarino 2011; van Es and Sherin 2008) and to increasingly use evidence to support analyses of teaching and learning (e.g., Sherin and van Es 2005; Stockero 2008a). Importantly, Sherin and van Es (2009) have also found that noticing skills developed via video analysis can transfer to classroom teaching situations.

This study builds on prior work to support prospective teacher noticing in two important ways. First, much of the work to promote prospective mathematics teachers' noticing currently discussed in the literature has taken place in mathematics methods courses, typically later in a teacher education program (e.g., Santagata et al. 2007; Star et al. 2011; Stockero 2008a, 2008b). Although this work has been found to be effective, this study examines whether noticing can be taught at the start of a teacher education program in order to provide a strong focus on students and their mathematics upon which PTs might build in later courses.

Second, many video-based teacher learning interventions discussed in the literature have used video clips that were purposely selected by experienced teacher educators (e.g., Borko et al. 2008; Seago 2004), eliminating the opportunity for teachers to determine which instances that arise during instruction are worthy of analysis. This may be problematic, since to productively notice and use student thinking during instruction, teachers need to learn to sift through the complexity of classroom interactions to recognize instances that can be capitalized on to support mathematical learning. Thus, teacher educators need to develop not only PTs' analytic abilities, but also their abilities to notice which instructional events should be analyzed because of their potential to support student learning. This study uses unedited classroom video that requires PTs to "sift through" the complexity of the classroom to identify important events.

This chapter reports on findings from the first two iterations of an ongoing design experiment in which prospective mathematics teachers were engaged in research-like analysis of unedited videos of mathematics instruction during an early school-based field experience. Key features of the learning intervention included individual analysis of teacher-perspective classroom videos and group discussion of the analysis supported by a mathematics teacher educator. The goal of the work was to cultivate prospective mathematics teachers' ability to notice, analyze, and consider how to capitalize upon important mathematical moments that occur during instruction. The research questions for the study included: (a) To what extent were project activities effective in helping PTs learn to notice important instances of students' mathematical thinking? and (b) What particular aspects of the activities supported the PTs' learning? The results reported here primarily address the first research question by reporting on transitions in the participants' noticing that resulted from this work. Preliminary insights into the second research question, as well as implications for future work, are discussed.

Theoretical Perspectives

The work is grounded in a particular vision of teaching—one in which teachers continuously build on student mathematical thinking in ways that are responsive to students' current understanding (Ball and Cohen 1999; Feiman-Nemser 2001; NCTM 2000). Teaching in this way involves the teacher carefully listening to students' ideas, analyzing the mathematics underlying them, and then making in-the-moment decisions about whether and how these ideas might be used to develop students' understanding of important mathematics ideas.

Teacher noticing is defined in a variety of ways in the literature (e.g., see chapters in Sherin et al. 2011). Sherin and van Es (2005) defined teacher noticing to include three components—identifying what is important in a situation, making connections between a particular classroom situation and broader principles of teaching and learning, and reasoning about the situation. Jacobs et al. (2010) added a fourth component of noticing to this definition—deciding how to respond. This project adopts a definition of noticing that includes all four components, with a particular focus on noticing important mathematics.

Although instances of student thinking that occur during instruction are central to teacher noticing, this work is also grounded in the perspective that not all instances of student thinking have the same potential to help achieve the goal of supporting students' mathematical learning. Thus, this research project aims to promote *mathematical noticing*—noticing of students' mathematical ideas that surface during instruction and have the potential to be built upon to support students' understanding of important mathematics. This is not to say that there are not other things that are valid to notice, such as instances that provide opportunities to develop student confidence or to cultivate norms for working in small groups. The work of the project, however, deliberately narrows the focus to student mathematics in order to help PTs consider what student mathematical thinking might be most productive to focus on during instruction in order to help students develop a deeper understanding of the mathematics in a lesson. Thus, this project adopts a definition of mathematical noticing that includes the following four components: noticing important student ideas, analyzing the mathematics within them, making connections to a particular framework, and deciding how to respond. The analysis reported here focuses on the first two components.

This focus on mathematical noticing is informed by two related research projects. In a study of novice mathematics teachers' instruction, Stockero and Van Zoest (2013) characterized pivotal teaching moments (PTMs)—defined as an instance in a classroom lesson in which an interruption in the flow of the lesson provides the teacher an opportunity to modify instruction in order to extend or change the nature of students' mathematical understanding. In this study, five types of PTMs were identified that had significant or moderate potential to support students' learning of mathematics: extending, incorrect mathematics, sense making, contradiction, and mathematical confusion. The finding that mathematical moments that are important to notice during a lesson might fall into a small number of categories informed decisions about where to focus participants' attention during the project activities.

An ongoing research project is working to characterize "teachable moments" in a mathematics classroom—referred to as Mathematically Significant Pedagogical Opportunities to Build on Student Thinking (MOSTs) (e.g., Van Zoest et al. 2013). MOSTs are seen as occurring at the intersection of student mathematical thinking, significant mathematics, and pedagogical opportunity. In other words, high-leverage instances of student thinking that occur during a lesson must be student generated, involve mathematics that is related to a learning goal for students in the class, and provide the teacher an opportunity to build on student thinking to develop understanding of important mathematics. This framework provides a strong mathematical focus to teacher noticing and was used in this study to focus participants on moments that occur during a lesson that have the potential to be used by the teacher to enhance students' learning of mathematics.

