Preservice Elementary Teachers' Development of PCK-Readiness about Learners' Science Ideas

by

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DEDICATION

To David and Zoe Jane

Without you two, this dissertation would have been done sooner, easier, probably better,
and without two (make that three) moves, two pregnancies, a new language,
and juggling a toddler and baby…
and I wouldn't have it any other way.
Thanks for the constant support and perspective, respectively.

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ABSTRACT

Preservice elementary teachers face many daunting challenges as they learn to teach science. Teacher educators try to design methods courses that help them meet these challenges and prepare them for the experiences they will have as student teachers and new teachers. Because they often do not spend much time with students, it is a general assumption that preservice teachers are unable to develop pedagogical content knowledge (PCK) with respect to their learners' ideas.

Rather than focus on what preservice teachers are unable to do, however, this dissertation explores how a methods course might foster consideration of learners' science ideas, an important component of PCK. Perhaps preservice teachers can learn to develop PCK-readiness, thus putting them in a good position to develop rich usable PCK once they have more experience in the classroom. This new idea of PCK-readiness is the focus of this study.

This study follows a class of preservice teachers through an elementary science methods course. It describes the trajectories of eight focus preservice teachers' thinking about their learners. It also explores how the entire class made sense of a set of activities designed to foster consideration of learners' ideas.

Results indicate that with scaffolds, preservice teachers are able to think in complex ways about their learners' ideas, including considering how to use those ideas in

instruction. The trajectories of the preservice teachers varied but generally showed growth in thinking about learners' ideas, although some were focused on or influenced by particular events or assignments during the course while others made more consistent growth in several areas. Generally, the course activities supported thinking about how to deal with learners' ideas but not the characteristics of those ideas.

This study contributes to the field by providing a description of how a range of preservice teachers engaged with the activities in the methods course. In addition, it describes the kind of influence that a methods course might have on preservice teachers' development of a crucial aspect of learning to teach. Finally, it explores how thinking about preservice teacher learning in terms of PCK-readiness gives new insight into what preservice elementary teachers are capable of and how teacher education might best prepare them for successful careers as science teachers.

CHAPTER 1

INTRODUCTION

Elementary science teachers face a challenging job. They are expected to teach up to five subjects each day, and expectations for this teaching are on the rise. Current reform documents (American Association for the Advancement of Science, 1993; National Research Council, 1996) advocate inquiry-oriented science to help students develop deep conceptual understanding of science topics. Teaching science in this way requires a working knowledge of students' ideas about science concepts.

Pedagogical content knowledge (PCK) is an understanding of content, learners, learning, and pedagogy that enables teachers to teach particular content to particular learners (Shulman, 1986). Effective teachers are able to use their pedagogical content knowledge to select instructional strategies and representations that will appropriately and effectively help their learners better understand the content. Developing this knowledge is, understandably, quite difficult. Preservice teachers' lack of experience limits their ability to develop PCK (van Driel, De Jong, & Verloop, 2002; van Driel, Verloop, & de Vos, 1998). However, some work has been done to describe aspects of preservice teachers' PCK development (Davis & Petish, 2005; Zembal-Saul, Blumenfeld, & Krajcik, 2000). This dissertation builds on the work of those who suggest that with supports, preservice teachers are able to think in complex ways and can develop aspects of PCK.

Much of the work on preservice teacher knowledge does not take into account learning trajectories as they develop over time. Some studies measure knowledge at a particular point (often describing what *is not* there) rather than following changes. Most of these studies conclude that teachers cannot develop PCK rather than examining what the very beginnings of PCK might look like. Finally, few studies explore a diverse set of data, and even fewer do so using design-based research. They typically focus on one particular aspect of PCK as measured in one or two data sets rather than looking at the complexity of a learning context (such as all of the assignments in a methods course) to see how it might foster development of PCK. This study follows preservice teachers over the course of a semester and looks at how they made sense of the activities in their methods course in order to develop the building blocks of PCK, which I call PCK-readiness.

Research Questions

In this study, I describe how preservice teachers' thinking about learners' ideas in science changes over the course of a semester. I think about this kind of thinking in preservice teachers as *PCK-readiness*, or developing the building blocks to rich, usable PCK. In addition, I investigate the influence of a set of activities designed to help preservice teachers consider learners' ideas. For my purposes, "learners' ideas" includes both prior knowledge and alternative conceptions about science concepts. There are two sets of research questions that guide this study.

Research Question 1: Describing trajectory of learning over time

How does preservice teachers' PCK-readiness develop over the course of a semester with respect to thinking about and using students' ideas? Specifically, what

characterizes the development of understandings of learners among preservice teachers with different initial ideas? How does the preservice teachers' treatment of students' ideas change over the course of the semester?

Research Question 2: Support of focused activities

How does preservice teachers' use of focused assignments on students' thinking (FAST activities) within the methods course support them in considering student ideas? More specifically, do different FAST activities foster different aspects of thinking about students' ideas? What kinds of thinking does the set of FAST activities as a whole support? (The use of the term FAST is not intended to imply assignments that do not take much time to complete.)

The first set of questions focuses on how eight preservice teachers make sense of the experiences in their methods course. Specifically, I investigate how their trajectory of considering learners' ideas develops over the course of the semester. The second set looks at how activities designed to foster consideration of learners' ideas do or do not help preservice elementary teachers develop building blocks for PCK with respect to learners' ideas. These questions are investigated using data from preservice teachers' work within the methods courses over the entire semester. This work informs the field's understanding of how preservice elementary teachers' PCK develops and how careful attention to this development within methods courses can help preservice teachers prepare for teaching.

Becoming an Elementary Science Teacher

Answering these questions adds to the knowledge about how preservice elementary teachers learn to teach science. I view becoming a teacher as a series of

gradual developments rather than distinct stages (Feiman-Nemser, 2001). As such, it is important to learn what kinds of thinking preservice teachers are capable of and how that knowledge prepares them for the challenges they will face as they move from preservice to practice. Learning how best to help them develop these building blocks to PCK is the primary goal of this dissertation.

Becoming a science teacher today presents some daunting challenges. As mentioned above, reform documents advocate inquiry-oriented teaching. Preservice teachers struggle with learning in inquiry-oriented ways (Roth, McGinn, & Bowen, 1998) and in thinking about inquiry and science as non-linear (Windschitl, 2003). In addition, teaching through inquiry requires careful attention to learners' prior knowledge and non-normative science ideas. Attending to these ideas and knowing how to deal with them in instruction is difficult for preservice teachers.

Because elementary teachers must learn to manage their classroom, develop subject matter knowledge (for science and all other subjects they teach), develop instructional strategies, find and learn to use curricular materials, and attend to their learners' science ideas, it is not surprising that they initially struggle to focus on their students' learning (LaBoskey, 1994). Often, this lack of emphasis on learners' ideas takes two forms. First, preservice teachers tend to emphasize interest and engagement instead of learning. Often because of negative experiences in their own science backgrounds, they want students to have a positive view of science (Anderson, Smith, & Peasley, 2000; Bryan & Abell, 1999; Trumbull, 1999). Second, they struggle with knowing what to do with learners' ideas. Even when they know what those ideas are, they are often at a loss when thinking about how to deal with them in their science

instruction (Magnusson, Krajcik, & Borko, 1999; D. Smith & Neale, 1989). Both of these struggles make sense given the challenges and expectations placed on preservice and new elementary science teachers.

A major goal of this dissertation is to see how and to what extent a methods course can support preservice teachers in moving beyond these challenges. For example, can scaffolds designed to help preservice teachers focus on what students learned during a lesson help move them beyond caring only about interest and engagement? Can preservice teachers learn to think in terms of dealing with their learners' ideas in planning for, enacting, and reflecting on instruction? I certainly do not expect preservice teachers to develop the kind of usable PCK practicing teachers might have in dealing with these ideas. I do hope to foster PCK-readiness that might make them well-started beginners (Hollon, Roth, & Anderson, 1991) as they enter teaching. This dissertation, outlined below, strives to answer these questions.

Structure of Dissertation

This dissertation is organized into six chapters. Chapter 1 described the goals of the study, including the contribution it makes to the field of preservice teacher learning.

Chapter 2 positions this study in the context of work others have done. The chapter presents the set of expectations elementary science teachers are expected to meet in terms of their subject matter knowledge, teaching of other subjects, and teaching science in light of recent reform movements. Then, I show how an understanding of learners' ideas is imperative in order to teach science in ways that are advocated. However, learning to attend to learners' ideas is difficult for preservice teachers; I describe the challenges they typically face in considering their students' learning. I also

explore supports that have proven helpful in learning to think about their learners' ideas. Finally, I present the construct of PCK-readiness and the ways in which thinking about preservice teacher learning in this way contributes to the field.

Chapter 3 describes the methodological decisions that guide this study. In answering the first set of research questions, I follow eight preservice teachers through the entire methods course and analyze their coursework and interviews for evidence of their thinking about their learners' ideas. In answering the second set of research questions, I look at how all the preservice teachers in the course made sense of the set of FAST activities and how each (and the set as a whole) fostered thinking about learners' ideas. In Chapter 3, I describe the methods course, including all applicable assignments. In addition, I describe how I chose my focus preservice teachers, designed my coding scheme, and decided on my method of analysis.

Chapter 4 explores the eight focus preservice teachers' development over the course of the semester. After analyzing their set of coursework and interviews, I describe their thinking over the semester in terms of trajectories. Several different types of trajectories are described. For example, some preservice teachers make consistent progress in their thinking, others change their ideas after a particular event, and still others do not seem to engage in thinking carefully about their learners' ideas. The trajectory of each preservice teacher is described, along with themes that emerged across the group.

In Chapter 5, I describe how the entire class made sense of each FAST activity. First, I present the results for each specific activity and the kinds of thinking that were or were not supported. For example, after reflecting on an interview with a child, the

preservice teachers engaged in describing learners' ideas and thinking about those ideas while planning for instruction. Then, I discuss the set of FAST activities as a whole. Here, I explore the spectrum of thinking that occurred over the semester and the areas in which the preservice teachers did not engage. For example, in general, the FAST activities supported preservice teachers in thinking about how to deal with learners' ideas. This is encouraging, especially in light of current work that suggests this is difficult for them. However, rarely did they think about other issues such as the importance, difficulty, or resilience of learners' science ideas.

Chapter 6 explores possible reasons for these findings and implications for teacher education and future research. In particular, the construct of PCK-readiness is explored in light of the results. While the progress preservice teachers made, especially though the use of the scaffolded FAST activities, is impressive, it certainly does not represent the kind of usable PCK one might see in an experienced teacher. However, through developing building blocks to PCK, I show that these kinds of experiences set them up to be well prepared to develop PCK once they are practicing teachers. The potential for further work on PCK-readiness is explored as well, including what kinds of experiences might best set up preservice teachers for practice and how those building blocks could be used to develop rich, usable PCK.

CHAPTER 2

THEORETICAL FRAMEWORK

Previous work guides this study of preservice elementary teachers' thinking about their students' ideas. First, I examine the expectations for elementary science teachers in light of recent reforms. Then I describe the knowledge that is needed in order to meet these expectations effectively and challenges that preservice and new teachers typically face in developing this knowledge. I present supports that can help preservice teachers think about their learners in more complex ways. Finally, I discuss PCK-readiness as a lens for looking at the initial stages of PCK development.

Expectations for Elementary Science Teachers

Expectations for elementary science teachers are high; they are expected to care for their young students, create an atmosphere that fosters learning and behavior management, plan short and long term for all subjects, and be experts on all subjects they teach. The expectations for their *science* teaching in particular are high as well. Elementary teachers must be experts in all areas of science, not just one, as is often the case for middle and high school teachers. In addition to subject matter knowledge, teachers must know how best to teach that knowledge. Current reform documents (American Association for the Advancement of Science, 1993; National Research Council, 1996) advocate inquiry-oriented science to help students develop deep

conceptual understandings of science topics. This kind of science teaching is often drastically different from the types of science the preservice teachers have experienced as students or observed in their field placements (R. Smith, 1999).

Inquiry-oriented teaching involves supporting students in asking scientifically oriented questions, linking explanations to evidence, connecting these explanations to scientific knowledge, and communicating and justifying findings (National Research Council, 2000). Teaching in this way requires that teachers pay careful attention to the ideas their learners bring to the classroom because these determine the kinds of understandings they will construct (Bransford, Brown, & Cocking, 2000).

Reform-oriented practices are complex and difficult; adopting these ideas and practices is especially challenging for preservice teachers. Not much work has been done on the ways in which preservice and new teachers learn to teach inquiry-oriented science (Davis, Petish, & Smithey, 2006). Often, preservice teachers struggle with *learning* in inquiry-oriented ways (Roth et al., 1998). One might imagine that if preservice teachers struggle to learn science in this way, learning to teach it is even more challenging. Other research shows that preservice teachers often have linear views of inquiry and science, which influences their learning as well (Palmquist & Finley, 1997; Windschitl, 2003). Thus, learning to teach in a way that meets expectations is challenging for today's preservice teachers. Learning what inquiry means, how to learn science in this way, and how to *teach* science in this way are all difficult for preservice teachers. Because preservice teachers cannot teach inquiry-oriented science without attending to their learners' science ideas, the knowledge that they have about those ideas is a critical piece of their development as teachers. This knowledge is described next.

