

Utilizing an Iterative Research-Based Lesson Study Approach to Support Preservice Teachers' Professional Noticing

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Abstract

The purpose of this study was to explore how participation in iterative cycles of a modified model of lesson study could potentially provide preservice teachers opportunities to develop the ability to notice students' science thinking. Using a case study approach, we examined how six preservice teachers illustrated aspects of *professional noticing* while engaged in a modified model of lesson study during an early field experience practicum. We analyzed video and artifacts from five lesson study cycles, mapped how the preservice teachers professionally noticed throughout each cycle, and examined interactions between the three components of noticing. Participants' abilities to attend to student thinking ranged from general descriptions of how students were exploring and discussing the content, to detailing the specific actions and words of individual students (attending), and to identifying patterns of student thinking across the class and across the five lessons (interpreting). The preservice teachers were able to respond to students' thinking at various levels, thus demonstrating the ability to engage in the three components of noticing and sometimes connected their observations (attending) to their interpretations and their responses to how students were thinking. We believe participants' abilities to notice can be attributed to the iterative approach to our model of teaching, reflecting, and revising through the lens of assessing and revising lessons based on students' learning needs in an authentic context. Finally, we conclude with recommendations for supporting preservice teachers as they further develop their abilities to professionally notice.

Key Words: professional noticing, lesson study, elementary preservice teachers, field experiences

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Introduction

For teachers to meet the needs of all learners, they must know how individual students conceptually process content and then determine next steps for instruction (Donovan & Bransford, 2005; Jacobs, Lamb, & Philipp, 2010). To do this, teachers must have knowledge of content, as well as knowledge of how to effectively teach, and then design and implement lessons based on what their students understand about the content (Hiebert, Gallimore, & Stigler, 2002). However, it is well documented in the science education literature that elementary teachers typically have low confidence and limited understanding of science content, often contributing to poor or no teaching of science (Appleton, 2006; Davis, Petish, & Smithey, 2006). Even with these obstacles, teacher preparation programs must find ways to support preservice teachers to learn about how students think about science to develop their knowledge of teaching, and then consider how to respond instructionally to that thinking.

Davis (2006) explains that providing preservice teachers with practical experiences that are “as authentic as possible while still providing guidance and direction” is one step towards developing effective pedagogical practices (p. 368). In teacher education programs, authentic experiences are commonly embedded through early field experiences but the degree to which guidance and direction are provided often varies (Abell, 2006). Within elementary science methods in particular, there is little evidence indicating how early field experiences impact preservice teachers’ attitudes or understanding of teaching science; especially with respect to the aims of teacher preparation described above (Abell, 2006). Abell (2006) suggests this gap in understanding could be “due to the lack of a well-conceived theoretical base of field research” (p. 75). This is one need our study intends to address.

Within the fields of mathematics and science teacher development, both *professional noticing* and *lesson study* have received significant attention as being ‘theory-driven’ or even ‘theory-building’ approaches to reflecting on and informing practice (see Amador & Weiland, 2015; Choppin, 2011; Fernandez & Zilliox, 2011; Jacobs et al., 2010; Marble, 2007; Mutch-Jones, Puttick, & Minner, 2012; Russ & Luna, 2013; Talanquer, Tomanek, & Novodvorsky, 2013). Professional noticing is a construct that was introduced for the purpose of “unpacking the in-the-moment decision making that is foundational to the complex view of teaching” and often focuses on understanding students’ thinking (Jacobs et al., 2010, p. 169). Lesson study is a method of professional development that focuses on improving instruction through the refinement of lessons with the purpose of improving teachers’ knowledge, promoting collegial accountability, and emphasizing the role of student learning when making pedagogical decisions (Lewis, 2002; Lewis, Perry, & Murata, 2006). From our review of the research we have found that although both constructs focus on the examination of student thinking in the act of teaching, they are often discussed as separate approaches to developing professional knowledge. However, given their aims we contend that merging the two constructs may serve beginning teachers well. Therefore, the purpose of this study was to explore how participation in iterative lesson study cycles within an elementary classroom setting could potentially provide preservice teachers with an authentic and guided (Davis, 2006), experience to initiate the development of professional noticing. Thus, the following research question guided our investigation: *By participating in a research-based lesson study cycle focused on gathering and analyzing evidence of students’ science thinking, how*

do preservice teachers engage in the three components of professional noticing (attending, interpreting, and responding)?

Theoretical Framework and Relevant Literature

In the sections below we describe the theoretical underpinnings of professional noticing and lesson study to illustrate how we perceive these two constructs as relating to one another, and thus having the potential to complement one another in developing preservice teachers' professional knowledge for teaching science.

Professional Noticing

Stemming from work on professional vision, the term “professional noticing” refers to a mechanism for analyzing how teachers pay attention to students' reasoning about concepts. Mason (2002) refers to professional noticing as a core practice that influences all aspects of teaching, including noticing students' thinking, evaluating students' actions and understandings, and considering appropriate responses. To professionally notice, teachers must combat habitual mechanical behavior and become aware of their actions, how their actions are influencing students, and most notably, how students are reasoning (Mason, 2002; 2011). Philipp (2014) argues that “teachers are responsible for doing more than understanding their students' reasoning”, they also have to act on their understandings to improve instruction (p. 286). This demands repeated iterations of noticing, responding, and reflecting on the processes of learning and teaching. In this process, teachers' ‘reflection-on-action,’ ‘reflection-in-action,’ and ‘reflection-through-action’ all contribute to how they process what they notice (Mason, 2002). When teachers reflect-on-action, they retrospectively consider their teaching after a lesson. During reflection-in-action, teachers are aware of their inner thoughts while teaching and may even talk out loud to expose their reflective practice. Finally, when teachers reflect-through-action, they become aware of their pedagogical and content decisions by engaging in practice. As teachers take part in these types of reflection, they gain an awareness of all aspects of their decision-making and become cognizant of what and how they professionally notice. Within the field of mathematics education however, Mason's (2002) description of noticing has been interpreted for use with inservice teachers to mean characteristics of attending to and making sense of instructional contexts through reflection *in* practice, and as such is referred to as *professional noticing* (Mason, 2011).

Within the literature on developing noticing with preservice teachers, the concept of professional noticing most often aligns with Mason's description of reflection *on* practice. It is the view of professional noticing that we adopted for this study. More specifically, we have adopted Jacobs et al.'s (2010) definition of professional noticing, which includes *attending* to students' thinking, *interpreting* students' thinking, and *responding* to needs within students' thinking. Attending (component one) to students' thinking includes “highlighting” or “making call-outs,” or effectively, making observations about specific details about a students' thinking (Jacobs et al., 2010, p. 172). Interpreting students' thinking (component two) is the process by which one connects the students' actions or words to research on the development of mathematical thinking. In our case, this interpretation involves analysis of evidence-based interpretations as compared to research on how students develop an understanding of specific science concepts. Finally, responding to students' thinking (component three) involves making a decision or a plan of action (intended response) based on what was learned.

From our review of studies about preservice teachers that took a similar stance to professional noticing, we noted the context for studying preservice teachers abilities to professionally notice typically involved the use of video-recordings rather than the authentic context of their own teaching (Star, Lynch, & Perova, 2011; Stockero, 2008a, 2008b; Talanquer et al., 2013). Many researchers also agree that noticing is a skill that must be learned and does not come automatically for novices, including preservice teachers (Carter, Cushing, Sabers, Stein, & Berliner, 1988; Jacobs et al., 2010; Levin, Hammer, & Coffey, 2009; Miller, 2011). For example, Huang and Li (2012) compared the noticing practices of ten novice educators with ten expert educators and purport that both novices and experts were able to attend to students' thinking, but expert teachers were more cognizant of developing higher-order content-specific thinking and focused less on teachers' guidance, being basic pedagogical skills. These findings are similar to Star and Strickland's (2008) findings that novices often attend to static features of a classroom environment and have limited observation skills for attending and making decisions on the basis of students' thinking.