Methodology

Context

The participants in the study were seven secondary mathematics prospective teachers (PTs); four were members of the first cohort that participated in the project in the Fall 2011 semester, and three were members of the second cohort that participated in Fall 2012. The teacher education program in which the participants were enrolled is very small, so the participants included all students with a mathematics major and some students with a mathematics minor who were enrolled in an early field experience course during each semester. Each participant was paired with a different experienced mathematics teacher at a local middle or high school to complete a 14-week early field experience. The field experience course is one of the first education courses that students in the teacher education program enroll in and is usually taken either late in students' sophomore year or early in their junior year of study.[1] Typically, this field experience consists of observing classroom instruction and assisting the teacher as needed, usually by working with individual students. Additional activities were added to the course as part of the project.

The Classroom Video

Each week, one PT in the cohort was assigned to video record a mathematics lesson taught by his or her cooperating teacher. The recording took place on a rotating basis, resulting in each PT recording two or three classroom lessons during the semester. Due to school scheduling and technical problems, there were two weeks where cohort 2 PTs did not collect the video, so the video from cohort 1 was used instead. The video was recorded from a front-of-classroom perspective to allow the participants to view the classroom as a teacher, rather than as a student. The instructional portions of each video were left unedited for the PTs to analyze; portions of the video where the teacher was tending to administrative tasks or where students were working quietly at their seats were cut from the video and excluded from the analysis since students' mathematical ideas could not be heard during these activities.

Members of each PT cohort analyzed the same set of eight (cohort 1) or nine (cohort 2) different videos during the semester. Note that because of the way the video was collected, the two PT cohorts did not generally analyze the same video, except for the two videos from the first cohort that were also used with the second cohort. Although an attempt was made to place the members of each cohort in a range of mathematics classrooms, the specific mathematics content of each video was not controlled because the focus was on noticing students' mathematics regardless of content. In short, the instruction that was recorded was mostly teacher led with various degrees of student interaction; the courses ranged primarily from middle school to geometry classes, with one calculus lesson analyzed by cohort 1. Table 1 summarizes the videos by PT cohort; note that videos C and F were coded by both cohorts.

Project Learning Activities

Each week, the PTs used the Studiocode video analysis software (SportsTec 2011) to individually code one classroom video, guided by an evolving and increasingly explicit coding framework focused on noticing instances of students' mathematical thinking. Early analysis activities were intended to focus the PTs on the students in

[1] Students do not apply to the teacher education program until they have established a GPA at the university; most students apply during their second year and start taking education courses during their third year of study.

Table 1 Summary of the video coded by each cohort

Video number	Cohort 1		Cohort 2	
	Video	Description	Video	Description
1	A	8th grade—patterns and variables	I	6th grade—absolute values; equations and expressions
2	B	8th grade—decimals and scientific notation	J	Algebra—exponents
3	C	Geometry—special triangles and quadrilaterals	K	Geometry—introduction to proof, grounded in segment congruence
4	D	8th grade—Pythagorean theorem and Pythagorean triples	C	Geometry—special triangles and quadrilaterals
5	E	Calculus—product and quotient rules	L	6th grade—factoring and exponents
6	F	8th grade—probability	M	Algebra—parallel and perpendicular lines
7	G	Geometry—inscribed and circumscribed circles	N	6th grade—percents and decimals
8	H	8th grade—test review; lines and scatterplots	O	Algebra—unit conversion
9			F	8th grade—probability

the classroom video and on their mathematics; later activities also incorporated the idea that some instances of student mathematics provide better opportunities for supporting student learning than others. The PTs' coding frameworks and interactions with the researcher are described in the following.

Early in the semester, PTs were asked to code the classroom video for "mathematically important moments (MIM) that a teacher needs to notice during a lesson" and write a brief explanation of their reasoning. The definition of a MIM was intentionally left ill-defined to allow the researcher to understand what the participants viewed as mathematically important during a lesson. The researcher and a graduate research assistant independently coded the same video as the members of the PT cohort and then met to discuss their own and the PTs' coding and decide which instances to discuss in a weekly meeting with the PTs. When coding, the Studiocode software produces a "timeline" of coded instances that can be merged to compare the coding of multiple coders. The merged timeline that showed all of the PTs' coding was used during the weekly meeting so the PTs could visually compare their own coding to that of the other members of their cohort. The researchers' coding was not shared with the PTs.

During the early group meetings, the researcher pushed the PTs to consider what was important mathematically about a particular instance and what the teacher had to notice; this pushing was intended to focus participants on students and their mathematics, rather than on teaching. Approximately six to eight instances were discussed at each weekly meeting; they included instances identified as a MIM by one or more participants (including both instances that were and were not identified as MIMs by the researchers), as well as some instances that were not identified by any PT but were deemed important by the researchers. The latter instances were primarily used to push PTs to attend to more subtle mathematical issues underlying student ideas—for example, ideas that were incomplete or that included imprecise language.