PCK with Respect to Learners' Ideas

As discussed above, the expectations for teaching inquiry-oriented science are challenging. In order to meet these expectations, teachers need to have rich, usable PCK, but how does a preservice teacher move towards becoming an expert? In a review of professional growth among preservice and beginning teachers, Kagan (1992) asserts that during the initial years, teachers have three goals, one of which is gaining knowledge about their learners. As this knowledge is acquired, however, it must be integrated and transformed into usable knowledge that can be used in the moment of teaching (Davis, 2004; Linn & Hsi, 2000). Through integrating their knowledge and experiences, preservice teachers can begin to form PCK.

Of course, there are other types of knowledge that expert teachers use and that contribute to their PCK. Subject matter knowledge, for example, is a key component of effective teaching, as is pedagogical knowledge. Having a deep understanding of the content and strategies to effectively teach the content are imperative. However, in this study, these types of knowledge are neither measured nor emphasized, although previous work points to preservice elementary teachers' lack of rich subject matter knowledge in science (e.g., Cochran & Jones, 1998) .

Teachers who have well developed pedagogical content knowledge know how to teach specific content to specific learners. This involves transforming subject matter knowledge into useable knowledge for teaching and an understanding of learners; subject matter knowledge is necessary but not sufficient in knowing how to teach well (Shulman, 1986; Wilson, Shulman, & Richert, 1987). Building on Shulman's (1986) work, others have expanded the construct of PCK to include rationales for instructional decisions and

specific aspects of knowledge and beliefs needed to teach effectively (Grossman, 1990; Magnusson et al., 1999). For example, Ball and Bass (2000) have expanded work on PCK to include the idea of "flexible knowledge." Briggs and colleagues (2007) also explore how to measure the ability of teachers to use their knowledge flexibly. Expert teachers are able to apply their knowledge about a concept during instruction to accommodate students' ideas about that concept.

While there is literature on many aspects of PCK (to varying degrees), this study is focused on how preservice teachers learn to attend to their students' ideas in science. Without question, knowledge about learners is an integral aspect of pedagogical content knowledge (Borko & Putnam, 1996; Grossman, 1990; Magnusson et al., 1999; Shulman, 1986). This involves predicting learners' areas of difficulty, knowing how to effectively represent content to learners, and dealing with nonscientific ideas in planning and instruction. This attention to learners allows teachers to effectively foster rich conceptual understandings as advocated in reform documents.

While acquiring PCK is an essential step in becoming an effective science teacher, the ability of preservice teachers to develop PCK is tenuous. One reason for this difficulty is preservice teachers' lack of experience (van Driel et al., 2002; van Driel et al., 1998). In a review of the literature, van Driel and colleagues (1998) state that "[t]eacher training programs usually do not exert a major influence on science teachers' PCK" (p.682). However, if carefully fostered and measured, changes in PCK have been shown to occur, even in preservice teachers with limited experience with teaching and learners. In fact, some studies describe specific aspects of preservice science teachers' PCK development (Anderson et al., 2000; Davis, 2004; Davis & Petish, 2005; Zembal-

Saul, Krajcik, & Blumenfeld, 2002). The area of PCK this study focuses on involves knowledge of learners' ideas.

Before teachers can teach effectively, they must have a working knowledge of students' ideas (Magnusson et al., 1999). This involves a rich understanding of the characteristics of learners' ideas and how to deal with those ideas during instruction.

Characteristics of Learners' Ideas

Understanding the characteristics of learners' ideas allows preservice teachers to develop a working knowledge about ideas without having to be able to attend to them in instruction. This knowledge entails describing and anticipating ideas, acknowledging the difficulty, resilience, and importance of ideas, and appreciating the factors that contribute to their ideas. These aspects of understanding learners' ideas are all related to one another.

Describing learners' ideas is straightforward but important. Few preservice teachers have much access to "real" learners for an extended time, and engaging with them about their science ideas is not common. Interviewing students and describing their ideas can allow preservice teachers to think about their own instruction (Anderson et al., 2000), although often at a surface level by looking for what students do not know and where their instruction might start. However, listening to and describing learners' ideas is critical for PCK development because preservice teachers are forced to stop and listen carefully to their learners (D. Smith, 2000).

Being able to anticipate learners' ideas is a part of PCK (Magnusson et al., 1999). In fact, the ability to predict ideas was seen as a key difference between novice and expert teachers in one study (Meyer, 2004). While expert teachers knew the ideas their

learners would probably have (as well as tools to deal with them), novice teachers either assumed they would enter with no prior knowledge or were unable to predict what those ideas might be.

Preservice teachers need to understand that some ideas are more difficult than others for children to learn. In fact, knowing the common learning difficulties for any given concept is a critical component of PCK development (van Driel et al., 1998). Preservice teachers often encounter a tension between acknowledging the difficulty of an idea for their students and knowing when to move on (Bryan & Abell, 1999).

Related to the idea of difficulty is resilience. This is the idea that learners' ideas are often resistant to instruction. Simply telling them that an idea is correct is unlikely to change their thinking (Linn & Hsi, 2000; J. Smith, diSessa, & Roschelle, 1993). This aspect of learners' ideas is critical to becoming a teacher. Without it, planning instruction is a simple matter of curriculum coverage. However, as preservice teachers gain an appreciation for the resilience of learners' ideas, instruction becomes a more complex issue because instruction does not guarantee that they will adopt the scientifically normative idea (Watson & Konicek, 1990).

In order for preservice teachers to attend to their learners through their instruction, they must understand why doing so is important. In general, preservice teachers do acknowledge that learners' ideas are important (Abell, Bryan, & Anderson, 1998; Anderson et al., 2000; Howes, 2002; Meyer, Tabachnick, Hewson, Lemberger, & Park, 1999), even when they are unable to think more about how to deal with them in instruction.

Students do not come into a learning environment as blank slates. They have a set of experiences, both in schools and out, that contribute to their science ideas. Preservice teachers' understanding of and appreciation for these factors can vary (Rodrigues, 1999). Initially, preservice teachers can show resistance to change as it pertains to teaching for a diverse set of students, but over time, some can appreciate this need. Often preservice teachers assume that learners, especially those from an urban setting, enter a learning situation with little or no prior knowledge (Meyer, 2004). Part of becoming an expert teacher is gaining an appreciation for the many factors that contribute to the ways students make sense of the world.

Each characteristic of learners' ideas is related: describing ideas leads to predicting them. Once resilience is understood, the importance of them is evident. Even before preservice teachers are able to use their learners' science ideas in instruction, thinking about the characteristics of them is an important building block in developing their PCK.

Dealing with Learners' Ideas in Instruction

Knowing about ideas is one thing; dealing with them as a teacher is another. Just because a teacher might know what learners' ideas are, that does not mean she is equipped to appropriately handle them in instruction (D. Smith & Neale, 1989). The second set of aspects related to learners' ideas is how to deal with them during instruction. This includes finding out learners' ideas and dealing with them before, during, and after instruction.

A first step in learning what to do with ideas is finding out what students' ideas are in the first place. Initially, students' ideas are seen as a starting place for instruction

or of little importance (Kagan, 1992). However, work is currently being done to assess the importance science teachers place on finding out student ideas. One study in particular is developing an assessment tool to measure the role that finding out ideas plays in evaluating instructional activities (Briggs et al., 2007).

Planning for instruction is a common practice in an elementary science methods course. While access to learners and instruction time is scarce, thinking about how one might teach is potentially productive. Through planning for actual and hypothetical lessons, preservice teachers are given opportunities to think about how they might attend to their learners' science ideas (Davis, 2006a, 2006b).

Dealing with learners' ideas during instruction is difficult. Preservice and new teachers are often overwhelmed and tend to focus on management or other aspects; student learning is often not easily emphasized (Bryan & Abell, 1999; Kettle & Sellars, 1996). However, a sign of expertise in teaching is the ability to reflect "in action" (Hatton & Smith, 1995; Schon, 1982), so this building block is important to emphasize in preservice teacher education, even if it is difficult for preservice teachers.

Because preservice teachers do not have many opportunities to teach, their reflections on these experiences are important. Scaffolded reflections after instructions have proven effective in supporting preservice teachers in considering their learners' ideas (Zembal-Saul et al., 2000).

Summary

Preservice teachers need to understand both characteristics of learners' ideas (D. Smith, 2000) and how to deal with those ideas in instruction (D. Smith & Neale, 1989). Some of these aspects are more well-represented in the field than others, and some are

easier for preservice teachers to gain traction on than others. However, we do know that expert teachers with usable PCK are able to understand their learners' ideas and attend to them as they teach. Therefore, this set of knowledge is critical for preservice elementary science teachers to begin to develop.

Preservice Teachers' Challenges in Developing PCK about Learners

The previous section described the knowledge that teachers need in order to meet the expectations put upon them in teaching science. Not surprisingly, preservice teachers face challenges in developing this rich usable knowledge about their learners. One of the clearest themes in the literature is that preservice teachers do not spend much quality time with learners. The amount of time they spend in classrooms is minimal, and little of that is spent in instruction. In addition, many early teaching and learning experiences are (understandably) focused on instructional decisions rather than learners. Initially, then, preservice teachers are focused on themselves rather than on their students' learning (Fuller, 1969; LaBoskey, 1994). Although specific studies identify variations of how this plays out with respect to student learning, most find a tendency for learning to take a back seat (Anderson et al., 2000; Bryan & Abell, 1999; Trumbull, 1999). With respect to learners, preservice teachers face at least three specific challenges: they want students to be interested in science (but often do not think as carefully about their learning), they struggle in knowing how to teach subject matter knowledge in a way that addresses the ideas of their learners, and their own ideas about teaching and learning are resistant to change.

Preservice elementary teachers emphasize student interest over student learning

Preservice and new elementary teachers often give precedence to student interest or engagement over learning. Engagement in science is an admirable goal for teachers to have for their students. However, it often overshadows learning of science content and the emphasis turns to making science "fun." Preservice teachers want their students to enjoy science and come away with a positive image and feeling about science learning (Abell et al., 1998; Anderson et al., 2000; Bryan & Abell, 1999; Trumbull, 1999).

These goals of interest and engagement are difficult for preservice teachers to attain when they must also try to meet content goals. This is one of the most important tensions that preservice teachers must come to terms with as they become practicing teachers (Anderson et al., 2000). Often, when faced with the dilemma, preservice teachers choose to emphasize interest rather than content. Perhaps one reason content is not emphasized is that many preservice teachers did not learn much in their own science classes, and they assume the same will be true for their own students. One new teacher, in explaining why she emphasizes "fun" over science content, says, "I mean I kind of have in the back of my mind that they really, really are going to forget everything" (Trumbull, 1999, p.56). Some preservice teachers do not even acknowledge that a tension exists between making sure students enjoy their experiences and making sure they learn. In effect, they resolve the conflict by ignoring it (Anderson et al., 2000). For these preservice teachers, one would predict that learning would continue to take a backseat once they become practicing teachers. Therefore, it is critical that teacher educators provide opportunities to support preservice in learning to value their students' learning.

The literature suggests several possible reasons preservice teachers might emphasize interest over learning. One potential explanation is the influence of their own science experiences. Many preservice teachers emphasize the idea that they want their learners to have a very different experience in science courses than they had (Trumbull, 1999). Preservice teachers who report difficult or painful science experiences in their own histories want their students to *enjoy* science (Richmond, Howes, Kurth, & Hazelwood, 1998). Because they do not want their own students to be uninterested in science (as many of them were), they place importance on motivation.

Another possible explanation for focusing on student interest exists. Preservice teachers have a limited understanding of conceptions of learning, science content and inquiry concepts. Since they do not understand these crucial aspects of teaching science, they focus instead on what they feel they do understand – motivation. For example, in one study, preservice teachers frequently focused on motivation but rarely mentioned understanding as a goal for their teaching (Abell et al., 1998). The authors argue that because preservice teachers did not have rich knowledge of instructional strategies or conceptions of learning, their beliefs about effective teaching were based on keeping motivation high. Similarly, preservice teachers' lack of understanding about constructivist-oriented teaching methods can influence how certain activities are taught. Preservice teachers see "fun" or "hands-on" methods (such as scientific inquiry) as an engaging and exciting way to teach science without considering their impact on learning (Zembal-Saul et al., 2000). Unintentionally, then, constructivist teacher education programs could be promoting this focus on motivation by emphasizing active and fun

activities without helping preservice teachers understand the rationales for using these methods.