Russ and Luna (2013) argue that professional support for teachers should focus on providing opportunities for changes in teachers' epistemological framings because framing drives local patterns in teacher noticing. They found that focusing on such patterns during lesson enactment, as a necessary component of teacher noticing, can result in inferences about cognition. Furthermore, Talanquer et al. (2013) suggest preservice teachers should "engage in either inquiry experiences guided by theoretical models or well-supervised authentic science practices" to improve their noticing (p. 205). It is therefore evident that teachers need opportunities early on with learning to professionally notice and that authentic experiences of examining their own classroom practice, rather than video of others teaching, may better serve to initiate their abilities to professionally notice. Zembal-Saul, Blumenfeld, and Krajcik (2000) found that preservice teachers place an emphasis on students' thinking during the stage of planning and throughout the lesson reflection process; therefore, suggesting the opportunity to then revise the lesson based on students' ideas about the concepts. Indeed, Jacobs et al. (2010) compared the professional noticing of preservice and inservice teachers and found that attending and interpreting developed with teaching experience, and that all three components (which includes responding) were fostered through professional development. These findings support the need for models, such as lesson study, that scaffold and provide opportunities for preservice teachers to professionally notice within an authentic classroom setting.

Lesson Study

The initial model lesson study, referred to as Japanese Lesson Study, was conceived with the intention that teachers would learn to reflect collaboratively on authentic practice in order to improve the design of a particular lesson (Lewis et al., 2006). Lesson study teams typically consist of a group of four to six teachers, and may include a knowledgeable other, such as a professional development or content expert, who come together to set a research goal for student learning, and study curriculum and standards (Fernandez, 2002). Following this, they collaboratively plan a lesson, drawing on multiple resources including curricula and research studies about the topic. In this process, they anticipate student learning, focus on long-term goals for students, and purposefully select the content and pedagogical approaches of the lesson (Lewis et al., 2006). One teacher in the group then teaches the lesson to students as the other members conduct research by

observing the teaching and taking detailed field notes focused on student learning (Fernandez, 2002; Lewis et al., 2006; Murata, 2011). After the lesson, the group meets for an extended time to reflect and discuss their observations regarding the lesson. They consider the data they collected and formulate connections between the learning that occurred, the lesson content, and the broader principles of teaching and learning (Lewis et al., 2006). The group then revises the lesson plan for another member of the group to implement in his or her classroom. The remaining members observe the revised lesson and the reflective cycle repeats.

As the premise of lesson study gains recognition in teacher education, differences in implementation as compared to the Japanese Lesson Study model are occurring, and there is a need for understanding how these differences alter the effectiveness (if any) of the original model (Lewis et al., 2006). With respect to teacher preparation programs in particular, the teaching portion of lesson study is frequently replaced with either peer teaching during which university students teach lessons to other university students, or with teaching to small groups of elementary students (Carrier, 2011; Fernandez & Zilliox, 2011; Sims & Walsh, 2009). Indeed, Abell, Appleton, and Hanuscin (2010) found that preservice teachers' opportunities to actually teach, revise and teach again are often limited. An example of this type of modified approach is referred to as Microteaching Lesson Study (Cavin, 2008; Fernandez, 2010) and involves preservice teachers working with approximately 5-10 elementary students or peers. Although this method has gained merit with respect to developing preservice teachers' abilities to teach, it is unclear how preservice teachers transfer this knowledge to the more authentic experience of teaching a whole class of elementary students.

Sims and Walsh (2009) explored this issue of transfer over the course of a two-year study but found that by the end their version of lesson study was quite removed from the initial intent and design of the Japanese Lesson Study model. For example, in the first year of implementation, they held true to many aspects of traditional lesson study with preservice teachers co-planning a lesson, teaching, viewing videos of others' teaching, and then debriefing. However, the researchers found the lesson plan template, which was designed to help facilitate the lesson study, was rarely used in the debriefings and the preservice teachers actually viewed the lesson plan template as something to complete for the purpose of an assignment rather than as tool for modifying teaching. Therefore, in year two, they revised their approach and replaced the authentic classroom teaching component with a form of lesson study mirroring that of microteaching as described above. With this change, the researchers found the preservice teachers were able to engage in more effective lesson critiques and reflection because they were able to observe and gather evidence in real time. However, the authentic and iterative experiences of the Japanese Lesson Study model were removed.

Marble's (2007) approach to using lesson study maintained several key aspects of traditional lesson study including the use of authentic classroom teaching and multiple iterations of the same lesson. Results from his study show the preservice teachers were reflective about their practice and made changes during various iterations in the lesson study cycles. There was little evidence though that the preservice teachers made their revisions to the lesson based on students' understanding of the science concepts.

Across the studies we reviewed on the use of lesson study with preservice teachers, none have explored the use of lesson study for initiating their abilities to professionally notice students'

thinking in science. More specifically, for the most part lesson study in the context of elementary science teacher preparation has focused on developing instructional strategies and retrospective reflection on their own or their peers' instruction with no attention has been given to gathering evidence of student thinking (*attending*), analyzing this information for understanding with respect to the learning objectives of the lesson (*interpreting*), and using this analysis to then make instructional decisions for improving learning (*responding*). However, we posit that lesson study, albeit a modified version for use in early field experience, can offer support in each of these areas of professional noticing. Thus we believe the implications gleaned from our study have the potential to significantly contribute to the field of preservice teacher education, and more specifically the design of early field experiences that will engage preservice elementary teachers in the act of reflection-on-action for developing professional noticing.

Modifying Japanese Lesson Study for Use in Early Field Experience

Like Lewis et al.'s (2006) model, our model consists of four steps: studying curriculum, planning lessons, conducting research, and reflecting. However, given our setting of science teacher preparation, our model splits these two steps between two contexts – the science methods class and an early field experience course. For the purpose of this study, we focused our analysis on steps three and four our lesson study model for it was here where preservice teachers engaged with elementary students to learn about their thinking of science. On the following page, Figure 1 presents our modified model of lesson study in comparison to the model Lewis et al. (2006) describe as illustrating key characteristics of lesson study. In this study, there were five lesson study cycles, resulting in five lessons taught. The preservice teachers were guided through the research process of gathering data using a Lesson Observation Form (LOF) designed specifically for our model of lesson study (See Appendix A). Each week two members of the team-taught a science lesson to the whole class of elementary students while the other four preservice members gathered data using the LOF. Preservice teachers observing the lesson took notes of student actions and conversations as they related to the lesson objectives, noting specifically how students were thinking about and demonstrating their understandings of the concepts. The LOFs provided a scaffold for the preservice teachers observing the lesson to record students' actions and specific words (see Part 1: Field Notes) relating to the unit (*attending*). Using the evidence of students' actions and words, space was also provided for the preservice teachers to describe what they thought students understood and how they were making sense of it (*interpreting*) (see Part 2: Discussion Items). Finally, the final section of the form asked the preservice teachers to provide suggestions for revising the lesson (*responding*) given concerns they noticed in student thinking about the content (see Part 3: Suggestions for Lesson Revision).

The LOFs were brought to the team's weekly collaborative post lesson reflection meeting that occurred immediately following the lesson (from now on referred to as lesson study reflection meeting), and were used to initiate discussion and provide evidence regarding student learning. The university facilitator used a protocol developed by the research team to guide the lesson study reflection meetings. The protocol included discussion of what went well in the lesson, evidence of students' learning (*attending*), and improvements to the lesson based on this evidence (*responding*). The preservice teachers who taught the lesson were first asked to professionally notice by sharing their reflections of how the lesson went with respect to the students meeting the lesson objectives. Next, peers were asked to contribute their comments followed by comments

from the classroom teacher and university facilitator. Discussion on the first two points generally lasted about 20 minutes, with the final 10 minutes devoted to discussion about lesson revisions.