During the weekly meetings, the PTs were also pushed to consider whether instances that they collectively agreed were MIMs might fall into categories. These categories—informed by the researcher's prior work on PTMs (Stockero and Van Zoest 2013), but not made explicit to the PTs—were codeveloped by the PTs over the course of several meetings. As the categories were developed, the PTs were given the additional task of labeling each MIM that they identified in a video according to the category to which they felt it belonged. Subsequent meetings included refining and adding to the categories to more accurately describe the types of moments that were deemed important to attend to during a lesson. Although the names of the categories differed slightly, both cohorts had final categories related to student questions, wrong answers, incomplete answers, and unexpected (alternate) correct answers. Cohort 1 also developed categories of generalizing and multiple answers, while cohort 2 had a common misconceptions category.

Approximately midway through the semester—following the fourth video (video D) for cohort 1 and the fifth video (video L) for cohort 2—the framework for coding became more explicit when the PTs were asked to read an excerpt from a paper about MOSTs (e.g., Van Zoest et al. 2013)[2] and to recode two formerly analyzed videos to identify instances that met three defined criteria—student thinking, mathematically significant, and pedagogical opportunity. This reading was meant to provide language to discuss the student thinking and mathematics of an instance, as well as to introduce the idea that some moments that occur during a lesson provide the teacher a pedagogical opportunity to build on students' thinking to support their understanding of mathematics. After this framework was introduced, the PTs were asked to code subsequent videos for MOSTs instead of MIMs, and to discuss all three components of a MOST in their explanation of each selected instance in addition to labeling each instance by type.

Table 2 chronologically summarizes the project activities and shows the alignment between the activities and the videos described previously for each cohort.

Data Collection and Analysis

Data for the study included the PTs' individually coded Studiocode video timelines and video recordings of the weekly group meetings. The researchers used Studiocode to analyze all of the video timelines. The analysis process included adding an additional level of research coding to the timelines previously coded by the PTs; the meeting videos were used to help with the coding if a PT's written explanation of an

[2] The paper that the participants read during the project was a precursor to the current work on MOSTs. In it, the construct was referred to as a Mathematically Important Pedagogical Opportunity to Build on Student Thinking (MIPO) (Leatham et al. 2011).

Table 2 Summary of project activities, aligned with videos

Activity	Cohort 1	Cohort 2
PTs individually code for MIMs and give general explanation of importance of each moment	Videos 1–4 (A, B, C, D)	Videos 1–5 (I, J, K, C, L)
PTs codevelop categories of MIM types at weekly meetings	Primarily videos 2–4; modified as needed in later videos	Primarily videos 2–5; modified as needed in later videos
PTs read MOST paper and recode two prior videos using new framework	After video 4; recoded videos B and C	After video 5; recoded videos C and L
PTs individually code for MOSTs and give explanation of three components	Videos 5–8 (E, F, G, H)	Videos 6–9 (M, N, O, F)

instance was unclear. The unit of analysis for the research coding was any instance (MIM or MOST) that was coded by a PT. Thus, the length of an instance was determined by the PTs' coding, not by the researchers.

Building from coding frameworks used in previous studies (van Es and Sherin 2008; Stockero 2008a, 2008b), each important instance in a video that was identified by a PT was coded by the researcher and a graduate research assistant for agent, topic, and mathematical specificity (see Table 3 for codes). As defined in these prior works, agent refers to *who* the participants focused on in their description of an instance, and topic refers to *what* was focused on. For the agent code, student–teacher interactions were coded as either student–teacher, or teacher–student, depending on who was focused on first in a PT's comment. Some instances received two codes for agent or topic if the participant discussed two separate ideas in his or her explanation of the instance; in general, however, double coding was kept to a minimum. Because the focus of this work was on mathematical noticing, van Es and Sherin's (2008) specificity code—defined as how the teachers in their study discussed the events they noticed—was modified to focus on the specificity of the mathematics that the PTs discussed. Thus, in addition to using the subcodes of *general* and *specific,* a third code, *nonmathematical* was added to code instances of noticing that were focused on issues or events that were not mathematical in nature. During the coding process, the researchers met regularly to discuss, refine, and verify the coding; each instance was discussed until agreement on the coding was reached.

To give the reader a sense of the coding, consider the following PT explanation of an instance: "*The student asks a question about the placement of negative signs and the order [of the points] in finding slopes and the teacher uses this opportunity to go more in depth about finding slopes.*" For this instance, the agent was coded as *student–teacher* because the statement focuses first on the student's question, and then on the teacher's response. In this case, the student was considered the primary agent and the teacher was considered the secondary agent. The topic of this instance was double-coded as *question* and *explanation* because the PT noticed both the question that the student asked and the teacher's action—in this case, re-explaining

Table 3 Code definitions and sample codes

Coding category	Description	Codes[a]
Agent	Who the PT focused on in an instance	Teacher (T) Individual student (SI) Group of students (SG) Teacher, then students (T/S) Students, then teacher (S/T) Mathematics (no person)
Topic	What about the agent was focused on	Teacher explanation Student question Student thinking Student participation Understanding of the students as a group
Specificity	Whether and in what way the mathematics was discussed	Nonmathematical Specific mathematics General mathematics

[a] The agent and specificity code lists are complete, but the topic code list is a sample that includes the codes that are discussed in this chapter

how to find a slope. The specificity was coded as *specific mathematics* because it is clear that the PT is noticing mathematics related to calculating the slope of a line using two points.

