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Abstract

A noticing framework was introduced to prospective teachers (PTs) as a tool to use for analyzing student work. The purpose of this study was to determine the impact of PTs' use of a noticing framework for: 1) interpreting students' mathematical thinking; and 2) reflecting on and discussing future implications for teaching. The study also sought to determine where PTs needed, if any, further support in engaging in the process of noticing. Using a coding schema that reflected three levels of understanding (periphery, transitional, and accomplished), a frequency table was constructed that allowed PTs' use and understanding of a noticing framework to be analyzed.

Introduction

As prospective teachers (PTs) make the arduous journey from being learners of mathematics to becoming teachers of mathematics, the requirements of teacher education programs ultimately support or fail to support the understanding and knowledge gained (Dewey, 1933; Barnhart & van Es, 2015). Researchers have stated that to improve the practice of teaching one must be engaged in the sense-making of student conceptual knowledge and procedural knowledge with purposeful guidance (Dewey, 1933; Schon, 1983). According to Barnhart and van Es (2015), the work of mathematics educators is to scaffold what is attended to and how that information is being interpreted by PTs. Mathematics teacher educators (MTEs) then hold the responsibility to guide PTs in making instructional decisions that align with student understanding (Darling-Hammond & Bransford, 2005; Davis, Petish & Smithey, 2006; Zeichner & Liston, 1996). Without structured support, research has shown that PTs' analyses of student knowledge tend to focus on aspects of the classroom typically related to management rather than to student understanding of content (Barnhart & van Es, 2015).

Shulman (1986), with the introduction of pedagogical content knowledge, shifted the way in which MTEs thought about and taught mathematics to PTs. Shulman (1986) defined pedagogical content knowledge (PCK) as, (a) knowledge of ways of representing content and (b) knowledge of students' thinking regarding content including conceptions, preconceptions, and misconceptions. Vygotsky (1962), relating to the notion of PCK, stated that scientific knowledge provides a means for teachers to "interpret, transform, and reframe their information or spontaneous knowledge about students' mathematical thinking" (Carpenter, Fennema, & Franke, 1996, p. 5).

In their research, Stevens and Hall (1998) utilized disciplined perception, the act of noticing based on a particular profession. MTEs' use of disciplined perception becomes essential to the success of PTs and the manner in which PTs navigate the transition from learner to teacher of mathematics. Often, noticing is focused on the students' reaction to content, but for this study, we chose to focus on the way in which MTEs may or may not notice what their students bring into the classroom. For example, not only noticing students' understanding of content, but also pedagogy related to mathematics instruction. For this study, we focus on how MTEs support the development or fail to develop PTs' PCK related to knowledge of student thinking through the use of professional noticing.

Theoretical Framework

Professional noticing consists of three interrelated stages: Attending to students' strategies, interpreting students' mathematical understandings, and deciding how to respond (Jacobs, Lamb, & Philipp, 2010); it develops with practice as opposed to naturally with teaching experience (Jacobs et al., 2010). Employing the framework of professional noticing is based on intentional moves within a classroom setting, where individuals focus on specific aspects related to student learning. Professional noticing aligns with the *Standards for Preparing Teachers of Mathematics* (AMTE, 2017) and the

Principles and Standards for School Mathematics (NCTM, 2000) because it is a framework for teachers to build on students' mathematical thinking.

The Association of Mathematics Teacher Educators (AMTE) advocates that beginning teachers should "anticipate and attend to students' thinking about mathematics content" (AMTE, 2017, p. 6). Moreover, the National Council of Teachers of Mathematics (NCTM) states that "effective teaching of mathematics uses evidence of student thinking to assess progress toward mathematical understanding and to adjust instruction continually in ways that support and extend learning" (NCTM, 2014, p. 10). Thus, MTEs need to provide experiences for PTs that allow them to analyze how students think about mathematics and support them in using this knowledge to plan and modify their instruction (Ball & Forzani, 2009; Clements & Sarama, 2014). MTEs can help PTs analyze mathematical thinking that, subsequently, informs teaching by including *the action* of professional noticing (Jacobs, Lamb, & Philipp, 2010) in their courses.