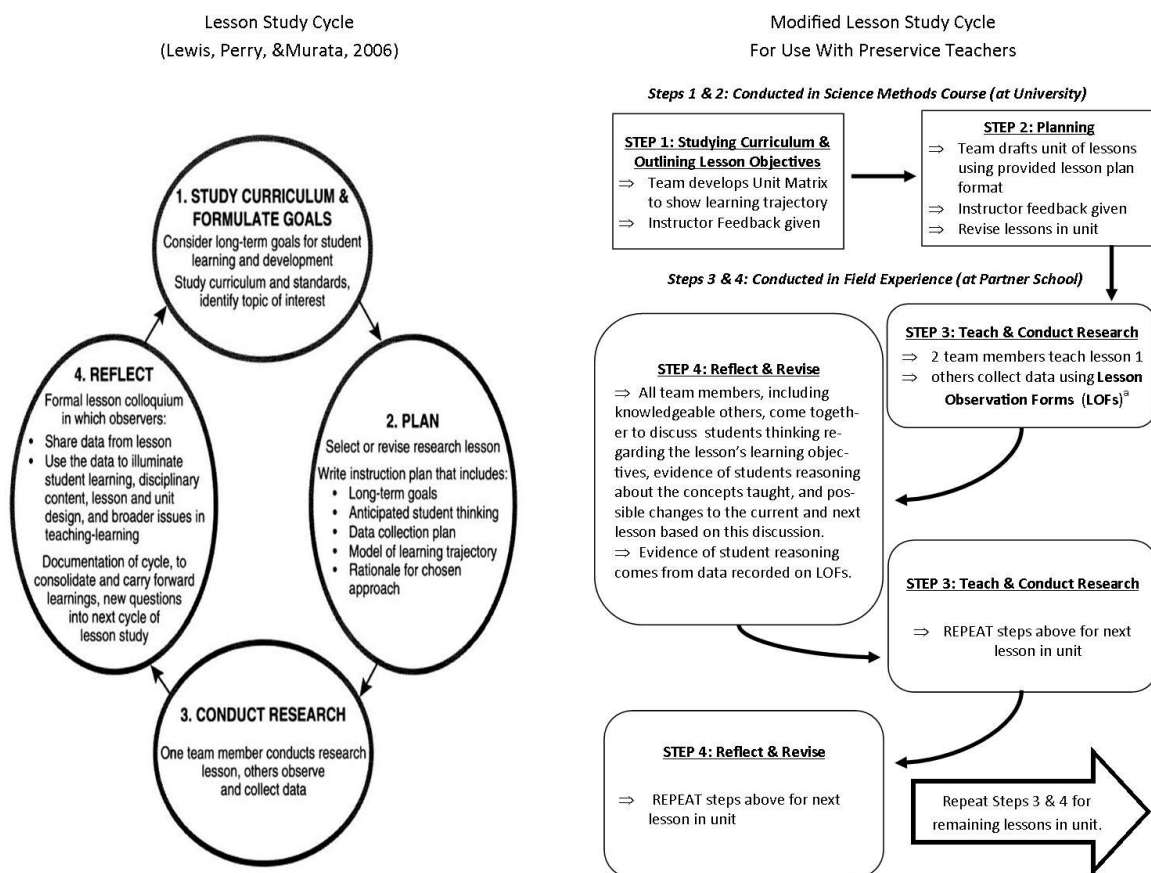


Figure 1. Comparing Japanese lesson Study cycle to the modified lesson study cycle used in this study.

During the following week, the two preservice teachers who taught the lesson were required to submit a written lesson plan revision. No protocol for this revision process was provided other than the preservice teachers were asked to track their changes and provide justifications for each change made. The intended goal was to submit revisions that highlighted the changes from the original lesson plan (developed in steps 1 and 2 of the lesson study cycle) that the lesson study team had suggested during the lesson study analysis meetings (*responding*). The lead preservice teacher for each lesson was also required to submit an individual lesson reflection paper, and other members of the team were encouraged to submit a reflection paper to assist them with individually processing what they learned from observing the lesson each week. The purpose of the reflection paper was to give the preservice teachers an opportunity to delve deeper into how they viewed the effectiveness of the lesson in developing students' ideas about the science concept (i.e., lesson objective), make improvements for the lesson (*responding*), and provide a rationale for these improvements based on comments made during the team's lesson

study analysis meetings (*attending and interpreting*). These individual reflection papers were intended to emphasize the notion of ‘reflection-through-action’ as part of developing the preservice teachers professional noticing (Mason, 2002).

Methods

As previously stated, the purpose of our study was to explore the use of a modified lesson study in an early field experience to understand the affordances it may offer in developing preservice elementary teachers’ abilities to professionally notice (i.e., attend to, interpret, and respond to student thinking). We utilized a case study approach (Patton, 2002) to gain an in-depth understanding how a team of preservice teachers collectively noticed students’ thinking when provided with a structured field experience that was iterative and modeled a research approach (i.e., evidence-based) to informing practice. The preservice teachers described in this paper offer a “case from which one can learn a great deal about matters of importance [that are] worthy of in-depth study” (Patton, 2002, p. 242). We felt it was important to keep our unit of analysis for this study focused on the team because our model of lesson study places a strong emphasis on collaborative teaching experiences. Our particular team (or case) of preservice teachers was purposively selected because they demonstrated a common range of abilities for developing professional noticing characteristic of most preservice elementary science teachers (Amador & Weiland, 2015). Furthermore, case study research involves the examination of a particular issue within a bounded system through multiple sources of data (Merriam, 2009). The boundary of our system was that of a semester-long early field experience. Our data collection was confined to the last five weeks of the semester as the field experience was shared with the mathematics methods course. Additional information about the context of the early field experience setting and the six preservice teachers on the team is described below.

Setting and Participants

The setting for this study was a first grade classroom in an elementary school located in a mid-sized Midwestern town near the university where the preservice teacher participants were enrolled in their teacher preparation program. The school was considered of average performance relative to the other schools in the district, which scored above average on statewide assessments. There were twenty-one first grade students in the class. The school district used the FOSS (Regents of the University of California, 2011) science series and so, based on the classroom teacher’s selection, the preservice teachers developed a mini unit of five lessons based on ideas from the FOSS curriculum titled Solids and Liquids¹. This part of the lesson study cycle aligns with steps one and two of our modified lesson study model and occurred in the science methods course. The context for study begins with steps that occur in the field (steps 3 and 4—please refer back to Figure 1) due to our focus on the potential of lesson study to engage preservice teachers in the act of professional noticing through reflecting on their actions.

All six preservice teacher participants were females, in their third year at the university, and between the ages of 20 to 22. The preservice teachers were enrolled in the same science methods course and corresponding field experience, in addition to the mathematics methods and introduction to special education courses. Most of the preservice teachers in our study had completed three of the four required science content courses. Participants were paired for the

¹ The science methods course required the lessons be developed using the 5E learning cycle (Bybee, 1997).

purpose of completing the various requirements for the field experience, and included: Lisa and Gwendolyn, Emily and Rachael, and Kelsey and Mindy (all pseudonyms).

It is important to note that the university facilitator (the supervisor for the field experience) and classroom teacher also served as members of the lesson study team, but were not included as case study participants because of our focus was on understanding preservice teachers' development of professional noticing. Both served as outside observers and experts, or what is sometimes referred to in the lesson study literature as 'knowledgeable others' (Fernandez, 2002). The university facilitator was a second year doctoral student in science education with four years of K-3 teaching experience and in addition to facilitating this field experience taught a section of science methods to another cohort of 24 preservice teachers. The classroom teacher was in her 23rd year of teaching and had not participated in lesson study prior to this research, but had taken part in project-specific training around lesson study.