Preservice teachers struggle in dealing with students' ideas

A second challenge in developing PCK about learners is that "dealing with" learners' ideas, or having strategies to attend to them in instruction, is challenging for preservice teachers. In a summary of studies exploring teachers' pedagogical content knowledge of students' ideas, Magnusson and colleagues state that "[t]he pattern of findings from this type of study is that although teachers have some knowledge about students' difficulties, they commonly lack important knowledge necessary to help students overcome those difficulties" (Magnusson et al., 1999, p.106). Teachers, especially new and preservice teachers, struggle in knowing what to do with their learners' ideas. One reason teachers struggle with dealing with their students' ideas is their own weak subject matter knowledge (Ball & Bass, 2000; Carlsen, 1992; D. Smith & Neale, 1989). Smith and Neale (1989) conducted an extensive study of elementary teachers' subject matter knowledge and how it affects their teaching. Weak subject matter knowledge often prevented teachers from predicting students' ideas. However, even when they knew the scientific ideas, they did not address their students' ideas in their teaching. This study illustrates the importance of going beyond simply having teachers predict students' ideas. The next step - knowing how to use these ideas in instruction – is crucial in impacting teaching practice.

Not surprisingly, this issue is even more challenging for preservice teachers than for practicing teachers. While preservice elementary teachers have most of the obstacles practicing teachers have (such as inadequate subject matter knowledge in science), they

also have limited classroom experiences with children and teaching. Therefore, they are not initially very likely to effectively deal with students' ideas. Meyer (2004) found differences between how preservice and practicing teachers viewed students' ideas. Preservice teachers looked at knowledge as static, so they focused on finding out which bits students knew and did not know and then how to fill those gaps. Expert teachers were able to focus on their students rather than the instruction or the content knowledge; they also held a much more complex view of learning and brought that to their instructional decisions as well. Meyer suggests that teacher educators should provide more experiences that allow a more complex view of prior knowledge to develop and to look more closely at how the shift from novice to expert happens. This dissertation attempts to outline the very beginnings of that shift. A barrier to this development is the resilience of preservice teachers' own ideas about teaching.

Preservice teachers' ideas are resistant to change

Preservice teachers must integrate what they are learning in their university courses with those they are learning in classroom contexts. They must also reconcile those experiences with ideas about good teaching that are personally held beliefs. Constructivist teacher education programs cannot assume that preservice teachers will simply abandon their beliefs in lieu of those presented in methods courses (Feiman-Nemser, 2001; Richardson, 1996). In order for preservice teachers to develop a positive professional identity, there must be congruence between their own ideas about of effective teaching, their teacher education program's conceptualization of effective teaching, and their practicum context's support of their development (Anderson et al., 2000; Mahlios, 2002). Like children, then, preservice teachers' own ideas are resilient

and resistant to change. Preexisting beliefs and images play a central role in "filtering" the content of coursework done in the university setting. Often, these beliefs and images are inflexible. For professional growth to occur, prior beliefs and images must be modified and reconstructed. "It is a novice's growing knowledge of pupils that must be used to challenge, mitigate, and reconstruct prior beliefs and images. Whether a novice is able to accomplish this also appears to depend on the novice's biography" (Kagan, 1992, p.142). This growth of knowledge about one's students is critical for PCK development. The next section explores supports that facilitate preservice teachers in attending to their learners' ideas, and, perhaps, changing some of their own ideas.

Supports that Help Preservice Teachers Consider Learners' Ideas

The majority of the literature about preservice teachers discusses what they are unable to do. However, some literature suggests that preservice teachers, given some supports, are capable of meaningfully considering their learners' ideas, although they still struggle with using them effectively in their plans or teaching (Lemberger, Hewson, & Park, 1999; Mellado, 1998; Meyer et al., 1999; Tabachnick & Zeichner, 1999).

Related work has been done with *students'* learning. For example, in one study, young learners, given careful scaffolds, were able to think in quite complex ways that challenged many earlier ideas about capabilities of young students (Metz, 2000). Also, over time and with careful instruction, students can learn to deal with data in quite complex ways, such as identifying "good" data or learning to ask meaningful questions about a set of data (Lehrer & Schauble, 2002). In a similar way, some work has shown that preservice teachers can think carefully about their learners when given supports to do so.

Preservice and new teachers have a tendency to think first of themselves as teachers and not focus on their learners (Fuller, 1969; Fuller & Bown, 1975; LaBoskey, 1994). However, several studies paint a more positive picture. With support, preservice teachers can learn to consider their learners' ideas. One aspect of preservice teacher education that seems especially relevant in supporting their thinking about learners is the programmatic support of this idea in the teacher education program (Lemberger et al., 1999; Zembal-Saul et al., 2000). This can foster preservice teachers' careful consideration of learners more than is typical and in more complex ways over time.

Another form of support is providing more interactions with learners. A trajectory of preservice teachers' consideration for their students is described by Lederman and Gess-Newsome (1999). Seventeen preservice secondary science teachers were interviewed several times throughout their methods course. They seemed to be concerned about their students, but a more detailed analysis showed that the students were actually viewed as "adversaries" that might compromise the lesson. Six of these preservice teachers were followed into their student teaching, and a change occurred in the way they considered their students. "The overwhelming presence of 'real' students within the context of student teaching compels the student teacher to immediately and necessarily shift their concerns from self to students" (Lederman & Gess-Newsome, 1999, p.202). Interactions with "real" students force preservice teachers to consider, at least to some extent, how their lessons actually affect their learners.

Activities in methods courses and field placements can also foster a richer consideration of learners' ideas. Over time, preservice teachers can become more likely to think carefully about specific students' ideas and predict which ideas will be difficult

for teachers (van Driel et al., 2002). In planning, teaching, and reflecting cycles, preservice teachers become more focused on learners in later cycles, both in planning and enactment (Zembal-Saul et al., 2000). Seemingly, focused attention on students' ideas in both methods courses and field experiences can help preservice teachers learn to work with their students' ideas.

The field does not yet seem to know how to assess the influences on preservice teachers' development. This is made even more complicated by the fact that many of these studies take place while preservice teachers are simultaneously taking university coursework and working in the field, as is the case in this dissertation. Most of the work seems to credit experiences with children for fostering preservice teachers in considering learners more carefully (Bryan & Abell, 1999; Grossman, 1991; Lederman & Gess-Newsome, 1999), although much of this comes from teacher self-report. Interestingly, preservice teachers report that the field experiences were more influential than coursework, even though results of one study show development in ideas directly fostered in the university course (van Driel et al., 2002). Some work suggests that methods coursework plays an important role as well (Kettle & Sellars, 1996; Zembal-Saul et al., 2000).

Regardless of the program or supports, it seems that preservice teachers will struggle with learning about and dealing with learners' ideas in their teaching. However, these studies suggest that teacher education experiences can encourage preservice teachers to develop a more complex understanding of their learners. This study builds on this idea by exploring how activities, some of which are directly focused on learners'

ideas, might contribute to preservice teachers' developing PCK-readiness. Each of these activities is described and justified in Chapter 3.

Preservice Teachers' Learning Trajectories

Even though preservice teachers struggle with using learners' ideas in instruction, a *trajectory of considering learners' ideas* seems to emerge. Learning trajectories are helpful ways to consider *how* learning develops rather than simply seeing early and later snapshots. Some work has been done about learning trajectories of preservice teachers (Anderson et al., 2000). Other ways of measuring teachers' development of PCK and their learning trajectories is emerging (Briggs et al., 2007), including measuring how teachers structure activities with their learners in mind and how to use this knowledge flexibly. Early in preservice teacher education programs or courses, preservice teachers pay little attention to learners' ideas in word or deed (Lemberger et al., 1999). Their focus is elsewhere, usually on themselves or in caring for the general well-being of their students (Howes, 2002). Over time, however, they become somewhat more focused on their students' ideas and seemed to understand the importance of them. This includes thinking about learners when planning (Zembal-Saul et al., 2000), writing about their beliefs about teaching (Mellado, 1998), and using student learning as information for pedagogical decisions (Haney & McArthur, 2002). Even though attention to learners' ideas improves, preservice teachers are typically not well-equipped to handle them in their teaching (Meyer et al., 1999; Tabachnick & Zeichner, 1999). So while teacher education experiences can certainly help preservice teachers develop their understanding of the importance of students' ideas, learning to respond effectively to them presents a more difficult challenge. Although the literature emphasizes that preservice teachers

cannot use learners' ideas in their teaching, a more careful analysis of these studies shows a trajectory in which preservice teachers become able to consider learners' ideas in more complex ways over time. While it is doubtful that preservice teachers can consider learners' ideas in the ways practicing teachers can, this study attempts to describe the building blocks that might later develop into usable PCK related to learners' ideas.

Becoming a teacher is a gradual process. Early work (Berliner, 1986; Fuller, 1969) compared experts and novices or thought about teaching in terms of discrete steps. However, as the field learned more about the nature of learning and specifically learning to teach, the work of becoming an expert was seen as more fluid, as evidenced by ideas such as a "professional continuum" (Feiman-Nemser, 2001), "advanced beginner" (Berliner, 1988), or "well-started beginner" (Hollon et al., 1991). In fact, the space between beginner and expert is becoming a rich source of knowledge about how people become teachers. Specifically, we know that as teachers develop new ideas and practices, their trajectories are typically uneven and prone to "fits and starts" (Anderson et al., 2000; D. Smith & Neale, 1989). It is this "bumpy" space that I explore in this study.

Specifically, I explore how preservice teachers acquire and integrate knowledge of attending to their learners as they navigate the space of becoming a practicing teacher. This involves developing both an understanding about the characteristics of learners' science ideas and also an understanding of how to deal with those ideas in instruction. These two types of knowledge form the building blocks of PCK.

PCK-Readiness

In the field of science teacher education (and teacher education in general), there seems to be a consensus that *preservice* teachers are unlikely to develop pedagogical content knowledge because they do not have much real teaching experience. Even though teacher educators cannot easily provide more exposure to learners, I hypothesize that they can provide experiences that prepare preservice teachers to develop PCK. I think of this as PCK-readiness. The parallel is to "reading readiness." Kindergarten teachers spend most of their school year helping their students develop "reading readiness." This involves a set of skills that is necessary for students to develop before they can actually read (for a review, see Farr & Anastasiow, 1969). For example, students need to know how to hold a book, which direction to turn the pages, the letters of the alphabet and the sounds each makes, general components of stories, etc. None of these skills are technically "reading," but every reader has these skills.

Certainly, there are differences between knowing how to read and knowing how to teach. For one, once a young child knows how to read, that knowledge becomes usable (as any parent or teacher who sees that "aha" moment knows). However, having well-developed PCK does not necessarily guarantee that a teacher knows how to use it in the moment of teaching (Ball & Bass, 2000). So in a sense, there are actually three steps to rich, usable PCK: gaining "PCK-readiness," putting these pieces together to form well-developed PCK, and finally, being able to use that PCK in teaching.

From a knowledge integration perspective (Davis, 2004; Linn, Eylon, & Davis, 2004; Linn & Hsi, 2000), this means that teachers begin to add new ideas to their repertoire and begin to make some connections between ideas (such as learning about

common ideas learners have about a concept and thinking about how a representation might foster learning about that concept). Initially, this knowledge might be in pieces (diSessa, 1988), such as contradicting oneself depending on the context. This collection of ideas might be called PCK-readiness. Then, as PCK-readiness gradually becomes more well-developed PCK, teachers are able to make more connections between their ideas (for example, between their subject matter knowledge and their knowledge about learners' possible ideas) and identify weaknesses in their own knowledge. Finally, teachers are able to use this integrated PCK as they teach in the classroom; the knowledge is no longer inert but can be called upon when needed. While more work should be done following the example of Ball and Bass (2000) to unpack how PCK becomes usable knowledge for teaching, this study focuses earlier in the trajectory. I investigate what constitutes PCK-readiness and how a methods course can provide some of the building blocks to prepare preservice teachers to develop PCK.

There are many things a preservice teacher can know before she becomes a teacher or even has much experience with learners. Preservice teachers can learn about science content, how to represent content to learners, and common ideas their learners bring to science class. Even if she is not able to immediately integrate this knowledge into well-developed PCK, she will be armed with PCK-readiness as she adds ideas to her repertoire and makes some connections that will help her develop an understanding of her learners sooner and better. Even if this initial knowledge is in pieces, perhaps these pieces form necessary building blocks to well-developed PCK (and eventually, usable knowledge). My construct of PCK-readiness guides this study; an implication I take from most studies, even ones that show what preservice and new teachers can not do, is

how teacher educators can turn the experiences that preservice teachers do have into an opportunity to help preservice teachers develop PCK-readiness.

Chapter 3 presents the methodology of this study. This includes a description of how the course assignments and study were designed, using design-based research as a framework. The methods course and participants are described in depth, as are my methods of coding and data analysis.

CHAPTER 3

METHODS

This chapter describes the methodology used to collect and analyze data across the science methods course with regard to facilitating preservice teachers in considering learners' science ideas. The chapter opens with a study overview and brief discussion of design-based research and how this perspective informs the methodology of this study. Then, I describe the context for the study. A rationale and description for each data source and how they are organized and used in conjunction with each other is presented. Finally, I portray the coding scheme and method of analysis I used.