In their work, van Es and Sherin (2008) describe a three-part learning to notice framework which we chose to implement for this study: 1) select a noteworthy aspect within a classroom, 2) use knowledge about the context, and 3) make connections between classroom events and aspects of teaching and learning. When introducing professional noticing, we intentionally selected activities that were complex so that as PTs entered into the work we were able to define their level of understanding clearly. As an exploratory exercise, we asked our students to use professional noticing based on a series of student responses related to the question, "Mishaa has three dogs: Jason, Boy Blue, and Dakota. Jason is 5 years older than Boy Blue. Dakota is 3 years younger than Boy Blue. Their ages right now total 23. Figure out the age of each of Mishaa's dogs. Write down each dog's age and explain how you figured it out" (Seymour, D., DeGraw, M., & Ott, D., 1999).

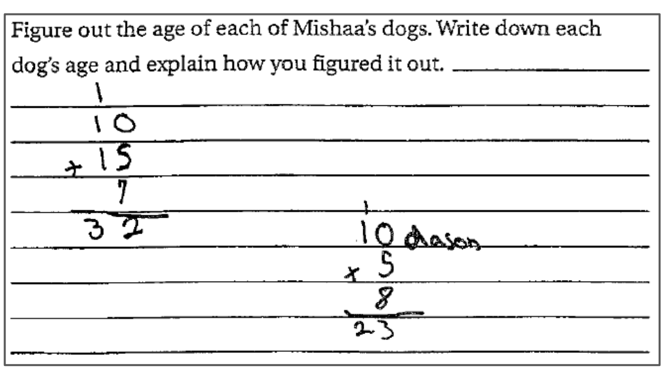
Figure out the age of each of Mishaa's dogs. Write down each dog's age and explain how you figured it out.

1
10
+ 15
7
32

1
10 Jason
+ 5
8
23

Figure 1. Example student response (Seymour, D., DeGraw, M., & Ott, D., 1999)

By providing a specific and structured experience, we were able to scaffold student thinking and articulate the nuances of the professional noticing framework.

The third and final aspect of the van Es and Sherin (2008) model is the manner in which the professional noticing is tied to the teaching and learning within the classroom. Shulman's (1986) pedagogical content knowledge work is the foundation for this criterion.

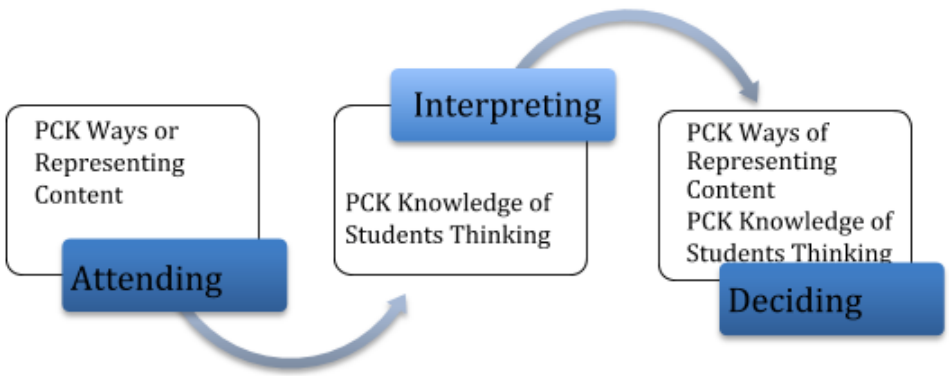

Figure 2. Relationship between PCK and Professional Noticing

The amalgamation of the concepts related to PCK and the professional noticing framework depicts the intersection of theory and practice (see Figure 2). PCK is a construct that develops over time but requires experience and integration in meaningful ways to support developing PTs. Philipp (2008) stated that PTs gain more "by learning about children's mathematical thinking concurrently while learning mathematics" (p. 8). Findings suggest that it is important for PTs to learn mathematics conceptually, as opposed to learn mathematics procedurally, so that they can teach their future students mathematics for understanding (Philipp et al., 2007). Although teacher noticing can be developed (Miller, 2011), learning how to notice develops with deliberate practice with purposeful experiences (Jacobs et al., 2010).