After all of the PT-identified instances were coded by the researchers, the researchers' coding was analyzed to characterize shifts in the PTs' noticing in each of the three coding categories. Even though the two PT cohorts did not analyze the same set of videos, the goal for the two groups was the same: to scaffold their noticing to increasingly focus on students' mathematics in the detailed and nuanced way that is the foundation of student-centered instruction. Thus, the aim of the analysis was to understand the extent to which the PTs were focused on students, specific mathematics, and evidence of how students were thinking mathematically or mathematical issues they were encountering. The analysis involved examining the PTs' foci at different times during the learning experience, and how their foci changed during the experience. The findings are discussed in the following section.

Results and Discussion

The data revealed that the PTs' noticing shifted in all three of the coding categories. These shifts in agent, topic, and specificity, as well as initial conjectures about what caused these shifts, are discussed in the following. Because the number of instances coded by PTs varied by video, the results are reported as percentages. To help the reader make sense of the findings, the total number of instances coded by each PT cohort, the average number of instances per PT, and the range of the number of instances coded by each PT are given in Tables 4 and 5 for cohorts 1 and 2, respectively.

Table 4 Summary of instances coded by cohort 1

Video	Total coded instances	Instances per participant	Range of number of coded instances
A	25	6.25	4–12
B	16	4	3–5
C	25	6.25	5–9
D	14	3.5	3–4
E	12	3	2–4
F	21	5.25	3–7
G	13	3.25	2–5
H	14	3.5	3–4

Table 5 Summary of instances coded by cohort 2

Video	Total coded instances	Instances per participant	Range of number of coded instances
I	15	5	3–7
J	13	4.3	3–6
K	12	4	3–5
C	12	4	2–6
L	13	4.3	3–5
M	5	1.7	1–2
N	8	2.7	1–6
O	5	1.7	1–3
F	12	4	2–7

Agent

The analysis of the agent coding revealed three different shifts in the PTs' noticing: (a) from teacher as the primary agent to students as the primary agent; (b) from the teacher alone to interactions between the teacher and students; and (c) when the student was the primary agent, from focusing on groups of students to focusing on individual students.

Figure 1 shows the percent of PT-coded instances in each video with a primary student focus, depicted chronologically. That is, it shows the percent of PT-identified instances coded as focused on individual students, SI (e.g., "The student explained her thinking [about] how to multiply percentages. The opportunity arises to explain why that is." PT6); groups of students, SG (e.g., "The students are trying to come up with a correct answer to something they don't know. Even if they aren't sure, they're still trying and coming close to the right answer." PT7); or student–teacher interactions where the student was discussed first in the PT's explanation of the instance, S/T (e.g., "[The student] was able to put her understanding of the pattern into a basic mathematical model. This helps the teacher drive the lesson forward." PT1). As can be seen in the figure, early on, fewer of the PTs' coded instances had a primary focus on students. This pattern is particularly evident for cohort 2, where in

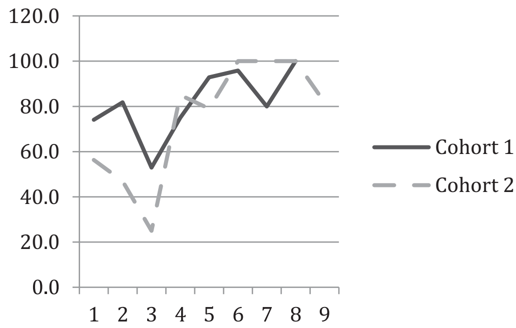


Fig. 1 Percent of participant-coded instances (by video) with a primary student focus

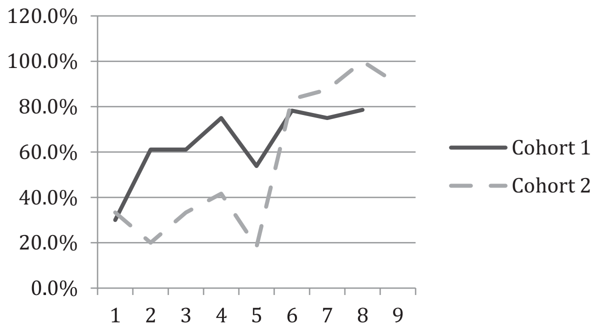
the second and third videos, less than half of the participant-identified instances had a primary student focus. After the third video, both groups exhibited a more consistent focus on students, with over 80 % of coded instances for both groups focused primarily on students in videos 5 and later. This shift is significant because focusing on students is key to implementing mathematics instruction that is responsive to students and their ideas about mathematics.