Study Overview

This is a descriptive study designed to portray how one class of preservice teachers made sense of the course activities. The design of the study is derived from this goal. The study follows a class of preservice teachers through a semester of elementary science methods. Two main research questions guide this work. The first set of questions is: How does preservice teachers' PCK-readiness develop over the course of a semester with respect to thinking about and using students' ideas? Specifically, what characterizes the development of understandings of learners among preservice teachers with different initial ideas? How does the preservice teachers' treatment of students' ideas change over the course of the semester?

In answering the first set of questions, I chose eight preservice teachers and

evaluated most of their coursework for the entire semester. In addition, I interviewed each of them at the beginning and end of the semester. Through analyzing this data, I hope to describe a trajectory of PCK-readiness in terms of their thinking about their learners' ideas.

The second set of research questions asks: How does preservice teachers' use of focused assignments on students' thinking (FAST activities) within the methods course support them in considering student ideas? More specifically, do different FAST activities foster different aspects of thinking about students' ideas? What kinds of thinking does the set of FAST activities as a whole support?

In answering these questions, the data was the class set of activities designed to scaffold preservice teachers' thinking about their learners' science ideas. These FAST activities highlight different aspects of learners' ideas, and they also engage the preservice teachers in a wide variety of tasks, from talking with children to reflecting on lessons to critiquing existing curricular materials. Through this set of activities, I hope to describe how each individual FAST activity and how the group of activities works to scaffold PCK-readiness of learners' ideas.

Design-based Research

Design-based research plays an important role in this study. While one primary goal of this work is to learn about preservice teachers' learning, another is to learn about how aspects of the methods course can foster and support that learning. Design-based research focuses on studying both the context and the learning that emerges from that context. It "focuses on understanding the messiness of real-world practice, with context being a core part of the story and not an extraneous variable to be trivialized" (Barab &

Squire, 2004, p. 3). There are only a few design-based studies involving preservice teachers, but methods courses are seen as an effective context for design-based research (Barab, Hay, Barnett, & Keating, 2000; Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003). In fact, an important implication of design-based research is using results to continually refine and guide instruction (Bell, Hoadley, & Linn, 2004).

Design-based research has several important features: it involves testing contexts while designing them, iterating through cycles of research and design, and developing and expanding theories in the field.

First, the context of the study is being tested while it is being continually designed and refined. "[D]esign experiments entail both 'engineering' particular forms of learning and systematically studying those forms of learning within the context defined by the means of supporting them" (Cobb et al., 2003, p. 9). This involves looking at individuals' learning while simultaneously looking at the effectiveness of the tools used to support that learning (Shavelson, Phillips, Towne, & Feuer, 2003). In this study, preservice teachers' learning is evaluated based on their use of the activities in the course (in answering the first research question having to do with preservice teachers' learning trajectories). Meanwhile, the effectiveness of the activities themselves is being evaluated as well (in answering the second research question having to do with how the FAST activities foster the development of PCK).

Second, design-based research involves iterative cycles of the contexts or interventions; as more is learned about what people learn from the contexts, the contexts are modified and studied again. In this study, only one full round of data collection and analysis was done. However, the methods class studied here has been the subject of

design-based research over the course of several years (e.g., Davis, 2006b; Davis & Petish, 2005; Smithey & Davis, 2002). During previous years and pilot testing, each data source has been used and modified where appropriate at least once. In turn, this study contributes to future modifications to the course and its assignments that will continue to be studied.

Finally, design-based research is done in an effort to add to the existing theories of learning. A design-based study should go beyond creating an effective environment in order to make assertions about how people learn (Barab & Squire, 2004; Bell et al., 2004). Developing these theories is important so that the field can develop a common language for communicating with one another, even when studies have different contexts or specific elements (Design-Based Research Collective, 2003; diSessa & Cobb, 2004). In this study, I hope to contribute to the field by creating links between particular activities and preservice teachers' consideration of their learners' ideas and by describing the trajectory of how that thinking develops over time. I also anticipate that the addition of the construct of PCK-readiness can add to the shared language in which the field describes preservice teacher learning.

The next section describes the context in which the study took place: the elementary science methods course.

The Elementary Science Methods Course

This study took place during the third semester of an undergraduate teacher preparation program. The four semester program emphasizes inquiry-oriented teaching consonant with recommendations of teacher education reform calls (e.g., INTASC, 1992) and subject-matter standards documents (e.g., AAAS 1993; NCTM, 1991; NRC, 1996).

During the first semester of the program, prospective teachers were expected to investigate the learning of a single student. In addition, their educational psychology course focused on the psychological foundations underlying student learning. The overarching emphasis during this first semester was on learners and learning. Students' ideas are also relevant (though not an explicit focus) during the second semester courses as well. Therefore, the preservice teachers should enter the semester with reasonably complex ideas about the importance of learners' ideas.

I was the instructor for the elementary science methods course and performed the interviews for the focus preservice teachers as well (Luft, Bragg, & Peters, 1999). This course took place during the preservice teachers' last semester before their student teaching experiences (for most preservice teachers). The course met once per week for three hours. The three main goals for the course were to foster preservice teachers in learning more about inquiry-oriented science instruction, learning to critique and adapt instructional materials, and learning how to find out and use students' ideas in their science instruction. The third goal is the main area of focus for this study.

There were two required books for the course: Teaching Science in Elementary and Middle School Classrooms: A Project-Based Approach (Krajcik, Czerniak, & Berger, 2003) and Inquiry and the National Science Education Standards (National Research Council, 2000) in addition to several other supplementary readings. Both of the textbooks advocate inquiry-oriented teaching and considering learners' ideas in teaching science. Coursework included completing weekly journals, teaching and reflecting on two science lessons, interviewing a student, and constructing a 4-6 week science unit, usually focused on weather-related concepts.

One important aspect of the course was the preservice teachers' use of CASES, an online learning environment (Davis, Smithey, & Petish, 2004, see http://cases.soe.umich.edu). CASES includes educative curriculum materials, private reflective journals, an online discussion space, and teaching resources. The CASES environment was designed to be aligned with the methods course; the curriculum materials have sections, such as driving questions, that the course emphasized and the preservice teachers included in their own units. The preservice teachers used CASES to reflect in their weekly journals, participated in online discussions, completed course assignments (such as reading and reflecting on an image of inquiry, described later in this chapter), and perused the curriculum materials for ideas for their own unit. This learning environment was also available to them during their student teaching semester and into their first years of teaching.

Participants

The participants in this study were the preservice teachers in my course who gave permission for me to use their work for research purposes (20 of 21 students). They were all traditional college-age students, 15 were white, and all but one were female. In addition, the entire class with one exception was a cohort; they took all of their education courses as a group for three semesters, so they knew each other well. Eight were selected to be focus preservice teachers; they participated in two interviews and I analyzed more of their coursework.

While the research reviewed in the previous chapter indicates that patterns certainly exist for preservice teachers, it is important to remember that preservice teachers, like children, are a diverse set of learners. They bring a variety of school

experiences, beliefs, field placements, and ideas to their teacher education experience. All of these affect how they think about and attend to their learners (Lortie, 1975; Richardson, 1996). For example, Zembal-Saul and colleagues (2002) found a wide range in student teachers' treatments of students' ideas. By choosing to focus on diverse cases, a richer picture of preservice teacher learning emerges. The process of choosing those cases is described in the next section.

Selecting Focus Preservice Teachers

I selected focus preservice teachers who at least initially thought about students' ideas differently, yet were somewhat representative of their peers. Eight preservice teachers were selected through purposeful sampling (Lincoln & Guba, 1985). On the first day of class, everyone was asked to complete a pretest in which they proposed changes to a lesson plan and gave rationales for those changes; this pretest is described later in this chapter. The pretests of everyone who agreed to participate in research were coded to see the range of preservice teachers' initial ideas about their learners, and eight that represent that range were selected to follow more closely throughout the semester. These eight focus participants were interviewed twice during the semester, and all applicable coursework was analyzed.

I selected my participants in this way for two reasons. First, much of the science teacher education literature is devoted to carefully studying a few individuals. Often, these participants are science enthusiasts (Luft et al., 1999; Powell, 1997) or are enthusiastic about improving their teaching; usually, the amount of effort required to participate in a study strongly influences who volunteers. My study only required participants to volunteer for two interviews, and no one I asked refused to participate.

Being able to select preservice teachers who represent a range of initial ideas allowed for a somewhat more representative sample (of a class, at least) than is typical.

The second reason for choosing a range of preservice teachers was to see how different "starting points" influenced the development of ideas over the course of the semester. Preservice teachers' initial ideas create different learning trajectories that lead to diverse beliefs and practice, even with the same teacher education experiences (Anderson et al., 2000). Constructivist learning theory holds that each individual constructs his or her own understandings based on existing ideas and experiences. Selecting a group of focus preservice teachers with different initial ideas provided a richer picture of how their ideas change over time and how different activities might support that development.

After reading the pretests, each preservice teacher was grouped into one of 4 general categories: relatively sophisticated thinking about students' ideas, more naïve thinking about students' ideas, interesting thinking about students' ideas, and those whom I knew I did not want to follow (because of very busy schedules, family circumstances, or not being a part of the cohort). I chose three people each from the sophisticated and naïve categories and two from the interesting category for a total of eight.

Riley, Amber, and Aruna were all selected because their initial ideas were somewhat sophisticated. For example, Amber wrote that lesson planning would be simple but learning lower if students' ideas were not taken into account, and she said that this was especially true for students who struggle the most. Beth, Kate and Katya were selected as showing some naïve ideas about students' science ideas. Beth wrote about giving students the correct answer in order to "get rid" of their misconceptions, although

she did encourage students to test their ideas. Kate initially wrote that an experiment would "for sure" clear up students' misconceptions and Katya's only suggestion was to tell students the correct answer. Interestingly, both of these ideas were cornerstones for growth over the semester for Kate and Katya. Wanda and Lara were both selected because of an interesting response in their pretest. Wanda wrote about a duality students might have if ideas were not addressed by the teacher; they might say one thing in school and really believe another. Lara made creative changes to the lesson plan that differed from her peers and her reason for changing a lesson was to increase student interest. Even though the selections were made based on a single data source, a wide range of ideas was represented, as the results presented in Chapter 4 illustrate.

Riley and Katya were partners in a first grade classroom. Aruna worked in a sixth grade classroom and Amber worked in a third grade room; by the end of the semester, neither planned on pursuing full time teaching as a career. Beth worked in a third grade classroom in which she planned to student teach. Wanda worked without a partner in a second grade classroom. Kate worked in first grade, and Lara worked in fourth grade; both planned on postponing student teaching for a year to finish university coursework. More complete profiles of all eight focus preservice teachers are presented in Chapter 4.

Data Sources: FAST Activities

Many of the course assignments served as data sources for this study, especially in following the eight focus preservice teachers. However, several were specifically designed to help preservice teachers consider learners' ideas. These Focused Assignments on Students' Thinking (FAST) are the focus of the second set of research questions. These assignments were analyzed for all 20 preservice teachers to see what

aspects of thinking about learners they seemed to foster. These FAST activities include focused discussions, teaching and reflecting on that teaching, a content conversation with a student, responding to an "image of inquiry", and critiquing instructional materials. The rationale, importance, and description of each FAST activity is discussed below.

Peer discussions

Conversations, both in person and online, provide opportunities outside of class for preservice teachers to discuss ideas with one another. Community plays a critical role in teacher identity development. Preservice teachers who are placed in a cohort show high levels of group participation and collaboration and are comfortable taking risks with one another (Beck & Kosnik, 2001). Therefore, social supports for preservice teachers (especially those in a cohorted program) have a strong potential for fostering change. Social supports are an essential component of teacher learning (Putnam & Borko, 2000). Teacher communities provide opportunities for intellectual and expertise development (Grossman, Wineburg, & Woolworth, 2001) as well as identity development. In online discussion, when preservice teachers are given the freedom to initiate their own topics, they tend to discuss aspects of teaching (though not necessarily science teaching) related to their professional identities (Smithey & Davis, 2004b). However, when carefully scaffolded, preservice teachers can also thoughtfully consider ideas from their courses (Mitchell, 2003; Smithey & Davis, 2004b). In addition, online discussions allow preservice teachers to learn from one another, both in terms of participating in a community with distributed expertise (Smithey & Davis, 2002) and learning from others who have a deeper understanding of an idea as well as from the multiple perspectives presented by peers (Harrington & Hathaway, 1994). In person discussions, when

scaffolded, can have similar benefits; the community plays a critical role in helping practicing teachers construct their own ideas (Grossman et al., 2001) and the same is presumably true for preservice teachers, especially those in a cohort.