We describe an activity and the results of the activity in which the Noticing Framework, Attend, Interpret, Decide, (Thomas, Fisher, Jong, Schack, Krause, & Kasten, 2016; Jacobs, Lamb, & Philipp, 2014) was used and completed within a mathematics content/pedagogy class. PTs at our university experience three mathematics content/pedagogy courses. This activity was completed during their third and final mathematics course. The purpose of this activity was to: 1) to illustrate how to implement the Noticing Framework; 2) to encourage PTs to describe student understandings of mathematical content, based on their understanding of mathematics education literature; 3) to allow PTs to see differences in how children respond to the same mathematical content and; 4) to identify gaps in PTs pedagogical content knowledge through the use of the Noticing Framework. The study aimed to explore the following questions:

1. How do PTs interpret students' mathematical thinking based on the Noticing Framework?
2. How do PTs reflect on and discuss future implications for teaching?
3. How can mathematics educators attend to PTs' novice interpretation of the Noticing Framework?

We fully understand that this research study is only a snapshot of the PTs ability to utilize the Noticing Framework, and do not expect a comprehensive understanding of the framework. However, an anticipated outcome for this study was to identify gaps in content knowledge, as well as, pedagogical decisions related to the PTs' interpretation of individual student needs. The Information gained through this study may focus MTEs' instructional practices with the intent of supporting the comprehensive development of the Noticing Framework.

The Instructional Activity

Before engaging in professional noticing, the PTs read the article *A New Lens on Teaching: Learning to Notice* (Sherin & van Es, 2003). In this article, the authors provide examples of how in-service teachers reflect on their teaching through noticing. It is essential for PTs to read this article to realize that noticing will help them make in-the-moment decisions (NCTM, 2000) and that there are a variety of ways to use noticing in their future classrooms. After the PTs have read and discussed the Sherin and van Es (2003) article, the MTE introduced the noticing framework to the whole class. PTs were prompted to come up with one to two questions that would help them to attend, interpret, and decide when analyzing student work. Figure 3 is an example of the questions.

Attend	What did the student(s) do? What strategies did the student(s) use?
Interpret	What does this mean about the student(s) understandings or misconceptions of the mathematics?
Decide	What are the next best instructional steps based on attend and interpret? What types of questions would you want to ask the student(s)?

Figure 3. Questions Corresponding to each stage of Professional Noticing

Once the PTs made sense of how to use professional noticing, the MTE gave them a mathematics problem to complete and provided them with student work to analyze in small groups using professional noticing. As a whole class, the PTs shared their analyses and discussed similarities and differences. Finally, the MTE posed the following questions (Figure 4) to the PTs. These questions are meant to stimulate the PTs' thinking about how to scaffold student learning and the next best instructional steps.

Summary Question 1	What is your mathematical agenda?
Summary Question 2	In a whole class discussion, in what order would you have the students share their work and why?

Figure 4. Summary Questions for PTs

At this point in the instructional activity, the MTE took on the role of a facilitator to encourage and manage discussions among the PTs. For example, there are often many different ways to interpret a student's mathematical understandings based on student work and, based on the interpretation, there are many different directions to go for the next best instructional steps. The MTE must have a robust knowledge of the mathematical content in order to guide the PTs to *notice* effectively. Indeed, this is a prime example of Shulman's (1986) PCK in action. In this instructional situation, the MTE modeled for the PTs what it looks likes for an instructor to call upon mathematical knowledge as well as drawing upon the MTE's knowledge of the ways students tend to engage with a particular problem representation, and what different responses tend to suggest to us about students' understandings. The MTE emphasized that although the steps are interrelated, it is important to first understand what the student did before deciding on the next best instructional steps. A challenge for the PTs is thoroughly analyzing student thinking of the mathematics before making recommendations for further instruction.