Although there was some continued focus on the teacher throughout the experience, the PTs' focus shifted from noticing the teacher alone to noticing teacher–student interactions. The percentages of teacher-focused instances for each cohort that were focused on teacher-student interactions can be seen in Table 6. Early on, when the PTs focused on the teacher, they often discussed only what the teacher did (e.g., "The teacher explains the difference between expressions and equations." PT1) without considering how the teacher action they noticed was likely to support student learning. Beginning with the fifth video, however, a significant shift was evident for both groups, with 89 % or more of all instances that considered the teacher (coded as T, T/S, or S/T) focusing on teacher–student interactions (coded as T/S or S/T). For example, in one instance, PT2 explained, "The student gives an equation for slope but she has the numerator and denominator switched. Instead of

Table 6 Summary of teacher-focused instances focusing on teacher–student interactions

	Cohort 1		Cohort 2	
Video	# Teacher-focused instances	Percent of teacher-focused instances focused on teacher-student interactions	# Teacher-focused instances	Percent of teacher-focused instances focused on teacher-student interactions
1	8	25.0	5	80.0
2	5	20.0	8	25.0
3	13	23.1	11	18.2
4	7	57.1	2	100.0
5	7	100.0	1	100.0
6	14	92.9	1	100.0
7	9	88.8	0	n/a
8	11	100.0	0	n/a
9	–	–	3	100.0

Fig. 2 Percent of primary student instances focused on individual students



just saying that the answer was wrong and giving the correct answer, [the teacher] connects the equation to rise/run. In doing this he gets the students to notice the problem with the equation." This shift was particularly strong for cohort 2, who collectively had no comments coded as focused on the teacher alone after the third video. This shift is significant in that it provided evidence that the PTs were beginning to think about how teacher actions support student learning, rather than on teacher moves independent of students.

A third significant shift occurred in how the PTs noticed students in the videos. Figure 2 shows the percent of coded instances with a primary student focus (coded as SI, SG, or S/T) for which the PTs were focused on individual students (SI). As can be seen in the figure, in the first video, when the primary focus of the PTs' noticing was students, the focus was on individual students a relatively small percentage of the time (30 % for cohort 1; 33 % for cohort 2). Their focus was more often on groups of students, with many PT comments offering assessments of the understanding of the group of students as a whole based on a single student comment. For example, the PT comment, "Students struggle to give a definition for [quadrilateral]" was coded as focused on a group of students, while the explanation, "[The student] was able to see the connection, which led to finding an equation" was coded as focused on an individual student.

The shift in focus from student groups to individual students began as early as the second and third videos for cohort 1, with about 60 % of student-focused instances centered on individual students in these videos. This same shift did not occur until later for cohort 2—in the sixth video—although after this time, their focus on individual students appeared stronger than cohort 1. The cause of this difference in timing warrants further investigation, but may be related to the specific classroom videos that each group analyzed. Overall, however, both PT cohorts demonstrated a significant shift in their focus on students during the experience, with the percent of student-centered comments focused on individual students ranging from 75 to 100 % in the last three videos.

Topic

Although the topic of the PTs' noticing was the most difficult to make sense of—mainly due to a larger number of codes spread out over a relatively small number of participants—the analysis revealed several shifts that are worth noting. In particular, decreases in the PTs' noticing of teacher explanations, claims about the understanding of an entire class, and student participation were documented, as were increases in PTs' noticing of student thinking and student questions and other evidence of mathematical confusion. These are discussed in the following.

Some topics of the PTs' noticing were coded less frequently as the learning experience progressed. Two of these shifts were closely related to the previously discussed shifts in agent. First, related to the decreased focus on the teacher alone (i.e., not in interaction with students), the PTs in cohort 2 became less focused on the teacher's explanation of the mathematics for its own sake—that is, explanations that were not in response to students' questions or comments. In the first three videos, 38 % of their instances were coded as teacher explanation, whereas only one instance of teacher explanation was coded after this time, and this instance was focused on how the teacher used a student idea to better explain a concept. Cohort 1 began with a low focus on teacher explanations (10 % of instances in videos 1–4) and increased it slightly (20 % in videos 5–8); it was encouraging, however, that all but 3 % of instances in these latter videos were in response to student questions or comments. Second, related to the previously discussed shift in agent from groups of students to individual students, there was a decrease in PT comments that made overgeneralized claims about the understanding or lack of understanding of the class as a whole. In the last four videos, the two cohorts combined had only 4 % of documented instances (3.3 % for cohort 1; 6 % for cohort 2) focused on making claims about group understanding, compared to about 21 % of instances in the first four videos (18 % for cohort 1; 26 % for cohort 2).

Another decrease in focus was on how students participated in the class or worked with one another (e.g., "There are students with their hands raised that give up on what they wanted to say, and the guy in the back doesn't try to participate the remainder of the class." PT3). This more affective noticing focus was relatively prevalent in the first few videos, particularly for cohort 1, which had 10 documented instances (15 % of total instances) in the first three videos. During the latter half of the experience, it was documented only once for each cohort (1.7–3.3 % of instances). Although important to learning in general, affective noticing such as this does not directly support the learning of mathematics content; thus, this seems to be a productive shift in attention as it indicates that the PTs were becoming more attentive to issues directly related to students' mathematical learning.