Preservice teachers participated in weekly online discussions in response to instructor and peer initiated threads. For this study, one instructor-initiated thread (focused on attending to learners' idea and content goals) was to be analyzed. However, over the course of the semester, the preservice teachers did not seem engaged in participating in the online discussions. After a class discussion initiated by the preservice teachers, I decided to offer an option; this falls in line with design-based research, where the context changes as needed while research is ongoing within that context. I provided a prompt related to learners' ideas. Preservice teachers could choose whether to participate in the discussion online or in a group of their peers. Those who chose to engage in a peer discussion were responsible for writing a summary and reflection of that conversation. Since all but two preservice teachers opted for the peer discussion, no online discussion posts were analyzed. This decision is discussed more in Chapter 5. See Appendix A for an instructor initiated online discussion thread starter pertaining to learners' ideas and the parallel peer discussion prompt and directions

Reflective Teaching

Preservice teachers typically do not often have opportunities to teach and reflect on that teaching. In many methods courses, they are only able to do so a few times. However, by providing a framework for planning, enacting, and reflecting, preservice teachers can develop their PCK, especially when given multiple opportunities to do so (Zembal-Saul et al., 2000). In Zembal-Saul and colleagues' study, preservice teachers

spent time planning lessons, enacting them, and reflecting on them afterwards. In the second cycle, the authors found that the preservice teachers had more complex and accurate representations, so seeing growth in even this short amount of time is feasible.

The reflective teaching FAST activity is informed by the one in Zembal-Saul's work. Twice during the semester, preservice teachers taught a science lesson in their placements. After doing this, they turned in a lesson plan and a journal entry reflecting on their teaching; the lesson plans were typically done in pairs and the journal entries were individually completed. One section of the lesson plans asks preservice teachers to predict ideas their learners will have, but the plans were not coded because the only evidence related to learners' ideas was a list of predicted ideas in response to the lesson plan template. In their reflections, which were coded, preservice teachers were asked specifically about their students' ideas during the lesson. See Appendix B for the instructions given to preservice teachers for this assignment.

Content Conversation Reflection

Interviewing students about science content is not an uncommon practice in methods courses. Smith (1999) advocates that these experiences with learners are crucial for preservice teachers. "Reading articles that describe research on children's thinking about how plants get their food is interesting. Having real children describe in their own words that 'trees have long branches that touch the ground so that they can get the food from the soil' is much more compelling" (p. 182). According to Smith, these experiences develop three types of PCK. First, preservice teachers learn that children have alternative conceptions and that these are important to know, including developmental differences about specific science concepts. Second, they begin to realize that they need the ability

to generate good questions that can be used to find out what children are thinking, so that they can plan lessons to address those ideas. Finally, preservice teachers learn about particular tasks and materials that provoke and reveal children's thinking about the topic.

Once during the methods course, preservice teachers each interviewed one child about their understanding of the science concepts they planned on including in their units. After this interview, they reflected on the experience, including describing their learners' science ideas and how they planned on using this information as they plan their unit. This activity had a very strong focus on learners' ideas, both in terms of eliciting and reporting on those ideas and thinking about how to deal with these in instruction. See Appendix C for guidelines for preservice teachers' reflections on these conversations.

Images of Inquiry Reflection

The "images of inquiry" described in this study are developed by the CASES research team (Davis & Krajcik, 2005; Davis et al., 2004; Smithey & Davis, 2004a). Even though the narrative vignettes included in the images are not cases, many of the considerations for using them with preservice teachers are similar. Both exemplary and dilemma-based cases can make salient certain aspects of teaching for preservice teachers (Merseth, 1996), and the images of inquiry include components of each. Typically, cases provide teachers with authentic situations that are complex in some ways and simple in others. Asking preservice teachers to consider the choices that another teacher made can foster a strong image of themselves as teachers of science (Abell et al., 1998). Another way to learn about preservice teachers' thinking is to explore the rationales they give for their decisions or opinions. This can reveal what preservice teachers value and rely on when thinking about their teaching (Jones & Vesilind, 1996) and show how these

influence identity development (Anderson et al., 2000; Smithey & Davis, 2004a). Preservice teachers were asked to consider the choices around learners' ideas made by the image teachers and to think about what they would do in similar circumstances.

Within the CASES website, preservice teachers read about how fictional "image teachers" teach particular lessons (see Figure 3.1). For each image teacher, preservice teachers can read about the experience level, grade level, and unit the teacher is teaching. In addition, each image teacher has an area of emphasis, such as attending to learners' ideas, establishing a culture of inquiry, or promoting inquiry in a culture of high stakes testing. Twice during the semester, preservice teachers read vignettes of how different teachers modified and taught lessons on the CASES website.

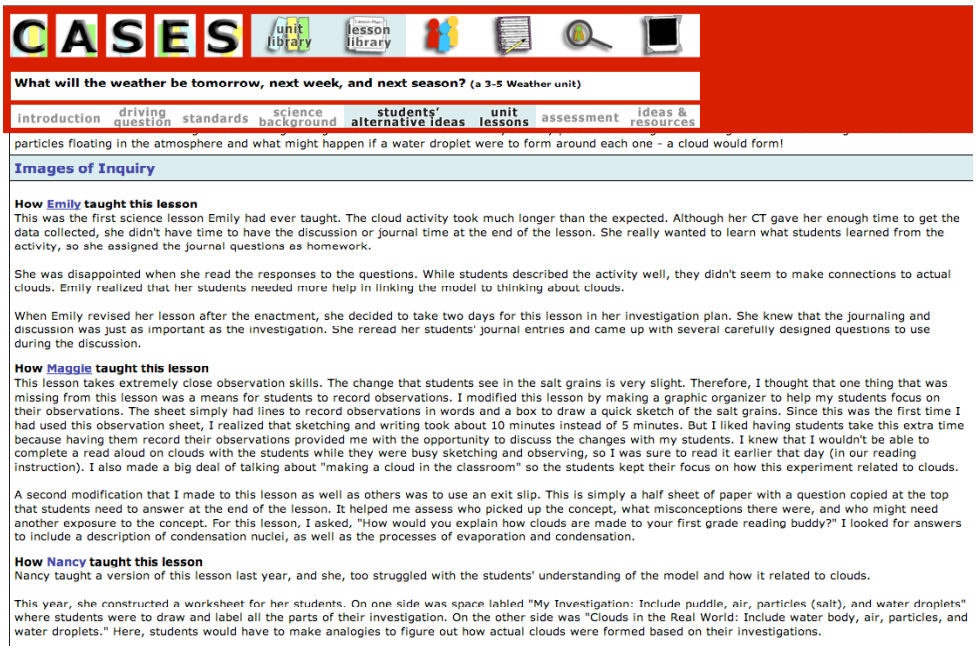

Figure 3.1: Images of Inquiry from CASES website

During the first Images of Inquiry assignment, they read about Nancy and Emily, image teachers whose focus is learners' ideas. The preservice teachers responded in their journals to questions about these images. In the second assignment, preservice teachers

chose the image teacher they wanted to read about and respond to. Most of the preservice teachers did not focus on learners' ideas, although they had the option to do so. Appendix D contains the guidelines for the preservice teachers' reflections for both images of inquiry assignments.

Lesson Critique

Asking preservice teachers to critique and refine existing curricular materials is likely a less common activity within methods courses (Schwarz et al., in press). However, by asking preservice teachers to analyze and revise existing activities and lessons, preservice teachers can develop skills that every teacher needs. In addition, these scaffolded assignments can support preservice teachers in making substantive changes to typical lessons (Davis, 2006b). In this study, the critique assignments include a focus on helping preservice teachers consider their learners' prior knowledge and alternative conceptions as they revise the lessons.

Twice during the semester, pairs of preservice teachers critiqued and refined a lesson given to them. The first time (critique #1), they evaluated it based on criteria they generated. The second time (critique #2), they did so using one of six class criteria generated by the instructor based on the class set and on instructor goals (one of which included attention to student ideas). This activity did not force preservice teachers to focus on learners' ideas other than generating a criterion related to it, but analysis included both the criteria and critiques that dealt with learners' ideas. See Appendix E for each assignment.

Data Sources: Other Assignments

The assignments presented in this section are the additional assignments in the course that were not FAST activities. However, they played an important role in the course and shed light on preservice teachers' PCK development, so they were analyzed in answering the first research set of research questions, where I focused on eight preservice teachers and looked at a larger sample of their coursework.

Weekly journals

Reflection is an important part of becoming a teacher (Davis, 2006a; Hatton & Smith, 1995). Each week, preservice teachers reflected in their journals. Some reflections were in response to assignments (such as an image of inquiry or reflective teaching, discussed above). The others were not guided and typically involved reflecting on some aspect of their placement. These journals were unprompted, so preservice teachers were not guided to focus on students' ideas. The instances where preservice teachers discussed their learners in any way were coded and analyzed.

Pre/Post Test

Asking preservice teachers to critique science lessons allows teacher educators insight into how they are thinking about their learners (Davis, 2006b), as described above. At the beginning and end of the semester, the preservice teachers evaluated a lesson plan, made modifications to it, and answered questions about students' ideas about the concept and how to deal with them in instruction. The lessons and questions were identical at the beginning and end of the semester. The science concept (light and color) was not a focus of the class or of units the preservice teachers created, so there should not have been a change in subject matter knowledge from pre to post. Some questions in this

activity were designed to focus directly on learners' ideas. See Appendix F for the assignment.

Interviews

Written work alone might not provide preservice teachers with adequate opportunities to express their ideas. In many of the assignments described above, preservice teachers could very reasonably focus on aspects of science teaching other than their students' ideas. Therefore, in order to more directly probe their thinking about this topic, an interview was conducted with each of the eight focus preservice teachers at the beginning and end of the semester. This is the only data source that was not a course assignment. The purpose of the interview was to learn more about their current understanding of the characteristics and importance of students' ideas. During the interview, I asked each preservice teacher general questions about learners' ideas, such as how a teacher might find them out and why it is important to do so while teaching science. I also asked about the aspects of attending to learners' ideas that the preservice teachers felt were confusing, overwhelming, or difficult to attend to as a new teacher. Finally, in the second interview, I asked each preservice teacher about changes she noticed between her pre and post tests and about what she learned from the semester regarding learners' ideas. This provided the opportunity to have conversations directly related to the aspects of learners' ideas in which I was most interested. See Appendix G for the interview protocol.

Surveys

At the beginning of the semester, each preservice teacher was given a survey that asked him or her about their interest and knowledge in teaching different aspects of

elementary science. In addition, they were asked to provide one word that best described their science knowledge and science teaching. The survey was not designed for this study, but their self-descriptions and reports of knowledge were informative. However, it is important to note that preservice teachers' self-reports should not be taken as necessarily accurate reports of their subject matter knowledge.

Unit Plan

An additional assignment was not used as a data source but was frequently referenced by the preservice teachers. Each pair of preservice teachers created a 4-6 week science unit, which included is a five-day investigation plan and a list of likely alternative ideas. Like the reflective teaching lessons, there is little to analyze in these units other than a list of ideas. There was not a forum for preservice teachers to reflect on how and why they thought about learners' ideas in the unit per se, so these were not analyzed. The more substantive thinking about students' ideas takes place in other assignments done in preparation for the unit (such as the content conversation).

Data Management

In order to help the reader better make sense of the different data sources, Tables 3.1 and 3.2 show them grouped by different criteria. Table 3.1 illustrates how each data source was used to answer the research questions of this study. Table 3.2 presents a schedule of data collection over the course of the semester.

In Table 3.1, the data are categorized in terms of research question. Since one research question deals with changes in preservice teachers' understanding and use of students' ideas over the whole semester, the primary data sources occurred either over the entire semester or at the beginning and end of the semester. However, all data sources

were used in answering this research question. For example, even though those sources that occurred multiple times might establish a trend, other sources, such as the content conversation, were coded to analyze if this trend was supported in the other work the focus preservice teachers did during the semester. The second research question investigates the influence of the FAST activities in fostering PCK development. The data sources for this question are the FAST activities. The reflective teaching assignment is included as primary data in both groups because it can show how preservice teachers' thinking changes from the first enactment to the second. The act of planning, teaching, and reflecting can serve to foster richer and more complex considerations of learners (Zembal-Saul et al., 2000).

Table 3.1: Data sources and Research Questions

Research Questions	Description	Data Sources
Description of change over time	Describes focus preservice teachers' thinking about learners' ideas and how this knowledge develops over the course of the semester	Pre/Post test Interviews Journals Reflective Teaching All other FAST activities
Support of FAST activities	Highlights the thinking about learners' ideas that results from doing these activities.	FAST Activities: Content conversation reflection Image of Inquiry reflection Peer discussion Critique activities Reflective Teaching

Table 3.2 illustrates when different data sources were collected. Unless otherwise noted, all assignments were done outside of class time. Also, even though 6 journal entries are listed, the preservice teachers were given two "free passes" on their journal assignments to be used whenever they wish. Therefore, most preservice teachers only complete 4 unguided journal entries during the semester.