Data Collection

Data sources included the LOFs, video of the five lesson study analysis meetings, individual lesson reflection papers, and revised lesson plans. Video of each lesson taught was also reviewed but not for the purpose of data analysis; rather to provide context for what was read and coded in the other data sources (especially the LOFs). In total twenty LOFs were collected and analyzed to examine the evidence preservice teachers independently recorded about students' actions and words (*attending*) relating to properties of solids and liquids. The form also asked preservice teachers to describe how the students demonstrated their understanding (*interpreting*), and to provide suggestions for lesson revision (*responding*). Video from five lesson study analysis meetings (about 30 minutes each) were analyzed to examine how the preservice teachers collaboratively discussed the lesson. Again the university facilitator guided these meetings by prompting preservice teachers to reflect on students' actions or words (*attending*) and to consider revisions to the lesson (*responding*). From the five lessons taught, fifteen individual reflection papers were collected to examine what preservice teachers individually noticed about student thinking (*attending*), and if and how they interpreted and responded to that thinking. Finally, the two lead preservice teachers for each lesson submitted revisions to the lesson (except for lesson five, as it was taught during the last week of classes). The preservice teachers were asked to highlight/track change modifications they would make to the original lesson plan based on the collaborative lesson study reflection meeting. Both the post-teaching reflection papers and the lesson plan revision were submitted within one week of teaching the lesson. Table 1 provides a summary of the data collected for each lesson.

Table 1

Data Sources

Lesson/Topic	Lead and Co-Lead Teachers	Data Collected from Each Lesson
1 – Exploring Solids	Kelsey Mindy	<ul style="list-style-type: none"> • Lesson Observation Forms: Lisa, Gwendolyn, Rachael, Emily • Lesson Reflection: Kelsey, Mindy, Emily • Lesson Revision: Kelsey

2 – Exploring Liquids	Lisa Gwendolyn	<ul style="list-style-type: none"> • Video of lesson taught and post-teaching debriefing • Lesson Observation Forms: Kelsey, Mindy, Rachael, Emily • Lesson Reflection: Lisa, Emily, Gwendolyn • Lesson Revision: Lisa • Video of lesson taught and post-teaching debriefing
3 Classification: Bits and Pieces	– Rachael Emily	<ul style="list-style-type: none"> • Lesson Observation Forms: Kelsey, Mindy, Lisa, Gwendolyn • Lesson Reflection: Rachael, Emily, Mindy, Lisa • Lesson Revision: Rachael • Video of lesson taught and post-teaching debriefing
4 – Sorting: Solids and Liquids with Water	Mindy and Kelsey	<ul style="list-style-type: none"> • Lesson Observation Forms: Lisa, Gwendolyn, Rachael, Emily • Lesson Reflection: Mindy, Emily, Kelsey • Lesson Revision: Mindy • Video of lesson taught and post-teaching debriefing
5 Application: Exploring Oobleck	– Emily Gwendolyn	<ul style="list-style-type: none"> • Lesson Observation Forms: Lisa, Rachael, Kelsey, Mindy • Lesson Reflection: Emily, Gwendolyn • Lesson Revision: missing data • Video of lesson taught and post-teaching debriefing

Note: Bolded names indicate lead teacher for the lesson.

Data Analysis

We began our analyses by organizing each of the data sources into tables for each lesson. Our purpose was to examine how the preservice teachers recorded and discussed students' thinking as it related to the science content taught. While there were many content and pedagogical topics raised within a single lesson, we focused our organization to topics that pertained specifically to the learning and teaching of identifying properties of solids and liquids. We selected one core idea from each lesson based on the learning objective the preservice teachers identified for the lesson. We then mapped this idea into three columns to understand how the preservice teachers were engaged in attending to, interpreting, and responding to students' thinking across this one core idea. This allowed us to understand the relationship between noticing components and how preservice teachers persevered through a core idea as they were explicitly guided through the phases of professional noticing. Each map contains a brief description of the lesson, the name of the two preservice teachers who taught it, and quotes from each data source that relate to the core

idea. Comments relating to a lesson's core idea are bolded and italicized in each map. Analysis of each data source according to the professional noticing framework is described below.

- **LOFs** – the three parts of this form align with the three aspects of noticing, so each section of the form was analyzed accordingly. The field notes allowed preservice teachers to record specific ideas, thoughts, or actions made by students with respect to the content (*attending*). Section two focused on explaining what students understood about the content and how they understood it given their comments and actions (*interpreting*). The third section of the form asked the preservice teachers to offer suggestions for improving the lesson based on students' understanding of the content (*responding*).
- **Lesson Study Analysis Meeting video** – like the LOFs, this data source sometimes spanned across all three components of noticing because the preservice teachers would occasionally begin with sharing what they wrote for field notes (*attending*) and then discuss what the students were thinking during observations (*interpreting*) as other preservice teachers shared their students' comments and actions. Finally, preservice teachers would discuss suggestions to improve the lesson or to modify the following week's lesson (*responding*).
- **Lesson Reflections and Revisions** – these data sources aligned with the responding portion of the lesson map, but occasionally a preservice would reiterate some of the student comments and interpretations from the lesson that were shared out in the lesson study analysis meeting and/or recorded on LOFs.

Authors one and two conducted the process of developing the maps. The two authors completed multiple iterations of independent coding and collaborative discussion to create each map (Patton, 2002). Author three served as a neutral third party, reviewing each map for consistency in charting the content across the three columns, as well as accuracy of coding the examples within each column. As a result, she was able to assist with any discrepancies between authors one and two's coding when needed. All authors participated in reviewing the five maps to identify the overall findings with respect to the three components of professional noticing. These mutually agreed upon findings are discussed below.

Findings

We begin with describing how our case of six preservice teachers were collectively engaged in attending to, interpreting, and responding to students' thinking as part of their participation in steps three and four (the field experience) of our modified lesson study model. We share trends we observed across the five lessons to provide the reader with an overview of how the preservice teachers' professional noticing skills were developing throughout the five weeks. To illustrate the intricacies of these maps, we end our presentation of the findings with a detailed description of the map for lesson study cycle three. We elected to use map three to delve deeper into our findings because we found it provided the richest examples of the interactions of each component of noticing, as well as how these interactions were supported along the way by the various components of the modified lesson study model.

Attending to Students' Thinking

The preservice teachers' abilities to attend to student thinking ranged from general descriptions of how students were exploring and discussing the content, to detailing the specific actions and words of individual students, and to identifying patterns of student thinking across the

class and across the five lessons. The lesson study model employed offered the preservice teachers the experience of teaching students and observing their peers teach in an authentic first grade classroom, allowing them to learn to observe and record detailed field notes about student thinking and then collaboratively discuss patterns in students' thinking and recognize issues related to the students' schemas about solids and liquids, sometimes across multiple lessons.

Initially the preservice teachers made general observations of student thinking that included descriptions of what they believed students understood about the concept with little supporting evidence. This level of attending indicated that preservice teachers were aware of and paying attention to students' thinking, but were not actually attending to specific examples of student comments to support their interpretations (Levin et al., 2009). For example, the objective of lesson one was to identify properties specific to solids, and students were encouraged to use multiple senses in identifying these properties. Students were also introduced to solids that do not fit traditional understandings of solids (e.g., being hard and a particular shape). However, looking across the LOFs for this lesson, we found very few indications of comments recorded that represented individual students' thinking. The majority of the recordings included comments such as, "They are all hard and they won't change shape. They are all solids. Solids didn't take the shape of the cup" (Gwendolyn). The data thus indicated that Gwendolyn was aware of the general consensus of the group students with whom she was sitting, but attention was not yet given to understanding individual students thinking about unique properties of solids.

As the iterative approach of the modified lesson study model progressed, the preservice teachers began to develop a deeper level of attending to students' thinking by citing specific student actions or words. For example, lesson four entailed combining solids with water to observe what occurs when some solids dissolve and others do not dissolve. In her written individual lesson reflection, Emily described one boy's thinking, "When I poured the water and a salt together then strained it Xander² said the salt would dissolve and turn from a solid to a liquid when I strained it. I thought that was a great observation and it showed me that he understood a lot." In this example, Emily quoted Xander's words, and concluded that he was thinking about how matter can change. This level of attending focused on the details of student thinking through direct evidence. We found several instances of this level of attending to individual student thinking throughout the data sources, namely the LOFs and the lesson study analysis meetings.