There were also some topics that were focused on more frequently by PTs as the experience progressed. One such topic was student thinking, which overall was stronger in the later videos (Table 7). This shift was not consistent, however, as cohort 1's focus on student thinking was strongest in the middle videos, while cohort 2's focus was strong in the first video, and then diminished before becoming

Table 7 Percent of instances coded with student thinking as a topic

	V1	V2	V3	V4	V5	V6	V7	V8	V9
Cohort 1	0.0	0.0	4.0	21.4	8.3	14.2	7.7	0.0	–
Cohort 2	25.0	0.0	0.0	8.3	7.7	40.0	62.5	80.0	25.0

strong again in the later videos. To illustrate a focus on student thinking, consider PT5's explanation of the importance of one instance: "This is a common mistake in probability problems where the items aren't replaced. The student mentally removes [student]'s name from the number of girls but forgets to remove her from the total number of students." As can be seen in this example, when focusing on student thinking, the PTs were making sense of how students seemed to be thinking mathematically, rather than just whether they were thinking correctly or incorrectly. This more nuanced focus on student thinking is essential in order for a teacher to use student thinking during a lesson. Because helping PTs learn to notice student ideas was a primary objective of the learning activities, the increasing and decreasing nature of the PTs' focus on this topic requires further investigation.

A second topic that received increased focus was student questions—particularly those that were conceptual in nature—and evidence of student mathematical confusion, which was implied from both their questions and mathematical comments (e.g., "A student is confused about concurrent and [the teacher] answers his question by explaining the difference between concurrent and the circumcenter. I think this is the best method to answer his question because you can see after that he understood after the explanation." PT2). This shift in focus was most significant for cohort 1, which had only 5 % of instances coded as questions or confusion in the first four videos, compared to 58 % in the last four videos. Although the shift was not as dramatic for cohort 2, they still had more than twice the number of instances coded in this category for the latter half of the experience compared to the first (8 % of instances early; 21 % of instances late). As data from future iterations of the work are analyzed, it is likely that this coding category will need to be refined to separate conceptual questions that introduce new mathematical ideas or provide an opportunity to go beyond the mathematics of the lesson, from questions that indicate confusion about the mathematical ideas at hand. This more fine-grained level of coding may provide insight into whether PTs were focused on instances that provided opportunities to clarify the mathematics in the lesson, or those that might be used to make connections among lessons. Both of these foci are important, but very different, ways that a teacher could use student thinking productively, so it would be helpful to understand in more detail the degree to which the PTs focused on each.

Specificity

The analysis of the specificity coding indicated that the PTs collectively transitioned to becoming both more focused on noticing instances that were mathematical in nature and more specific in their discussion of the mathematics of an instance. These shifts are discussed in the following.

Despite the fact that the PTs were given instructions to code “MIMs that a teacher needs to notice during a lesson,” some of their early noticing was focused on nonmathematical instances. For example, PT2 identified a teacher incorporating exercise into her lesson as a MIM, even though this activity is clearly not mathematical by nature. In the first two videos, 15 % of instances identified by cohort 1 were not mathematical; this group identified no nonmathematical instances after this time, however. In their first three videos, 13 % of instances coded by cohort 2 were not mathematical in nature, with only one nonmathematical instance documented subsequently in video 5. The shift away from nonmathematical noticing seemed fairly easy to facilitate by pushing the PTs to discuss the mathematics in each coded instance, but it is an important shift nonetheless since focusing on nonmathematical issues necessarily shifts teachers’ attention away from noticing students’ mathematics.

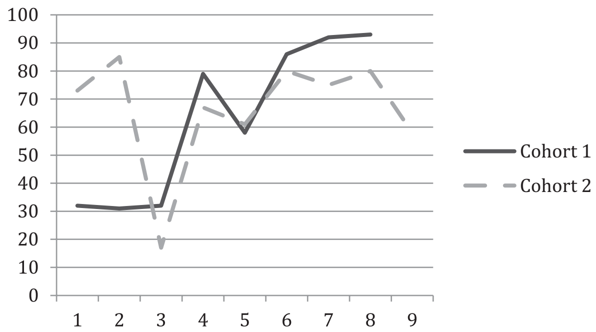
A second shift that was particularly strong for cohort 1 was from noticing general mathematical issues to those that were specific in nature. This shift is important because it indicates that the PTs were engaged in more detailed analysis of the mathematics in the videos and were able to attend to specific student ideas or teacher moves, rather than making general observations about the mathematics of the lesson. An example of general mathematical noticing is, “The student gave the wrong answer to the teacher’s question, but the teacher went along with the reasoning and then went through the process of double checking,” whereas an example of specific mathematical noticing is, “The student asks a question about the placement of negative signs and the order [of the points] in finding slopes and the teacher uses this opportunity to go more in depth about finding slopes.” Note that in the first example, while the PT was focused on the students’ mathematics, she did not discuss in her explanation a specific mathematical issue, just that the student gave a wrong answer. In fact, the comment itself gives no indication of the mathematics of the lesson. In the second example, it is clear that the PT was focused on calculations related to finding the slope of a line.