Table 3.2: Data Collection Schedule

Week	Data Source
1	Pretest (in class)
2	Journal Interview #1 (focus preservice teachers)
3	Journal
4	Image of Inquiry reflection #1
5	Critique #1 (in class) Content conversation reflection
6	Journal
7	Journal
8	Reflective Teaching #1
9	Critique #2 (in class)
10	Journal Images of Inquiry reflection #2
11	Reflective Teaching #2 Peer discussions
12	Post test (in class) Journal
13	Interview #2 (focus preservice teachers)

Data Coding

Using diverse data sources provided a rich and varied picture of preservice teachers' thinking. However, in order to use these together to form a coherent picture of their development, the coding scheme must find similar kinds of thinking in different kinds of data. Therefore, the same coding scheme was used for each data source. This allowed for comparisons across time and activity. Each data source was coded twice: once to capture *how much* the preservice teacher is considering learners' ideas, and once to capture *what* she thinks about those ideas.

Amount of focus on learners' ideas

Table 3.3 outlines the first round of coding. The purpose of this scheme was to capture when preservice teachers mention students' ideas in any way. Each piece of data

received a code that describes how much the preservice teacher focused on students' ideas.

Table 3.3: Amount of Focus on Learners' Ideas

Code	Criteria	Example
0	No mention of students' ideas	Journal entry that never mentions students' ideas
1	Cursory mention of student ideas but no discussion. Not a focus of the data source.	Journal entry about enacted lesson that mentions that one group had trouble with a concept.
2	Mention and discussion or reflection about student ideas. Not a focus of the data source.	Journal entry about enacted lesson with a discussion about one group of students who had trouble understanding the concept being taught.
3	Discuss student ideas as the focus of the data source.	Entire journal entry about a group of students who had trouble understanding a particular concept.

Description of Mentions of Students' Ideas

After each data source was coded for amount of focus on students' ideas, I then analyzed *what* they said when they mentioned students' ideas. This round of coding applied to all data sources that scored a 1, 2, or 3. Tables 3.4, 3.5, and 3.6 outline all the categories of this coding scheme, including two examples that illustrate the possible range of responses.

This coding scheme is designed to capture three types of thinking about learners. Recall that Smith (1999) asserted that knowing about the characteristics of learners' ideas and ways of dealing with those ideas are important aspects of preservice teachers' PCK. Chapter 2 highlighted the importance of each of these aspects for PCK development. The two concepts of characteristics of learners' ideas (see Table 3.4) and how to deal with those ideas (see Table 3.5) organize the coding scheme. A third category of students' ideas about scientific inquiry was also included initially but did not emerge as salient in any of the data so it is not described here. Finally, an "other" category was included to

capture additional aspects of learners' ideas not otherwise included in the coding scheme (see Table 3.6). Each of these sections of the coding scheme is described in more detail next.

First, I wanted to know what preservice teachers thought about the *characteristics* of students' ideas (Table 3.4). Often, preservice teachers have naïve ideas about the ideas of their students, such as that young children have no ideas about a topic or that scientifically non-normative ideas are easily "replaced" with correct ideas (Meyer et al., 1999). They may also have trouble anticipating what students' ideas will be (D. Smith & Neale, 1989). However, these ideas can develop into more complex thinking, like considering which ideas might be difficult for students to learn or being able to anticipate what ideas students might have about a concept (van Driel et al., 2002). This round of coding captures what preservice teachers think about the characteristics of students' ideas, regardless or how naïve or sophisticated those ideas are.

Table 3.4: Characteristics of Learners' Ideas

Code	Description	Example
Anticipating idea	Anticipates specific ideas that students could have about a particular topic or concept.	-Some of my students will probably think that clouds are really made of cotton. -My students don't have any prior knowledge about clouds
Describing idea	Describes what a student said or wrote about a particular topic	-Today, Sam said that clouds were made of cotton. -Juan told me he didn't understand why it rained.
Identifying important factors that contribute to idea	Identifies factors that influence or contribute to student's idea (developmental, previous experience or instruction, etc.)	-This idea is too hard for third graders because they're too young. -They understand the water cycle because they learned it two years ago.
Characterizing difficulty of idea	Characterizes difficulty students have (either though predicting or reflecting) with particular science concept	-Learning about cloud formation was harder for my students than I thought it would be. -Evaporation seems self-explanatory, so I don't think it will be hard for them.
Characterizing resilience of idea	Characterizes difficulty of changing the idea	-After the lesson, the students will understand this concept. -I know I'll have to pay attention because students are really convinced that condensation happens from holes in the glass.
Discussing importance of ideas	Discusses why attending to ideas is or is not important	-I need to know what my students think about weather so I will know where to start my unit. -I would get rid of this part of the lesson plan because it has to do with their prior knowledge.

The second category of codes captures preservice teachers' thinking about *how to deal with* these ideas in their science instruction (Table 3.5). Knowing how to address learners' ideas is difficult for preservice teachers (D. Smith & Neale, 1989; van Driel et al., 2002). Because preservice teachers often have naïve or static views of knowledge, their view of dealing with ideas may consist of finding out what students know and filling in content gaps (Meyer, 2004). This category of coding captures how preservice teachers think about finding out those ideas and how to deal with them before, during and after instruction.

Table 3.5: How to Deal with Learners' Ideas

Code	Description	Example
Finding out ideas	Reports or discusses ways to learn what students think about a concept	-Interviewing students isn't feasible for real teachers -I'll ask them to raise their hands if they don't understand.
Planning for instruction	Mentions students' ideas in preparation for teaching or planning the unit	-I know this will be easy for them, so I won't spend much time on this part -I plan to do a KWL to find out what they think about clouds before I teach the first lesson.
Making real-time decisions during instruction	Reflects on decisions made during instruction involving learners' ideas	-I could tell that they were confused by the activity, so I just decided to tell them the answer. -Amy convinced her group of a wrong idea, so I sat down with them and asked them questions until they changed their minds.
Making decisions based on instruction	Decides to take action (in unit or future lessons) based on instruction.	-I decided to take another day on this concept because most students didn't understand the lesson today -When I do my unit, I'll make sure to focus on why the investigation worked because no one seemed to understand after my lesson today.

Finally, an additional set of codes captures *other* ways in which preservice teachers consider their learners (Table 3.6). Often, preservice teachers are focused on engagement or management (Bryan & Abell, 1999) rather than their students' learning. Capturing when this takes place is important to begin to trace how careful consideration of learners can emerge from typical struggles of being a preservice teacher.

Table 3.6: Other Categories about Learners' Ideas

Code	Description	Example
Interest/Engagement	Students should be interested or physically engaged in the task (*not* intellectual engagement)	-I think this is a good lesson because the students will enjoy it. -I think students learn science better when they are motivated by finding out answers to questions.
Management	Discusses management decisions or their impact on student learning	-The students didn't understand because they weren't on task. -This time, I planned better for management, so I was able to listen to my students better.
Other	Discusses some other aspect of students' ideas.	

Data Analysis

Two types of analysis were performed for this study. For both types, I asked a colleague to code at least 10% of my data after a discussion of my coding scheme. Initially, inter-rater reliability was at 88% after the initial coding, but after a brief discussion of the discrepancies, 100% agreement was easily reached. In answering the first set of research questions, I used data from eight focus preservice teachers. Recall that eight preservice teachers were selected during the first week of the course based on their responses to the pretest. The goal was to select preservice teachers who were somewhat representative but who represented a range of ideas.

The analysis performed to answer the second set of research questions included work from all preservice teachers in the course who gave permission (including the eight focus preservice teachers). The second research question of this study asks about the influence of focused assignments on students' thinking (FAST activities). These assignments were designed to support preservice teachers in considering their learners' science ideas. Using the entire class provided a greater range of responses and a richer description of the range of thinking that occurs when using these supports or doing these activities.

Data Analysis for Research Question 1

My first research question asks: How does preservice teachers' PCK-readiness develop over the course of a semester with respect to thinking about and using students' ideas? In order to answer this, I identified patterns in both rounds of coding related to characteristics of students' science ideas and how to deal with students' science ideas. This involved answering the following subquestions: How do preservice teachers with

different initial ideas develop their understandings of learners? How does the preservice teachers' treatment of students' ideas change over the course of the semester?

In an effort to begin to describe a trajectory of considering learners' ideas, I initially looked at the eight focus preservice teachers' responses to the pre and post tests and corresponding interviews given at the beginning and end of the semester. Since these tasks were identical, changes that occurred over the semester emerged in differences in their responses at the beginning and end of class. These were the initial pieces of evidence for describing the major changes that took place during the semester. The other data sources were used to supplement (or refute) initial findings.

I also looked at other course assignments that occurred more than once for evidence of growth between these activities. Initially, I suspected that these would be secondary data sources to the pre/post tests and interviews, but it turned out they were equally important in establishing preservice teachers' trajectories. For example, both Riley and Katya had an important event emerge in their first reflective teaching that changed their trajectory (see Chapter 4). Looking for evidence of change over time across the entire semester and within the semester allowed me to answer my research question and describe the trajectory of each of the eight preservice teachers' development in thinking about their learners. Finally, I also analyzed each individual's other class work to see what other kinds of changes might emerge or support trends identified by other data sources. For example, unstructured journal entries often played an important role in highlighting a particular line of thinking that emerged in other data.

Themes were identified by analyzing all data sources for each preservice teacher and seeing if specific codes pervaded work throughout the entire semester or became integral to a preservice teachers' thinking at some point in the semester.

Data Analysis for Research Question 2

My second research question asks: How does preservice teachers' use of focused assignments on students' thinking (FAST activities) within the methods course support them in considering student ideas? More specifically, do different FAST activities foster different aspects of thinking about students' ideas? What kinds of thinking does the set of FAST activities as a whole support? Through coding and analyzing each FAST activity, I evaluated which types of knowledge were fostered during these activities. For example, the content conversation was designed to foster preservice teachers' anticipation of their students' ideas and their thinking about attending to these ideas as they plan their unit. In fact, those concepts did emerge as salient in the coding of these data sources (see Chapter 5). Identifying specific aspects of thinking each activity fostered allowed me to discuss the impact these activities had on preservice teachers' thinking about their learners' ideas and on their development of PCK in relation to their learners. I also looked at the set of FAST activities as a whole to evaluate which types of thinking the course fostered and which types were not supported. For example, even though the importance of learners' ideas was intended to be an area of emphasis in the course, none of the FAST activities supported preservice teachers in considering this concept. By looking beyond individual activities, I was able to make claims about the course in general rather than each specific assignment. Perhaps, these findings will be more useful to readers not particularly

interested in the specific assignments in this course but in preservice science teacher education in general.

Developing Assertions

Once I identified themes and patterns in the data, I developed initial assertions based on the data for each research question. In order to test these assertions, I searched for disconfirming evidence (Erickson, 1986). Even though some data might support an assertion, it is important to look to see if there is data that contradicts the assertion. This was particularly important because of the varied types of data sources in this study. Second, when possible, I triangulated data sources in order to support my assertions. For the first research question, where I described preservice teachers' trajectories over time, I had many data sources to triangulate my findings and lend further support to my assertions. As each theme developed, I attempted to highlight these themes as they developed across multiple data sources (in the first research question) or across a group of individuals (in the second). Triangulation took a different form in answering the second research question, where I evaluated the influence of the FAST activities. In some cases, the work the preservice teacher did in completing a particular FAST assignment was the only data source. For example, preservice teachers were not required to reflect about their content conversation, refer to it in later work, or be interviewed about it. Any assertions I made about the role of content conversations in fostering preservice teachers' thinking about their learners were limited by this. However, even though there were not multiple types of data with which to triangulate, I had an entire class set of data, so I considered an assertion valid if it emerged among a group of preservice teachers in any given FAST activity.

Summary

This chapter described the methodological approaches used to guide the data collection and analysis for this study. The methods used to answer each set of research questions differs somewhat. In answering the first set of research questions, I selected eight preservice teachers and coded and analyzed a majority of their coursework and interviews. Themes emerged and assertions were developed from these data in order to describe their trajectory of considering learners' ideas across the semester. Each preservice teacher's trajectory is described in Chapter 4.

For the second set of research questions, I looked at a group of assignments designed to foster consideration of learners' ideas. Through analyzing all preservice teachers' work, I illustrated the type of thinking about learners' ideas that each FAST activity seemed to foster. In addition, I looked at these activities as a whole to see what kinds of thinking they did and did not support. Detailed results from each FAST activity and a discussion about the constellation of activities are presented in Chapter 5.

CHAPTER 4

PRESERVICE TEACHERS' TRAJECTORIES

This chapter describes the trajectories of eight focus preservice teachers over the course of the semester. I answer the following research questions: How does preservice teachers' PCK-readiness develop over the course of a semester with respect to thinking about and using students' ideas? Specifically, what characterizes the development of understandings of learners among preservice teachers with different initial ideas? How does the preservice teachers' treatment of students' ideas change over the course of the semester?

Eight preservice teachers were selected at the beginning of the semester (see Chapter 3 for more about the selection process). These "focus preservice teachers" were interviewed at the beginning and end of the semester regarding their ideas about attending to their learners (see Appendix G for the interview protocol). In addition, all applicable coursework was evaluated in terms of their consideration of learners' ideas. These data were used to describe individual trajectories over the course of the semester for each focus preservice teacher. These trajectories are presented and discussed in this chapter.