Finally, in order to gain a sense of ways in which the entire class was thinking about the content, it was helpful to examine patterns across individual students' thinking. This required that preservice teachers discuss individual students' thinking and then compare and contrast these ways of thinking to those of others. An example of this was found in the fifth lesson study cycle which introduced the anomaly of Oobleck. In their LOFs, the preservice teachers recorded the following statement (quotations are included when the preservice teacher was providing an actual quote from a student).

- Lisa: [Students said] 'It melts when you pick it up;' 'Every time you break it turns into a liquid'. 'When it drops it turns into a solid.'
- Kelsey: 'It is like a solid and a liquid – juicy and hard. When you put it on your finger it melts on. Feel hard when you touch it. It's a solid-liquid!'
- Rachael: 'It's both! [You can] squeeze [it] – solid, but then it melts'.

² All students' name are pseudonyms for purposes of confidentiality

Mindy: 'Every time you make it into a ball it's a solid.'

These LOF examples demonstrate how the preservice teachers detailed four different students' words as they explored the Oobleck. These observations were shared and discussed in the lesson study analysis meeting, and the preservice teachers began to make connections between students' statements. These connections were evident in Rachael's written lesson reflection, where she was able to describe patterns of students' thinking across the solids and liquids unit, and connect this to how the class was thinking about Oobleck:

Because we have drawn out descriptive responses throughout our lessons, the students have really learned to use more than just 'hard' and 'smooth' to describe solids and liquids...as a class, the students shared some very important observations and really described how the substance could be a solid or liquid. After being asked if they thought it was a solid or liquid, they said that it was both!

In each of the five lesson study cycles, preservice teachers were able to record and discuss specific observations based on how they attended to students' understanding of the lesson objectives. The iterative approach to the modified lesson study model, as well as consistent use of the LOF as a tool for data collection during the act of teaching, afforded the preservice teachers opportunities to revise their attending to skills across the five lessons. Furthermore, there were a few occurrences where the preservice teachers began to identify instances of students making connections between science concepts. From this finding we infer the preservice teachers were also beginning to develop their interpreting skills associated with professional noticing.

Interpreting Students' Thinking

The preservice teachers' individual interpretations of students thinking developed over the course of the five lessons. The majority of these individual interpretations were found only in the second part of the LOFs. For instance, in lesson one many of the comments written in Part two of the LOF form contained limited descriptions. Comments were focused on evaluations of what students understood and with little evidence of trying to comprehend how the students were thinking about the concept; in other words, the basis of their understanding (Harlen, 2015). An example of a limited interpretation is the following comment from Emily in which she wrote, "My students couldn't really understand what all the objects would be categorized as." However, by lesson two we started to see improvement in the preservice teachers' interpretations as students began comparing what they observed about liquids in lesson two to what they observed about solids in lesson one. The following comment from Rachael's lesson two LOF illustrates the sort of comparison comments we started to see from lesson two onwards, "They took the way the liquids looked and compared them to other things they've seen before."

By lesson three, some of the preservice teachers began drawing pictures depicting what they heard students saying about the materials. These drawings are another form of interpretation as they create a pictorial representation of what students say or do. An example of this type of symbolic interpretation was found in Mindy's LOF drawing from lesson three depicting the pouring of small/fine grain solids. She drew a container with grains and wrote, "said that it was more like a liquid here." She also drew grains on the table (a small pile and one separate grain) and drew an arrow to the single grain, writing "said it was more like a solid." Mindy then

interpreted her observations when she wrote the following: “They were able to recall their knowledge/understanding of what they learned in the previous weeks about solids and liquids” (LOF). This representation demonstrates how Mindy began to interpret the students’ actions when she wrote that students were connecting their observations of the many small pieces of solids to being “more like a liquid,” and thus recalling their understanding of liquids from lesson two and the individual pieces of solids being more like the solids from lesson one.

The exception to individuals improving their interpretation of students thinking was lesson four. We found no incidences in the individual LOF of the preservice teachers interpreting both what and how students were reasoning about the content. However, looking at the topic for this lesson – mixing solids and liquids (i.e., mixtures and solutions) – we suspect that interpretations were limited (i.e., focusing only on what they know and not how they know it) because the students themselves were not making comparisons in their observations to previous lessons or other experiences. As such, the preservice teachers had little to draw upon from the students’ comments to make sense of how the students understood what they were observing about the mixtures and solutions.

With respect to the lesson study analysis meetings, we found the greatest improvements in the preservice teachers’ abilities to interpret student thinking when they talked through their examples with their lesson study team. It was during this time that they started to elaborate on their individual interpretations recorded on the LOFs. With these elaborations they demonstrated a deeper analysis of the student’s reasoning. For example, following Mindy’s example from lesson three, she wrote on her individual LOF “recall[ing] their knowledge/understanding of what they learned in the previous weeks about solids and liquids.” However, in the lesson study analysis meeting she spoke about this idea in the following way with her peers,

Eliot wasn’t able to say, ‘Ok, this part reminds me of a liquid but I know it’s a solid and even when I take it out, that’s even more of a reason that it’s a solid.’ He wasn’t able to say that it was a solid [both] in the container and out because he is kind of stuck on the concept that if it is in a container, it’s a liquid (Lesson Study Analysis Meeting Three).

Here Mindy began to interpret the student’s thinking, suggesting that the student was not able to transfer his observations of solids and liquids in a container to understanding how small pieces of solids and how liquids act outside of a container. In some cases, the preservice teachers not only provided an interpretation of students’ thinking, but even began to link these interpretations to broader science theory and principles. An example of this higher level interpretation comes from Rachael in lesson two when she explained,

We had them pour [different liquids] materials into a cup to see how they would pour, and she said the paint poured slower than water, and Zoe said the paint poured slower than the water because it was lighter than the water...She is thinking of it as, like a rock falls faster than a feather because it is heavier. So she is applying principles of something else she has seen, like it falls faster because it’s heavier (Lesson Study Analysis Meeting Two).

Even though the preservice teacher may have held a misconception about gravity, she was attempting to analyze and interpret, based on scientific principles, why the student believed that one liquid pours faster than another. Regardless of perhaps her own misconception, Rachael

provided an interpretation of the student's thinking by suggesting that the student was applying her previous observations and knowledge (heavy objects may fall faster) to understand the properties of liquids, and attempted to connect this thinking to the scientific law of gravity.

Overall, the interpretation component of professional noticing progressed across the lesson study cycles. However, the LOFs were more limited in their coding of interpretation than the lesson study analysis meetings. Discussing with others that observed the same lesson afforded the preservice teachers the opportunity and the confidence to risk elaborating on how the students were thinking about the concepts. This ability to reflect at a deeper level due to peer collaboration is something Marble (2007) also found to be a benefit of lesson study.

Responding to Students' Thinking

Preservice teachers' responses to student thinking were evident on three levels: general pedagogical suggestions, strategies to support observations of solids and liquids, and strategies to understand the properties of matter (solids and liquids) and how matter can change phases. An example of each of these levels is outlined in the following paragraphs.

With respect to the first level, many of preservice teachers' suggestions for responding to students' thinking were related to general pedagogy (i.e., not specific to the concept of solids and liquids). For example, after lesson one, three, and four, the preservice teachers suggested using productive questions (Harlen, 2015) to focus students' observations of the various solids and liquids. This strategy of "productive questioning" was something that was discussed in their concurrent science methods course as a broad strategy for facilitating science learning.