In the first three videos, cohort 1’s explanations of their coding were more general in nature, with less than 35 % of instances coded as related to specific mathematics (Fig. 3). Cohort 2’s noticing was fairly specific from the start (with the exception of video 3), but the data were somewhat skewed by one PT whose explanations were consistently specific throughout the experience. Relatively early in the experience, before they had engaged with the MOST framework, both groups of PTs’ noticing became consistently more specific than general.

Explaining the Shifts

Although the analysis of the facilitation of the learning activities is ongoing, the timing of some of the documented shifts allows one to make informed conjectures about what might have prompted them. In general, there seems to be three factors that may account for the PTs’ shifts in noticing: (a) targeted facilitation moves during the weekly meetings intended to focus the PTs’ attention on specific aspects of

Fig. 3 Percent of PT-identified instances (by video) focused on specific mathematics



the video, (b) the reading of the MOST paper approximately midway through the experience, and (c) ongoing engagement in the project activities.

Targeted facilitation moves, particularly those employed early in the experience, appear to account for some of the documented shifts in the PTs' noticing. The relatively early shift toward a more consistent focus on students, for example, seems to be the result of the facilitator pushing participants to articulate what the teacher had to notice in each instance that they had documented (recall that the participants were prompted to identify MIMs that a *teacher needs to notice* during a lesson). Because a teacher does not need to notice his or her own actions, this move seems to have had its intended effect of focusing the PTs on the students in the video. Facilitator questioning also seems to account for the early shift away from nonmathematical noticing, as participants were consistently asked to discuss the mathematics in each instance during the weekly group meeting. In response to the facilitator questioning PTs about both of these foci, it was not uncommon for one PT to highlight that a moment identified by a peer either had nothing for the teacher to notice because it was just teacher talk, or that it was not mathematical in nature.

Other shifts, particularly those related to making sense of student contributions and the mathematics within them, may have been prompted by a different facilitation move—replaying portions of the video during the weekly meetings, sometimes several times, so that PTs could carefully listen to what was being said. This move seemed to help PTs learn to attend to the nuances of student comments, which may have helped them both to become better able to recognize when student contributions contained important mathematics and to shift toward becoming more specific in the way they discussed the mathematics of an instance. Shifts such as these are significant in that they support the focused noticing and ongoing analysis that is necessary to teach in a way that is responsive to student thinking.

After coding four or five videos, each cohort read an excerpt from a paper describing the MOST framework that highlighted key characteristics of "teachable moments" in mathematics: student thinking, significant mathematics, and pedagogical opportunity. After reading this paper, the PTs were asked to use the framework to inform their coding, which appears to have contributed to several shifts in their noticing. The timing of the PTs' increased focus on teacher–student interactions, for example, suggests that it was facilitated at least in part by introducing the MOST framework. In this case, it is conjectured that asking the PTs to think about the pedagogical opportunity that student thinking might provide helped them begin to consider ways in which a teacher might be responsive to student ideas.

Because the PTs engaged in the project activities over an entire semester, it is also possible that some of the documented shifts in noticing were the result of ongoing engagement over time. The focus on individual students, for example, seemed to continue to increase throughout the experience. It is also possible that some of the shifts were the result of a combination of activities, including the PTs' interactions with one another. Although the effects of sustained engagement and the interaction of learning activities are more difficult to document, understanding these effects will be the focus of ongoing data analysis. In any case, it is encouraging that significant changes in teacher noticing were documented over the course of the learning experience—changes that are likely to support their ability to engage in student-centered instruction.

Discussion and Conclusions

The results of this work indicate that it is possible to facilitate transitions in mathematics teacher noticing, even early in a teacher education program. While other studies have used videos to prompt similar changes in mathematics methods courses (e.g., Santagata and Guarino 2011; Sherin and van Es 2005; Stockero 2008a, 2008b), which typically take place near the end of teacher candidates' university coursework, this study attempted to do so at the start of a teacher education program, during a school-based early field experience. Focusing PTs on students and their learning of mathematics from the start of a teacher education experience offers the potential to build on this foundation during subsequent coursework, possibly resulting in an even stronger student-centered focus at the end of a teacher education program.

The data revealed that the PTs in this study were, in fact, able to increasingly notice important mathematical instances in unedited video recordings of classroom instruction. Their noticing became more focused on individual students and how teacher–student interactions affect learning. They also became better able to attend to the specific mathematical details of important instances that surfaced during a lesson. The coding of the topic of the PTs' noticing provided some indication that the participants became more focused on instances that were important mathematically rather than for social or affective reasons, less prone to make claims about groups of students, less focused on teacher explanations, and more attentive to issues directly related to student understanding—how they might be thinking mathematically, conceptual questions that they asked, and evidence of mathematical confusion. Together, these transitions are significant because noticing students and the details of their mathematical thinking is foundational to student-centered instruction; a teacher cannot build on ideas that they do not notice or of which they cannot make sense.