Summary of Results

One of the goals of this study was to choose focus preservice teachers with different initial ideas about learners in order to show a range of thinking. In fact, the

trajectories presented here are somewhat diverse, although there were some commonalities as well; most move preservice teachers towards PCK-readiness, though in different ways. I describe five different trajectories in the chapter and introduce each below.

The first type of trajectory was unfocused on learners' ideas. Not all preservice teachers in the course chose to emphasize students' ideas in their work. Some reflected on students' ideas productively when asked and reflected productively on other topics at other times. Other preservice teachers seemed to struggle to consider students' ideas (or other central themes of the course) in much depth.

The second type of trajectory was one that showed consistent growth; the preservice teachers who demonstrated this type of trajectory became more sophisticated over time without a drastic change in their thinking. This type of trajectory included preservice teachers with initially sophisticated and naïve ideas about learners.

Third, some preservice teachers experienced an intervening event that changed their trajectory in some way. After this event, they focused on an aspect of learners' ideas that they had not considered before.

A fourth type of trajectory shows preservice teachers who had a specific area of focus. Preservice teachers demonstrating this type of trajectory did not emphasize all aspects of learners' ideas but thought extensively about one aspect that was important to them.

Finally, one preservice teacher moved from certainty to uncertainty about her ideas towards the end of the semester.

This chapter first briefly introduces each of the eight focus preservice teachers. Then, each type of trajectory is described in detail. Finally, I present conclusions about these different trajectories and discuss themes that emerged as salient across the eight focus preservice teachers and the five types of trajectories.

Focus Preservice Teacher Profiles

Riley

Riley was placed in a first grade classroom and was very interested in teaching lower grades. Her major within the School of Education was language arts and her minor was math; she felt nervous about teaching science because she had not done well in her science courses. She was one of the few preservice teachers who answered on the survey given at the beginning of the semester that other subjects should take priority over science.

Over the semester, Riley showed consistent growth in her thinking about learners' ideas. Her first reflective teaching assignment served as an important event to Riley and she began to think about her students in different ways. Her ideas about the characteristics of learners' ideas grew as she began to recognize the variety of ideas a group of students can bring to a learning situation. As she learned that not all of her learners had the same ideas, this changed how she thought about dealing with those ideas as well. Singular strategies became ineffective for her, and she suggested a wider variety of strategies and also placed more emphasis on finding out her students' ideas. Riley's trajectory was somewhat "clean"; an experience in her classroom helped her challenge her simplistic ideas about the characteristics of learners' ideas, and once those changed, her ideas about how to deal with those ideas naturally followed.

Katya

Katya was Riley's partner in their first grade classroom. She was placed in a kindergarten classroom for her student teaching, which pleased her. Katya's major was language arts and her minor was science. On the survey, she said she was nervous about teaching and rated her subject matter knowledge and ability to teach science low.

Katya and Riley's first science lesson was pivotal for both of them. They were responsible for different parts of the lesson and it influenced their trajectories in different ways. For Katya, during the lesson and subsequent reflection, she realized the impact that finding out her students' ideas could have on their learning, and this aspect became very important to her. From that point on, Katya focused on finding out her students' ideas; in this area, she made consistent progress throughout the semester. Katya began with a change in dealing with ideas (through an emphasis in finding out students' ideas), which resulted in a later emphasis on the resilience of ideas – a characteristic of students' ideas. Towards the end of the semester, Katya used resilience of ideas as her rationale for finding out students' ideas; she believed that because learners' ideas were so resilient it was critical that the teacher consistently find out what those ideas were. So she seemed to have a nonlinear trajectory; first she developed a strategy that she felt was effective and important and later was able to use new ideas about characteristics of learners' ideas to rationalize this strategy. In addition, Katya's trajectory is unique in that it is not uniform; while her ideas change considerably in finding out her students' ideas and the resilience of those ideas, her other ideas regarding characteristics of and dealing with students' ideas did not change much.

Beth

Beth's practicum placement was in a third grade class, and she planned to student teach in the same class. Her major was social studies and her minors were math and Spanish. She hoped to teach either in a nearby urban city or in a Spanish speaking country; by the end of the semester, she was very interested in obtaining an international assignment after she graduated. In the survey, Beth said she was "excited" about teaching science and rated her science knowledge somewhat high.

Beth's trajectory involved developing rationales after she decided finding out students' ideas was an important strategy for science teaching, somewhat similar to Katya. Beth began and ended the semester with fairly sophisticated ideas about student learning compared to her peers. Initially, she suggested using multiple strategies to teach a concept. Her rationale for this was to reach all types of learners: she believed visual learners need one type of strategy and auditory learners need a different strategy, for example. As the semester progressed, her science teaching strategies and ways of dealing with her students' ideas did not change. However, her rationale for them did. Towards the end of the semester, her many strategies were needed not to match each supposed "learning style" but to provide multiple opportunities to change her learners' resilient ideas.

Wanda

Wanda was placed in a second grade classroom without a partner (for logistical reasons). Another pair was placed in another second grade class at the same school, so on occasion, she worked in their classroom. Wanda planned on staying in the same placement for her student teaching. In fact, she and her teacher decided that she should

teach the science unit she worked on during the methods class, so during her planning, she knew she would be enacting her unit the next semester. Wanda's major was math and her minor was science. She was enthusiastic about teaching science and rated herself very high on her teaching and subject matter knowledge. However, Wanda had an extremely difficult semester personally, and this influenced her coursework. She struggled to finish many of her projects and talked often about feeling distracted during the semester.

Wanda entered and left the semester with more naïve ideas about students' ideas than many of her peers. By the end of the semester, she was less clear about what she believed, but this was in contrast to being very certain that students' ideas were simple to clear up, as she was early in the semester. Wanda's trajectory was a "bumpy" one. Though it is clear she grew in her thinking over the semester, she did not consistently demonstrate more sophisticated ideas. Wanda often directly contradicted herself, and she gave different answers depending on the context of the question, a sign that her knowledge was in pieces rather than integrated. However, a comparison of her early and late ideas shows that by the end of the semester she had more consideration for her learners' ideas and recognized that dealing with these ideas throughout a unit of instruction was necessary. Though many of her ideas were not as nuanced as her peers, her trajectory was one of growth.

Kate

Kate was placed in a first grade classroom for her practicum. She was not planning to student teach until a year after most of her peers because she had more university requirements to take. Kate's major was social studies and her minor was fine

arts. She was nervous about teaching science and said on the survey that she would prefer that a colleague be responsible for teaching science to her students, though she rated her subject matter knowledge as "very good" for about half of the given topics.

Kate's initial ideas about the characteristics of her learners' science ideas were somewhat complex; she understood that simply telling students something was not sufficient to change their ideas. She believed that providing them with hands-on experiences, however, would "prove" concepts to them and change their minds. However, as her knowledge about students' ideas changed, her ideas about how to deal with those ideas evolved as well. Near the end of the semester, Kate was much less certain about how to deal with students' alternative ideas. She suggested more strategies than earlier in the semester but was quick to say there was no guarantee that any strategy would work. So while Kate's trajectory moved from certainty to uncertainty, it showed growth because her ideas about the characteristics of students' ideas and strategies effective in dealing with them were less simplistic than at the beginning of the semester.

Lara

Lara was placed in a fourth grade class, and like Kate, she was planning to student teach a year later than most of her peers. She was a language arts major and social studies minor. When asked to describe her feelings about science teaching in one word, she wrote "minimal." Her responses to the survey were minimal as well; she chose not to fill out most of the items.

Lara did not focus on students' ideas during the semester. Much of her coursework was thoughtful, though it rarely involved students' ideas, even superficially. When asked to reflect specifically on students' ideas in assignments or interviews, she

did so, though without much complexity. She did not focus much on the characteristics of students' ideas (except to note that they were not predictable) and her suggestions for dealing with those ideas were generally simple strategies designed to "clear up" all the alternative ideas, even at the end of the semester. Presumably, Lara grew in other aspects of becoming a science teacher during the course, but the concepts related to students' science ideas did not appear to have much resonance for her.

Aruna

Aruna's major was science (the only one of the eight focus preservice teachers) and her minor was math. She was placed in a sixth grade classroom. In the survey at the beginning of the semester, she indicated that she intended to pursue a career in teaching and said she was "excited" about teaching science, and she indicated this in the initial interview as well. During the semester, however, Aruna decided she did not want to teach and instead wanted to pursue an MBA and career in business, so she did not go on to student teach.

When asked specifically about students' ideas, Aruna had sophisticated ideas that grew throughout the semester. More than most of her peers, she was able to reflect about the concepts covered in the course and relate them to her own experiences with learners. However, she never brought up learners' ideas on her own. Like Lara, Aruna chose to reflect on other aspects of the course and the issue of learners' ideas did not seem to be one of importance to her.

Amber

Amber was placed in a third grade classroom. Her major was math and her minor was language arts. Amber's career goals did not include long-term teaching; she wanted

to be a school librarian and chose elementary education because she believed it to be a good path to being a librarian. However, she planned to teach for a few years in order to help her attain a position in a library. During the survey, her word to describe science was "ambivalent" and her word to describe science teaching was "more ambivalent." She made no apologies that her interests did not lie in becoming a science teacher. In addition, Amber had a difficult semester and got very behind on her work, so many of her journal entries were very short and done at one sitting. While she did not focus on student ideas, she also did not focus on many aspects of the course.

Not surprisingly given her career goals, Amber's trajectory was unique. It was not uniform in its growth in all areas of thinking about students' ideas. Instead, Amber excelled well beyond her peers in one area: considering factors that contribute to students' ideas. She began and ended the semester with thoughtful ways of attending to learners' contexts and backgrounds. Other areas of students' ideas, specifically how to deal with those ideas in instruction, did not seem important to Amber.

Differing Trajectories

Even though they were in similar teaching contexts and took the same course, many factors influenced the ways in which these prospective teachers learned to teach. One of the major goals of this study is to describe different preservice teachers' trajectories throughout the course of the semester. Of course, any teacher hopes that the students in a class develop more sophisticated ideas as the course develops. But how do individuals differ in their development? Here, several different trajectories are described. First, two preservice teachers, Lara and Aruna, made little progress in thinking about students' ideas, and their trajectories were not focused on students' ideas. Wanda and

Beth both had somewhat consistent trajectories; their ideas about learners' ideas developed over the course of the semester. Riley and Katya both made progress in their trajectory about students' ideas, and this progress was influenced by a particular event. In very different ways, Amber's and Wanda's trajectories emphasize one area: considering learners' contexts. Finally, Kate's trajectory moved from a position of certainty to uncertainty over the course of the semester. Table 4.1 shows which of the focus preservice teachers demonstrated each type of trajectory. Each of these trajectories is described in detail below.

Table 4.1: Summary of Focus Preservice Teacher

	Types of Trajectories				
	Not focused on learners' ideas	Consistent growth	Intervening Event	One area of emphasis	Certainty to uncertainty
Riley			■		
Katya			■		
Beth		■			
Wanda		■		■	
Kate					■
Lara	■				
Aruna	■				
Amber				■	

Trajectory unfocused on students' ideas

As described in Chapter 3, the science methods course had three foci: attending to students' ideas, critiquing and adapting instructional materials, and scientific inquiry. Even though attending to learners' ideas was an emphasis in the class, not everyone focused on their students' ideas in their work. Lara and Aruna are highlighted here as examples of preservice teachers who did not emphasize students' ideas in their thinking. Lara, even when prompted, did not seem to challenge herself in thinking about her

learners' ideas. Aruna chose to think carefully about other aspects of learning to be a science teacher rather than students' ideas.

Lara. Lara never seemed to choose to reflect about her students' science ideas. In the interviews and course work where she was asked to do so, she did, though not to the depth of some of her peers. Perhaps one reason this was not an area of importance to her was her belief that students' ideas are not predictable. She was the only one of the focus preservice teachers with this belief. When asked if she thought that over time she would be able to predict her students' science ideas she said

> From our point of view as teachers, like we know what the right answer is and it's like you can come up with maybe a few ideas that the kids are going to think, but they have so many other ideas by looking at it from another point of view, like their younger minds and stuff like that, that just, you're, I don't feel like you're ever going to really know (Interview 1).

At the end of the course, her response to the same question was similar, although she allowed that there would be common misconceptions (a concept emphasized in the course).

> I think it would be good if every kid's idea was predictable (laugh). Um, I think I'll have an idea of what their main misconceptions or their main ideas about things are but you never really know what they're going to throw at you (Interview 2).

Even though her language here was less strong, she ended with the idea that in the end, students' science ideas are still unpredictable. It makes sense, then, that of all the areas of her developing PCK, she would not choose to emphasize attending to her learners' ideas. It would seem like a waste of time thinking about how to attend to students' ideas when there was no rhyme or reason to what those ideas might be on any given day, unit, or year.

In fact, learners' science ideas almost never appeared independently in her journals, reflections on teaching, or other coursework. She did not seem to challenge herself in her thinking about students' ideas, even when asked specifically about them. At the end of the semester interview, Lara was asked what she would do if some students still did not understand concepts at the end of the unit. Her response emphasizes surface level understandings of the students.