Regarding the second level of suggestions, strategies to support observations of solids and liquids, we found that these sorts of comments often focused on supporting students' science practices (i.e., observations) to understand the content. These included creating posters that listed characteristics of solids and of liquids for visual learners and distributing only one solid or liquid at a time for students to make detailed observations of each substance. For example, in the LOF for lesson one, Emily attended to a students' thinking when she wrote, "They wrote in the journal about what they see and what they feel and [Jasper said], 'They are all things.'" Emily then interpreted that thinking when she wrote:

My students couldn't really understand what all the objects would be categorized as [the same]. When they finally understood they were solids they only thought of solids as being hard things like a board, a shoe, a bottle, etc. My students would just name the characteristics of each item not what they have in common.

Emily then responded to this line of thinking when she suggested in part three of her LOF, "Could give each student an object to describe and see if all the students can say how all the objects are similar." This example describes the process of how Emily attended to student thinking, provided some limited interpretation of the student's thinking, and then responded with a materials suggestion to provide students with more experience observing objects. While these types of responses would likely support students' understanding of solids and liquids, they were often more connected to how and of what students made observations rather than how the students were thinking about the content. As such, suggestions for an instructional response were limited to simply providing different materials for more experiences.

Lastly, for the third level of responses, which was also the least common, we found the preservice teachers focused on ways to support students with understanding not just properties of matter, but also phase changes. This level of response is critical in order to fully notice how students are thinking about scientific content (i.e., engaging in all three components). An example of this type of response can be found in map five with the lesson on Oobleck. Rachael commented in Part One of her LOF that a student said Oobleck is both a solid and a liquid, writing “It’s both!” indicating she had attended to the student’s exact words. She then interpreted this idea further in her LOF form when she wrote, “They really seemed able to describe the properties of the Oobleck. They could say how it was both solid and liquid and describe it as having certain aspects of both.” Rachael also interpreted this idea in the lesson study analysis meeting, “Cale started talking about water and ice in his journal entry. I asked him, is ice water, and he said – ‘well, yeah!’ So, at least of couple of them were starting to get it and see that solids can change into liquids even though liquids and solids are different.” In her personal reflection following lesson five, Rachael responded to this idea when she wrote, “I would have liked for them to do the diagram about Oobleck itself, listing the properties it had that were like a solid and those that were like a liquid, putting in the middle things they weren’t sure about.” From the same lesson, Emily also responded to students’ thinking about phases of matter when she said in the lesson study analysis meeting:

I would break it down even more... and then this [lesson] would have been way later because I feel like they might have been a little bit confused, ‘but you told me that solids are this and liquids are this, so why are these both the same,’ them already not knowing really what are specific solids and what are specific liquids, this kind of changed them up a little bit.

These findings suggest the preservice teachers were able to respond to students’ thinking at various levels, sometimes providing general pedagogical suggestions, but at other times responding to how students were engaging in science (i.e. observing) or how they were thinking about the science content (properties of solids and liquids).

Interactions Between Noticing Components and Supports Offered by Lesson Study

To more thoroughly address our research question we now present a deeper analysis of the map for lesson three (see Figure 2 on following page). Lesson three involved the elementary students observing and exploring pieces of solids, such as cornmeal, sand, rice, lima beans and pinto beans. The core idea identified and mapped across this lesson was the notion that, even though pieces of solids can pour like liquids, they differ from liquids because they can be held in one’s hand. The preservice teachers’ *attended* to this concept both individually and collaboratively in their LOFs and written lesson reflections (individual) and in the lesson study analysis meetings (collaborative). In their field notes, Gwendolyn and Kelsey noted students’ words. For example Gwendolyn wrote, “You can put solids in your hand. You can’t hold liquids.” This observation of students’ thinking extended into the lesson study analysis meeting when Rachael said,

Of the groups I saw, most everyone got to having the kids hold something in their hand, hold an actual piece of it, that was like a ‘click.’ Like when I was at [one table] and it was corn[meal] in the bottle and you said, ‘Take just a piece,’ they all took a piece and they were like, ‘Oh, it’s a solid’... Because up until that point they were all thinking it was a liquid. And this happened with a couple of other times [for other groups].

Emily then continued this thread of attending to students’ thinking through her independent written reflection on the lesson, “Some of the students said they were solids because you can

pour them in your hand. They said water wasn't a solid because you can't pick it up, pour it in your hand and be able to hold it." These examples suggest that the preservice teachers were able to independently attend to students' thinking, as well as discuss their observations with the team during the lesson study analysis meeting. Further, Emily was able to bring this notion back into focus when she reflected independently after the collaborative discussion.

Independent and collaborative *interpretation* of students' thinking about pieces of solids was evident in the LOFs and during the lesson study analysis meetings. Lisa noted in her LOF that students had an "ah-ha" moment regarding the differences between pieces of solids and liquids. She wrote, "AH-HA moment— crumb = solid; can't hold = liquid!" Emily furthered this interpretation of students' thinking when she connected her observation of one student (*attending*) to an interpretation of that thinking,

Annika said it was a liquid because it poured fast, but them being able to see that, they now come to the conclusion that if you can hold it in your hand it's a solid, and if you can't hold it it's a liquid. So they are at that point of the stage [of understanding] now (Lesson Analysis Meeting Three).

Kelsey continued this idea in the lesson analysis meeting when she said, "And [Annika] kept saying, 'It doesn't matter if it pours fast or slow, it's still a solid!'" In these examples, the preservice teachers transitioned from attending to students' thinking about how pieces of solids and liquids differ, to interpreting this thinking as an "ah-ha" moment. The preservice teachers noted that in the previous lesson on exploring liquids (lesson two), students observed that liquids pour and solids do not. Lesson three presented a discrepant event during which pieces of solids appeared to pour like a liquid, suggesting that the characteristic of pouring does not necessarily distinguish a solid from a liquid. The students then realized that a better way to distinguish pieces of solids from liquids is whether or not they can be held in one's hand. This interpretation of students' thinking could not have occurred without first attending to the observations students were making about holding the pieces of solids.

ATTENDING	INTERPRETING	RESPONDING
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Individual: Lesson Observation Form Part 1 - Field Notes

Gwendolyn: You can put solids in your hand. You can't hold liquids.

Kelsey: They all want to touch and feel the objects. [Students conclusion were] –solids can be held in hand, can take the shape if grouped together; liquids move, can't hold it, some are slow and some move fast.

Collaborative: Post Lesson Reflection

Rachael: Of the groups I saw, most everyone got to having the kids hold something in their hand, hold an actual piece of it, that was like a 'click.' Like when I was at [one table] and it was cornmeal in the bottle and you said, 'Take just a piece,' they all took a piece and they were like, 'Oh, it's a solid'... Because up until that point they were all thinking it was a liquid. And this happened with a couple of other times [for other groups].

Kelsey: And [Annika] kept saying, 'it doesn't matter if it pours fast or slow, it's still a solid!'

Individual Lesson Reflection

Emily: Some of the students said they were solids because you can pour them in your hand. They said water wasn't a solid because you can't pick it up, pour it in your hand and be able to hold it.

Individual: Lesson Observation Form Part 2- Discussion Items

Kelsey: They finally grasped that all solids can change shape as a group when poured altogether but individually they are all the same shape when poured. Also, you can pick up solids and hold it in your hand but you can't do that with liquids such as water.

Lisa: Even though solids can pour the "little crumbs" do not change. Solids can change shape – tall and skinny VS fat and short container AH-HA moment--- crumb = solid; can't hold = liquid!

Collaborative: Post Lesson Reflection

Emily: Annika said it was a liquid because it poured fast, but them being able to see that, they now come to the conclusion that if you can hold it in your hand it's a solid, and if you can't hold it it's a liquid. So they are at that point of the stage [of understanding] now.

Mindy: Eliot wasn't able to say, 'Ok, this part reminds me of a liquid but I know it's a solid and even when I take it out, that's even more of a reason that it's a solid.' He wasn't able to say that it was a solid both in the container and out because he is kind of stuck on the concept that if it is in a container, it's a liquid.