Methodology

The study reported here was conducted in the Spring 2017 semester at a state university in the southeastern United States. Participants included 21 elementary school PTs enrolled in a mathematics methods and content course focused on the development of children's mathematical knowledge, skills, and dispositions over time and ways to adapt instructional strategies to children's learning needs. For this paper, we report on the qualitative analysis of data related to three PTs who were selected because they were present for all class sessions and their responses on the professional noticing assignment were more complete and detailed than others in the course.

After the PTs had completed the instructional sequence as outlined above, we provided them with a packet of a sixth-grade student's work on algebra problems. The packet included five assessments conducted over four-weeks on algebraic expressions and equations that align with the sixth-grade Common Core State Standards for algebraic thinking (NGA/CCSSO, 2010). The PTs were instructed to individually analyze the student work to address the sixth-grader's mathematical understandings using the Attend, Interpret, and Decide Framework described by Sherin, Jacobs, and Philipp (2011). We analyzed the PTs' written responses on each question for Attend, Interpret, Decide, using a coding scheme to assess what PTs' noticed which we adapted from van Es' (2011) framework for learning to notice student mathematical thinking. The coding scheme is described in Figure 5. To analyze PTs' work, we used open coding (Corbin & Strauss, 2014) to determine the noticing level for "attend", "interpret", and "decide" on each problem of the algebra assessments.

Noticing Level	Description
Periphery	Made general impressions (e.g. "Student understands the questions.")
Transitional	Highlighted noteworthy events, general impressions—but included why they believed something occurred (e.g. "The student used logic to reason through the problem.")
Accomplished	Used evidence to elaborate on student understanding, made connections between the work and the next steps

Figure 5. Coding Scheme for Professional Noticing

Figure 6 is an example of a sixth-grade student's work that the PTs analyzed using the professional noticing framework (see Figure 3 and Figure 4), an MTE exemplary example, an example of how three PTs *noticed* the student work and how each part of the framework was coded. To solve this problem correctly, the values for x and y must be substituted into the expression and simplified. For example, $2x + 5y = 2(4) + 5(7) = 8 + 35 = 43$.

Evaluate the expression for the given replacement values:
2x + 5y for x=4 and y=7

24 + 57 = 81 = Anser

	Attend	Interpret	Decide
MTE exemplary example (Accomplished)	The student plugged in 4 for x and 7 for y, but did not multiply by the coefficients. Students added 24 + 57 = 81.	The student understands that the variable is a quantity, but does not understand that 2x means 2 times x and 5y means 5 times y.	Provide the student with pennies and show that 2 pennies is 2p and then provide students with 5 one dollars and show that 5 one dollars is 5d, then do the problem in a context so that the student is given 4 cents and 7 dollars to plug into the expression.
Student 1	the student inserted the given numbers for the variables (periphery)	the student did not understand that you must multiply the variables (transitional)	go over variable +their function w/ this student (periphery)
Student 2	insert value of variable for variable next to preceding # (transitional)	doesn't understand distributive property (periphery)	explicit instruction w/parentheses (periphery)
Student 3	the student replaced x+y w/their values in the ones' place and student added 2 values together (transitional)	the student doesn't understand that a variable is multiplied by its paired value (transitional)	give the student values (single values) paired w/ a variable + have them multiply by replaced variable's # (periphery)

Figure 6. Student Work and exemplary example, an example of three PT's analyses of the student work and how they were coded

Results

Once all of the PTs responses to the sixth-grade student work were complete, and the responses were coded using the scheme developed for this project, results of the noticing levels of understanding were analyzed. Table 1 shows the overall frequency of each response coded as periphery, transitional and accomplished within the three sections of the noticing framework used.

Table 1. Frequency of Response Type

	Attending	Interpreting	Deciding
Periphery	34	46	73
Transitional	18	35	40
Accomplished	84	56	24
Blank	35	34	34
Total	171	171	171

Table 2 provides the percentages of responses based on level of understanding divided by the total number of responses minus all blank responses.