The results are also significant in that they provide evidence that PTs not only can learn to analyze short preselected video clips of instruction (e.g., Borko et al. 2008; Seago 2004; Stockero 2008b), but can also learn to identify mathematically important instances in unedited classroom videos. Although short preselected video clips offer some advantages—such as less time for analysis and possibly a more focused discussion about particular issues the clip is intended to raise—sifting through the complexity of classroom interactions to figure out which student ideas have potential to be used to develop students' understanding of the mathematics is exactly what teachers need to do in order to enact student-centered instruction. In this way, learning to analyze unedited classroom videos might be advantageous in terms of helping teachers transfer noticing skills developed through teacher learning experiences to their classroom instruction.

The intervention in this study included many elements that are often missing from school-based field experiences: a clear and consistent focus on mathematics, engagement in structured analysis, and collaborative learning about practice with substantial mathematics teacher educator support. Each of these elements is critical to helping PTs take the most away from the time they spend in schools (e.g., Leatham and Peterson 2010a; Masingila and Doerr 2002). First, the early noticing of the participants in this study suggests that, without a clear push to focus on content, it is likely that PTs will focus instead on elements of instruction that are less central to student learning of mathematics. Second, as has been found by others (e.g., Santagata et al. 2007), analysis frameworks seem essential to give both structure to what is observed in the complex environment of a classroom and a language to discuss it. The evolving analysis framework in this study, including the labeling of important instances and the eventual introduction of the MOST framework, provided this structure and language for the participants and seemed to prompt changes in how and what the PTs attended to in the classroom videos. Finally, it has been suggested that teacher educator support—something that is often lacking during school-based field experiences—is necessary to effectively facilitate prospective teacher learning from such experiences (e.g., Leatham and Peterson 2010a; Oliveira and Hannula 2008). In this study, discussing common classroom videos with a teacher educator maintained a clear mathematical focus during the field experience and provided a means to challenge PTs' emerging ideas about the teaching and learning of mathematics. Together, these elements appear to have been effective in supporting desired transitions in noticing in this intervention.

Although the results are promising, further work is needed to fully understand the transitions that have been documented, as well as what specific activities and structures supported them. One of the limitations of the results reported here is the small number of participants; in particular, this limitation makes it difficult to make sense of some of the differences in noticing between the two PT cohorts. Recall, for example, that cohort 1 shifted from noticing student groups to noticing individual students earlier than cohort 2; cohort 1 also developed a stronger focus on students' conceptual questions and evidence of confusion. Cohort 2, on the other hand, developed an overall stronger focus on students and had a stronger focus on student thinking at the end of the experience. They were also more specific in their discussion of the mathematics throughout. Some of these differences seem to be attributable to the individual students in each cohort. For example, cohort 2 included a PT who consistently discussed the specific mathematics in each instance right from the start. Other differences may be the result of the interactions of the PTs within the group. Cohort 1, for instance, included a participant who challenged others when they made claims about the understanding of whole groups of students based on a single student comment, possibly reducing the number of such claims. Other differences may be the result of the way the group discussion was facilitated each semester, or participants' understanding of the mathematics of each lesson that was analyzed. These factors are being investigated as part of the ongoing analysis of the data; additional data are also being collected to determine whether similar trends are seen with other PT cohorts.

In addition, the analysis of the topic of the PTs' noticing has raised issues related to video selection that require further investigation. One of the reasons that the coding of the topic of the PTs' noticing was more difficult to make sense of was that some of the noticing topics seemed to be video or context specific. That is, instances related to some noticing foci were not seen in all of the videos. In the study, classroom video that was recorded by the participants was used to maintain a strong connection to practice. Analyzing the video from classrooms in which the PTs worked was intended to give a sense of reality to the experience; that is, the video portrayed students who were real to the PTs, rather than "other" students from classrooms that were special in some way. This meant, however, that what each PT cohort had available to notice was not always the same. In particular, there were three topics that seemed strongly dependent on the classroom culture or nature of a lesson: multiple student solutions, unexpected correct answers, and students correcting one another's mathematical thinking. Instances that instantiate these topics are only likely to occur, and thus be available to be noticed, in classrooms where the teacher allows multiple ideas or nonstandard ways of thinking to be made public and where students are engaged in discussion about mathematical ideas. Thus, although the mathematical content of the videos did not seem to be a factor, the context of the classrooms and, in particular, the nature of student–teacher interactions seem to be an important consideration. This context dependency raises interesting questions related to video selection that need to be explored in future work. Specifically, it may be the case that in future iterations of the work, videos need to be deliberately "inserted" into the sequence of videos that are analyzed to ensure that participants have access to a wide range of mathematically important instances.

In summary, this study provides an initial understanding of the outcomes of a set of activities designed to facilitate PTs' mathematical noticing and gives some insight into elements of such activities that might be critical to helping PTs learn to attend to important mathematical instances that arise during a lesson. Understanding the details of transitions in noticing and how to best support them in this context has the potential to inform interventions to support mathematics teachers in a range of contexts to engage in productive mathematical noticing during instruction.

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