Individual: Lesson Observation Form Part 3- Suggestions for Lesson Revisions

Gwendolyn: Maybe use water and a more thick liquid along with the solids next time.

Collaborative: Post Lesson Reflection

Emily: And today we just cut this idea of fast and slow off, and now look at it, now what is it, now it's like if I pour this water and I pour this cornmeal, well they're both pouring so they're probably both liquids, so now this is what this looks like...one boy was saying how you can't hold the water...Lesson 5 is going to mix them up because today they were all saying liquids you can't hold it but solids you can hold it. But the material in that lesson (Oobleck) they are going to be like 'wow' because it is going to be hard to hold – you can then you can't hold it.

Individual: Lesson Reflection and Revision

Rachael (reflection): Once each student got to hold an individual grain of the substance, they were then sure that it was a solid because the piece in their hand was definitely hard and not changing shape. These two descriptors were important because they came from our first lesson on solids, but we threw out our old definition of "solids don't pour."

Lisa: To better guide the exploration assistants should have specific guiding questions so each student will observe and infer similar characteristics and reasoning.

Rachael (revision): Explore Phase – new questions added: "Do you think this is a solid or a liquid?" "How do you know?" "Can you hold a piece of the substance?" "What do these items tell you about solids in general?"

Figure 2.–Examples of preservice teachers' professional noticing abilities from lesson three on solids versus liquids

Finally, preservice teachers were able to *respond* to their interpretations of students' thinking both independently and collaboratively. In her LOF, Gwendolyn wrote, "Maybe use water and a more thick liquid along with the solids next time." It is important to note, since

Gwendolyn did not explicitly connect the suggestion to the interpretation we can only infer that this suggestion was based on Kelsey's above quote from Annika. Gwendolyn's suggestion followed and extended Annika's thinking by contrasting water and a thick liquid with pieces of solids because water runs through one's hand quickly and a thick liquid may stay in one's hand longer. This could allow all students to compare the rate at which substances (water, a thick liquid, and pieces of solids) remain in the hand, thus leading to Annika's conclusion that, "It doesn't matter if it pours fast or slow, it's still a solid!" Emily responded to this when she said,

And today we just cut this idea of fast and slow off, and now look at it, now what is it, now it's like if I pour this water and I pour this cornmeal, well they're both pouring so they're probably both liquids, so now this is what this looks like and this is what this is, so it got better...one boy was saying how you can't hold the water.

Lisa then connected a suggested response to students' thinking. To address making this distinction between solids and liquids explicit, Lisa suggested, "to better guide the exploration assistants should be provided with specific guiding questions so each student will observe and infer similar characteristics and reasoning." This notion was carried into Rachael's written lesson revision when she added the following guiding question during the Explore phase: "Can you hold a piece of the substance?" This question would explicitly focus students' thinking to observe this characteristic of solids versus liquids. The third lesson study cycle thus indicated that the preservice teachers were able to engage in the three components of noticing, and tie their observations (attending) to their interpretations and their responses to how students were thinking about pieces of solids and how they differ from liquids.

Discussion

The results of this study indicate that participation in our modified lesson study cycle, which was designed specifically for use in an early field experience setting and focused on collecting and analyzing evidence of student thinking, can indeed support the development of preservice teachers' abilities to professionally notice. As we noted previously, many studies that have employed lesson study with preservice teachers have made significant modifications to the authentic context feature of traditional lesson study (e.g., Marble, 2007) or eliminated it altogether (e.g., Sims and Walsh, 2009).

Our study provides evidence that engaging preservice teachers in a modified form of lesson study that embraces the authentic context by placing an emphasis on understanding student thinking can support preservice teachers with beginning to develop all aspects of professional noticing (attending, interpreting, and responding). Indeed, our findings suggest that, with appropriate scaffolds, preservice teachers can challenge the tendency to focus on themselves as teachers and instead focus on how students are reasoning (Marble, 2007; Mason, 2002; 2011). We believe that, although the ability to notice may not be innate (Carter et al., 1988; Jacobs et al., 2010; Levin et al., 2009; Miller, 2011), our preservice teachers' abilities to notice can be attributed to the iterative approach to our model of teaching, reflecting, and revising through the lens of assessing and revising lessons based on students' learning needs in an authentic context.

Much of the noticing research with preservice teachers has relied on video observation (Huang & Li, 2012; Star et al., 2011; Talanquer et al., 2013). As Huang and Li (2012) noted, using only video for developing professional noticing resulted in preservice teachers focusing on lower cognitive examples of student thinking and basic pedagogical skills. Similarly, Star and Strickland (2008) found novice teachers attended to static features of a classroom environment, thus making limited observations associated with students' actual thinking. These outcomes may have occurred because video usually offers a focused perspective that makes it difficult to observe all aspects of the classroom, which in turn presents a challenge to interpreting more complex ideas about the students thinking and considering appropriate responses (i.e., developing all aspects of professional noticing). As Davis et al. (2006) found in their review on challenges facing new teachers, research investigating teachers' practices at both the elementary and secondary levels showed preservice teachers "tended to have very limited ideas about what to do instructionally with students' ideas" (p. 619). Given what we learned from our review the literature on early field experiences, we suspect that this may occur because preservice teachers are often limited in their opportunities to actually teach, revise and teach again (Abell et al., 2010). As Zembal-Saul et al. (2000) suggested, preservice teachers can emphasize students' thinking while lesson planning and throughout the reflection process, further suggesting the need for supporting preservice teachers to focus on students ideas about science concepts. Our study presents evidence that an authentic context can provide critical opportunities to notice, which perhaps extends those afforded by video. Furthermore, with the appropriate scaffolds (e.g., LOFs, protocol for the lesson study analysis meeting, and structures for integrating revisions that are student-focused) preservice teachers can focus on students' thinking during their discussions and reflections on teaching (i.e., 'reflection-on-action,' [Mason, 2002]).

In the sections below we elaborate on each of these scaffolds, and in particular with how they provide a critical contribution to the development of each component of professional noticing. Following this, we conclude with a discussion of implications for how we could continue to improve our model of lesson study with the intent of supporting even deeper connections among the three components of noticing.

Attending to Students' Thinking

The LOF developed for step three (Teach and Conduct Research phase) of our modified lesson study cycle proved to be a useful scaffold for the preservice teachers to learn to attend to and record student thoughts and actions about the science content. To reiterate, the LOF included an area for written observation notes, as well as a blank sheet to draw any visuals, diagrams, or other pictorial/graphical representations of what the students were saying and doing with regard to the content. Thus, the preservice teachers were required first to independently observe and record evidence of what students were thinking in order to fully engage in the lesson study analysis meeting. These meetings allowed for collaborative engagement in attending to student thinking through discussion of more specific details about a greater number of students, as each of the five observing preservice teachers (the lead preservice teacher did not complete a LOF) shared their written observations as well as added details they recalled from having just worked with the students. The university facilitator and the classroom teacher also had the opportunity to support the preservice teachers' in attending to specific instances of student thinking; indeed, the lesson study analysis meeting protocol encouraged their participation in this way. Therefore, we conclude

that the combination of a guided independent recording tool such as our LOFs, followed by a collaborative discussion that occurred in our lesson study analysis meetings can support preservice teachers in giving precise attention to students' thinking, and thus engaging in the first component of professional noticing (Hiebert et al., 2002; Jacobs et al., 2010; Zembal-Saul et al., 2000).

Interpreting Students' Thinking

Interpretations of student thinking are inherently connected to observations of students. Prior research has shown that while preservice teachers can attend to student thinking (Huang & Li, 2012; Star & Strickland, 2008), bridging these observations to interpretations of student thinking requires professional development (Jacobs et al., 2010). In our study, during lesson study the preservice teachers attended to student thinking in their LOFs and discussed these observations in the lesson study analysis meetings, and they were also able to begin to interpret their observations. Part two of the LOF emphasized describing what students know and how they demonstrate their knowing. We found that the preservice teachers often provided only limited interpretations in this section of the LOF, but deeper and more frequent interpretations of student thinking occurred in the lesson study reflection meetings. This is likely because the preservice teachers were able to hear one another's interpretations, as well as collaborate with the university facilitator and classroom teacher to understand how the students were thinking.