Table 2. Percentages for the Level of Understanding

	Attending	Interpreting	Deciding
Periphery	.25	.3358	.5328
Transitional	.1324	.2554	.2920
Accomplished	.6176	.4088	.2482

When relating the results to the first research question, how do PTs interpret students' mathematical thinking, PTs we able to correctly identify student thinking related to content 34% at a periphery level, 26% at a transitional level, and 41% at an accomplished level.

The results indicate that PTs have little experience with examining student work prior to this course. As PTs struggle to understand mathematical content related to algebra, it impedes them from being able to succinctly describe and understand what students are doing as they engage in mathematical thinking. The results also show that PTs seem to rely on their own experiences of learning mathematics when noticing student work. For example, many PTs commented on mathematical procedures and recommended explicit, direct instruction for the student (see examples in Figure 6).

The more telling results refer back to the second research question, how do PTs reflect on and discuss future implications for teaching? The results of this study indicate that PTs are unable to decide on appropriate instructional steps at an accomplished level. Seventy-five percent of the time, PTs responded at a periphery or transitional level when making decisions regarding instruction. For example, PTs made very general recommendations for teaching such as, "show how to better organize a problem" and "have student show work" as opposed to an exemplary example of "include more variables, progress into multiplication and division once the student understands addition and subtractions". These results guide MTEs to consider the additional support required to promote a more comprehensive understanding of pedagogical content knowledge. Based on this study, PTs also need more practice with analyzing student work with a focus on the mathematical content, reflecting on one's interpretation of student work based on the noticing framework, and making sense of analyses through discussion with other PTs.

Conclusion and Implications

In this study, framed by research on PCK and professional noticing, and with the implementation of a Coding Scheme for Professional Noticing (adapted from van Es, 2011) we were able to assess the development of PTs' use and understanding of noticing in the mathematics classroom. A focus on mathematical content knowledge, children's mathematical thinking, and ways of representing content were particularly important as PTs participated in the instructional activity. Preliminary findings indicate that through a deliberate scaffolding of course activities and projects, MTEs can help PTs learn to identify some components of pedagogical content knowledge using the noticing framework. PTs were somewhat successful in identifying a student's level of understanding (interpreting) but demonstrated a decrease in their conception of deciding what would be appropriate future instructional steps.

PTs' noticing, especially deciding, did not progress as hoped and more research is needed to determine how to scaffold PTs' learning. Analysis of the student work data suggests that PTs have had little experience with examining student work prior to this course and struggle to decide on how to proceed once student understanding is analyzed. PTs' initial interpretations seemed to rely on their own content understanding related to algebra only and limited the PTs in their ability to apply appropriate strategies to promote conceptual understanding for students. These results indicate the need for MTEs to spend more time reflecting on and discussing implications for teaching.

Engagement in this work allowed us to see PTs' understanding of the Noticing Framework and their development related to PCK, so that we, MTEs, can better identify strategies that will scaffold PTs' understanding related to mathematical content and pedagogy. Based on the results of this study, we need to focus more time and attention on the pedagogical decisions related to classroom tasks. When working with PTs we often spend a significant amount of time focused on content, but this study has shown that content alone will only allow students to progress so far. It is the comprehensive nature of PCK and the Noticing Framework that will change PTs' understanding of what it means to be a teacher of mathematics. Learning in teaching is life long; MTEs need to provide PTs with the capacity and support to realize the nuances of productive and meaningful engagement.

While the results of this study are promising, we acknowledge that limitations exist. First, although the findings took into account PTs' noticing of five assessments completed by one sixth-grader conducted over four-weeks on algebraic expressions and equations, the small sample size of participants (PTs) reported in this paper mitigates the broader implications that can be inferred from the findings. Second, the same instructor taught the mathematics methods and content course in which the data was collected. Thus, the PTs' noticing that is reported in this study might have been influenced by the instruction that they received on how to analyze student work and reflect on the content systematically. Third, we only looked at the PTs' responses for each question, rather than their overall level of noticing across the entire assessment. That being said, by analyzing their written responses on each question for Attend, Interpret, Decide, we have insight into how PTs make sense of student work and respond to student thinking. A more robust study would provide multiple data sources that capture the development of PTs' use and understanding of noticing in the mathematics classroom.

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