Finally, in the individual reflection and lesson revision stage of the lesson study process the preservice teachers were given time to synthesize all they had gathered from the collaborative reflection period and demonstrate how their own reasoning about student thinking informed their understanding of the effectiveness of the lesson. Yet, these two data sources indicated that the preservice teachers were either not willing or not able to further engage in this process independently. Therefore, more work is needed to better scaffold the connection between attending to and interpreting students' thinking; we suggest the use of more explicit prompts on the LOF and in the lesson study reflection meeting protocol to encourage preservice teachers to make this transfer. For example, the LOF could prompt preservice teachers to focus their observations on one specific student with whom they were working, and provide interpretations of and responses to this student's thought processes. This suggestion aligns with Mason's (2011) claim that "structured space" is needed for developing preservice teachers' awareness of students' thinking and use of this awareness to inform instructional decision-making.

Responding to Students' Thinking

Prior research has suggested that the ability to professionally notice is directly correlated to teaching experience (Huang & Li, 2012). Our findings indicate that the preservice teachers we studied were not only able to attend to and interpret students' thinking, but also able respond to students' thinking on three levels: general pedagogical suggestions, suggestions to focus scientific observations, and suggestions to deepen content understanding. In comparison to responses to student thinking that appeared only on the LOFs, those that appeared in the lesson study analysis meetings and the written reflection and revision data were more specifically connected to the selected core ideas about solids and liquids. We therefore surmise that collaborative discussion of responding to students' thinking is a critical aspect of the lesson study process that supports preservice teachers' noticing. Moreover, our model could have done more to scaffold the transfer between interpreting students' thinking and responding to this thinking, as responses connected to the content were less common than those related to scientific observation (science practices) and

general pedagogy. Preservice teachers may not have the experience needed to deeply interpret student thinking, nor the repertoire of science teaching methods (i.e., the pedagogical content knowledge) to independently engage in all three components of noticing without increased supports. It is in the connection between interpreting and responding that support from knowledgeable others (e.g., classroom teachers, field supervisors, and science methods instructors) is most critical (Abell et al., 2010). In the next section, we discuss possible additional scaffolds to further support these connections.

Conclusions

We have shared how, per Talanquer et al.'s (2013, p. 205) recommendation, we were able to engage preservice teachers in inquiry experiences guided by theoretical models to improve their noticing. We employed a modified framework of lesson study that included gathering and analyzing student data, and embedded critical scaffolds throughout the process in order to support preservice teachers' development of, and transfer between, the three components of professional noticing. Although the results of our study indicate our modified form of lesson study in an early field experience can support preservice teachers' engagement in all aspects of professional noticing, we recognize that there are some components that were better developed than others.

The structure of the LOF and the lesson study analysis meeting discussions clearly guided the preservice teachers through the act of attending to student thinking, interpreting student thinking, and considering revisions based on these interpretations. However, over the course of the five lessons we found that the preservice teachers' individual reflections and revised lesson plans included few of the specific revisions mentioned in the LOFs and the lesson study analysis meetings. We infer that these ideas did not transfer to these independent noticing experiences in part because of the one-week delay in submission of these two particular pieces of the lesson study cycle. As we stated in the description of our model, the preservice teachers were given a week to submit their personal reflection papers and lesson plan revisions. Similar to Zembal-Saul et al. (2000) we found that despite encouragement to synthesize the information they collected from their peers' LOFs and comments from the lesson study analysis meeting to use as evidence to justify changes to the lesson plan, the preservice teachers did not do so. This is likely because we did not provide them the necessary scaffolding. Therefore, to truly assess the degree to which preservice teachers are learning to plan instruction that responds to issues in student thinking, we have suggested a more structured protocol for the reflection papers and lesson revisions. For example, the three components of the noticing framework could be used to structure the format of these documents, and even be identified as such, explicitly guiding the preservice teachers (as do the LOFs) to make connections across the three components of noticing. Indeed, perhaps collaboratively creating a map with the team, similar to those we created in our own data analysis, could serve to make the connections across noticing components more explicit. In addition, to assess if their abilities to professionally notice are becoming an integrated part of their professional knowledge base, a gradual release could be employed in all scaffolds used in the lesson study cycle, requiring preservice teachers to take more responsibility for enacting these practices (Collet, 2012). This shift in responsibility may serve the preservice teachers well in developing their self-efficacy and identity as a teacher, which many researchers note is a challenge for novice teachers (Abell et al., 2010; Davis et al., 2006, Levin et al., 2009).

Another suggestion we have for improving the model is to build a stronger connection between the core aspects of the lesson study cycle and the methods course that preservice teachers are often taking concurrently. Opportunities within our lesson study model to notice individually and collaboratively occurred only in the field or as a field course assignment. We believe that bridging the lesson study model to include the methods course as part of the reflection and revision process (Step 4 of our model – please refer back to Figure 1) could strengthen the connection between theory and practice. This would better support preservice teachers to make revisions to improve student learning that are grounded in research about best practice, rather than personal opinion (Zeichner, 2010). Therefore, we suggest that this part of the process should be embedded within the methods course, rather than asking the preservice teachers to leave the field experience and independently revise the lesson plan. For this to occur there needs to be coordination across the elementary preparation program, perhaps through a spiraling theoretical framework (Knowles, Cole, & Presswood, 1994).

Finally, based on the noticing literature, we understand that the goal for developing professional noticing is for a teacher to eventually enact all three components while in the moment of teaching (Jacobs et al., 2010; van Es & Sherin, 2008), or what Mason (2002) calls ‘reflection-through-action.’ Although researchers have shown that learning to attend to students’ thinking can be a difficult task for some novice teachers, studies that include scaffolds have shown promise in this regard (Carter et al., 1988; Jacobs et al., 2010; Levin et al., 2009; Miller, 2011; Talanquer et al., 2013). Further, although beginning teachers have limited classroom experience, which may challenge their abilities to understand the basis of students’ ideas (Harlen, 2015) or how they are learning (Davis et al., 2006), our results indicate that these challenges are not insurmountable. Our research is an example of the possibilities for developing professional noticing at the preservice level when supported with a model of lesson study that offers opportunities for authentic teaching, an iterative approach to teaching, multiple forms of reflection (both individually and collaboratively), and scaffolds provided along the way that consistently place an emphasis on recording evidence of students thinking. We recognize that further research is needed to examine the critical next step of transfer to classroom practice will help to refine our model for lesson study for use in an early field experience further.

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Appendix A

Lesson Observation Form

Observer _____ Date _____

Teacher _____ Lesson _____

Lesson Observation Form³⁴

***Review the objectives and plans for the lesson. Observe students at a table where at least one of your FAI students is sitting. Record observations, not inferences, in your field notes.**

Field Notes

Include anything students say or do which demonstrates their thinking about the topic and concepts. For example, you might include comments and/or questions in group and whole class discussions, engagement with materials, or written work, including drawings or representations. *[This section also contains a blank page for preservice teachers to draw/write observations. Directions state, "Use this space to note any drawings or representations that your students construct"]*

Discussion Items: Summary Reflection on Students' Thinking and Reasoning

*Based on your field notes, describe how the students at your table demonstrated their understanding of the concepts in the lesson.

Discussion Items: Summary Reflection on How to Improve the Lesson

*Provide at least two suggestions for revising the lesson to improve student learning based on what you described above and anything else you recorded in your field notes.

³ It is recommended that more space/lines be provided between questions. Our original form fits onto 3 pages.

⁴ A slightly different version of this form, but used for a similar purpose, can be found in Amador & Carter, 2016.