> I think I would definitely toss a couple of review days in there while they're at the review with a game or something like that to try and get them um, to remember what they are doing because I feel like they remember when they're more interested in what's going on but I, from being like that fun you could also put in something with the book where they're actually going back to that text book and reading specifically what's going on and seeing if that helps at all (Interview 2).

For Lara, even at the end of the semester, students' ideas were not of critical importance. Her journals and other coursework were thoughtful in other ways, so perhaps she developed her PCK in other aspects of learning to teach science.

Aruna. Aruna consistently challenged herself throughout her coursework. Like Lara, Aruna rarely chose to consider learners' ideas. However, when asked about student ideas during interviews or other situations, she thought in sophisticated ways and brought up critical questions. For example, more than her peers, Aruna reflected on the resilience of students' ideas, even at the beginning of the semester.

> When teaching a lesson about science, if [existing] ideas are not addressed students will learn the new material and then wonder how that new material fits with their preconceived notions. In this situation they will either not be able to figure out whether their thoughts or those learned in class are correct or they will try to figure out how they can both be correct (Pretest).

In the first interview, Aruna also talked about inquiry as a powerful way to attend to her learners' ideas and challenge them as well.

> But um, and I think that once you start talking about things in the sense that you have to give evidence or prove their answer, um, when they are unable to prove the way that they originally thought about something or they find out like when they try to prove it that they get another answer then that's like their first step and then realizing like oh, maybe this isn't right (Interview 1).

Many of the concepts Aruna brought up in the early interview and her pretest are those that are addressed throughout the semester. Her ideas do not change much; her answers to the same questions in the posttest and interview look similar. Perhaps because Aruna began the semester with existing ideas that were consistent with those being taught, she chose to focus on other aspects of becoming a science teacher. Another possible reason for Aruna's lack of development with respect to students' ideas is her change in career goals. Recall that during the semester, Aruna decided to pursue an MBA instead of teaching. Although her grades were excellent and she continued to excel in her coursework, it is reasonable that she might not have immersed herself in challenging her ideas about science teaching.

Summary of trajectories not focused on learners' ideas. Neither Lara nor Aruna emphasized learners' ideas in their coursework. For Lara, it was a struggle to engage her in thinking about them at all; for Aruna, she thought carefully and in sophisticated ways, but only when prompted to do so. Neither Lara nor Aruna changed their ideas drastically over the semester. They are examples of how powerful existing ideas are. Lara, who believed that learners' ideas are unpredictable, never saw a reason to learn to attend to those ideas in her instruction. Aruna, who began the semester with ideas consistent with those being taught, never challenged herself to go beyond those initial (though

sophisticated) ideas. For these two preservice teachers, the semester did not seem to have a strong influence on their beliefs about the importance of attending to learners' ideas.

Consistent trajectories

Preservice teachers with consistent trajectories also did not show a drastic change in their ideas. They maintained many of their general ideas about how students learn science, but those ideas became more sophisticated and nuanced over the course of the semester. The two preservice teachers presented here, Beth and Wanda, had similar trajectories in that they did not show a stark contrast in their thinking at the beginning and end of the semester, even though there was growth. Beth came into the class with some sophisticated ideas about how children learn science, and her ideas changed in subtle ways over the semester. Wanda's initial ideas were somewhat naïve compared to her peers, and they continued to be so throughout the semester. However, she too, developed her ideas about how kids learn over time.

Beth. Beth began the semester with a somewhat sophisticated view of how students learn science. In her initial journal, she said that the most important things for a teacher to consider are her students' needs and abilities to learn science. Few, if any, other preservice teachers in the class brought up students as a primary focus in this journal entry. Thus, she entered the semester with some existing ideas about the importance of attending to her learners.

Another concept Beth focused on in her early work was learning styles. In her first journal (the same entry discussed above), she used learning styles as her rationale for using hands-on science, and later, in the first interview, she elaborated on the importance of using multiple strategies for science instruction in order to "hit" all the learning styles.

> I think that the best way teachers can teach is by hands-on learning in science because in this way they can physically demonstrate the science to their students. This gives the students not only an aural description of the science, but also a visual. This is ideal for adapting to all types of students. (Journal 9/9)

> I think that kids learn in tons of different ways and that um, the hands-on learners are not going to get much out of you lecturing, but the kids that learn from lecturing aren't going to get as much from the hands-on so I think it's important to like reinforce certain ideas in more than one way (Interview 1)

Later in the interview, Beth was asked whether her students' ideas about a concept would become predictable if she taught the same topic and grade for a few years. Again, Beth's response was guided by her beliefs about learning styles. Interestingly, here, she referred to a class of students as potentially having a particular style.

> You might have one group of students that's really into learning like based on a, in an activity based like hands-on stuff and other kids that are, you know learn better from a book, reading a book or story about something. Um, so I think depending on your group of students you might be able to make like generalizations overall if they would like it or dislike it or what they might struggle with, but it would really depend on each class you get and each of your students. (Interview 1)

In her early thinking, then, Beth was already thinking carefully about her learners, which was not typical for so early in the semester. She suggested using multiple instructional strategies in order to provide opportunities for all of her learners. However, she seemed to emphasize learning styles as her rationale for needing a variety of strategies. She had a somewhat simplistic view of learning styles as well; by suggesting that some students were unable to learn well from hands-on learning, she seemed to label students and select a learning style for each. However, her emphasis on meeting the needs of learners and recognizing that that requires multiple strategies is impressive compared to many of her peers.

In her second interview and coursework done later in the semester, Beth continued to suggest a variety of strategies to use in attending to her students' ideas. However, her rationale for these strategies changed. She objected to the multiple choice pretest her cooperating teacher used in her classroom not because it did not match all students' learning styles but because it did not most effectively show the teacher the ideas her students had.

> Like [the pretest] not really, it wasn't really testing their ideas…I didn't think [the pretest] did a good job at all. I think like a class discussion and like brainstorming ideas together um, would have been like much more beneficial for the teacher to see like how they, what they knew and what they thought about… I think the pretest might be better if it was more of like answering questions as opposed to like a multiple choice, because I felt like the multiple choice test they just guessed at a letter and they knew that they weren't being graded so they didn't really even have to think about it, they could just pick one. (Interview 2)

One could imagine Beth at the beginning of the semester suggesting that other pre-assesments would be needed to cover all learning styles; here though, her rationale for evaluating the strategy was its effectiveness of engaging students' ideas. On the surface, it may look like Beth did not make much progress in the *types* of instruction she suggests as being most effective. However, a closer look indicates that the *rationales* behind her ideas changed substantially.

Beth's shift towards focusing on students' ideas is seen in comparing a question from the pre and posttest. The question asked what should be done if students believe that things that are red have a higher temperature than those that are blue. In the pretest, Beth suggested giving students the correct answer and encouraging them to test their ideas if they have misconceptions.

> If some of my students had this idea, I would address it in the lesson by saying that we cannot generalize and say that all red colors are hot and all blue colors are cool, but rather we must test to see if these are in fact true. (Pretest)

In the posttest, she continued to suggest providing correct information for her students but in the form of a thought experiment. She did not suggest telling students the scientific information but carefully constructed a situation that would challenge their current ideas.

> If some of my students thought that red colors are hot and blue colors are cold, I would ask the students to think about different things in their lives that are blue and red. When they came up with examples, I would ask them to label if they are hot or cold. Showing that there are red things that are cold, like a red popsicle, and blue things that are hot, like a blue tea kettle, the students would see that the colors are not always hot or cold and that the effect from the experiment would be on the water and the light absorbed by the colors. (Posttest)

Beth began the semester with somewhat sophisticated ideas about learners. Therefore, her trajectory was subtle, but the changes she made were important. While she continued to suggest multiple strategies, she began to emphasize her students' ideas rather than their learning styles as the rationale for her instructional decisions. And as exhibited in the pre/post test differences, even though her instructional strategies were not drastically different, the differences reveal a shift in emphasis towards thinking about her students' ideas.

Beth identified this pattern in her own ideas. When asked what changes she noticed in her work on the pretest and posttest, she said:

> When I was doing [the posttest], I somewhat remembered what I had done the first time … I did like some similar things for the second time. But I feel like now that I'm reading my answers I feel like my second one is more thorough and more in-depth. (Interview 2)

Beth noticed that even though no drastic changes took place, there was growth in her ideas. Her trajectory began and ended with sophisticated ideas compared to many of her peers, and though her growth was subtle, it was substantial.

Wanda. Wanda's ideas were somewhat more naïve than those of her peers, both at the beginning and end of the semester, but like Beth, her ideas evolved over the course of the semester.

Most of her answers in the pretest were only one sentence and seemed to indicate that dealing with students' ideas was a simple endeavor. In the first interview, she emphasized "clearing up" ideas and implied that it was not complex to do.

> I: So can you talk a little more generally about why do you think it's important to figure out what your kids are thinking at the beginning of either a unit or a lesson?
>
> W: Um, well for one you want to clear up any misconceptions that they would have. (Interview 1)

Wanda immediately went on to discuss other reasons for finding out students' ideas without elaborating. When asked why it was important to pay attention to students' ideas at the end of the unit, she replied:

> to see if there are any more misconceptions that you could clear up at the end before maybe a test or whatever, their end project, you know. (Interview 1)

Early in the semester, she did not place much importance on the ideas students bring and how those might impact instruction. In fact, Wanda's ideas about the factors that contribute to her students' ideas will be discussed later in this chapter. Her emphasis was on what the teacher does to "clean up" the misconceptions; the assumption was that students' ideas would follow the intent of the teacher.

As the semester progressed, Wanda did show growth in her ideas. At the end of the semester, when asked what she would do if students still had an alternative idea after instruction, she suggested an experiment to convince the students.

> I would probably do like a big experiment maybe in front of the class since if they, like if they were doing investigations on their own and it didn't work out, maybe I would like walk them through step by step and say, okay now, look at

> this and like this is happening, why is this happening and try to like make it a really big event so that they would remember it and they would, it would change their minds or whatever they were thinking. (Interview 2)

On one hand, Wanda still seemed to have a somewhat simplistic idea about student learning. She believed that if she carefully walked students through an experiment and made it "a really big event" that it would "change their minds". However, her strategy of carefully guiding the class through an additional experiment was considerably more sophisticated than her earlier more simplistic suggestions to "clear up" misconceptions.

Wanda seemed to be in the midst of struggling with her ideas about effective instructional strategies. In the posttest, she gave a sophisticated answer when asked generally why teachers should attend to learners' ideas, which contradicted her quote above that an experiment would "change their minds or whatever they were thinking".

> It's important to find and correct the students' misconceptions. Many times, we assume that the evidence will prove to the students that the correct answer is the right answer, but many times, that's not the case. There are many things that children have discovered in their own life, and a half hour lesson probably won't change their minds. If the children leave with the same misconceptions after the lesson was taught, then what was the point? We might as well not even teach if we don't know what prior knowledge we're working with or need to correct. If we don't address the learners' ideas, then they will never change what they are thinking to what is correct. (Posttest)

These ideas are in line with those taught in the course and were given in response to a context-free question about the importance of learners' ideas in general. However, in the interview done the same week, she said she would address ideas at the end of a unit so she would not feel guilty about it.

> I think that it would be really important to clear up the misconceptions like … yeah I think I would feel guilty just leaving them because I would feel like I made them think those things and then they're just going to be more confused in the future. (Interview 2)

Wanda contradicts herself at times when thinking about learners' ideas. On one hand, when asked directly, she had sophisticated ideas about the importance of attending to students' ideas (although perhaps she was giving the answer she thought her instructor wanted to see). However, when asked in a context (she was asked to think about her first few years of teaching) and in a conversation, she did not give students' ideas the same importance. One of the reasons she gave for addressing misconceptions was to alleviate the teacher's guilt. Even when she thought more carefully about attending to her learners, Wanda still did not address the complexity of dealing with students' alternative ideas. Even though she wrote, "a half hour lesson probably won't change their minds," she never went any deeper than "clearing up" alternative ideas when prompted during the interview. Wanda's trajectory, though it gets more sophisticated over time, is not a clean growth curve. She has ups and downs as she works through her own beliefs and ideas.

Wanda's ideas over the semester went from simple and somewhat naïve to more complex and messy. This, however, is encouraging. While she was not identifying these inconsistencies in her thinking, she did seem to be questioning herself more and possibly had less certainty about the ease of clearing up alternative ideas. Kate, described later in this chapter, also has a trajectory that ends in less certainty about the best ways of attending to students' ideas.

Summary of consistent trajectories. Beth and Wanda's trajectories were similar in that they showed gradual change without an intervening event. However, they were quite different in the type of growth each showed over the semester. Beth seemed to enter the semester with an understanding that students' ideas are important to attend to. With this cornerstone in place, she honed her understandings over time and made subtle but

important changes. Wanda's growth was more focused around developing some of the cornerstones of PCK-readiness as she gradually began to consider her students' ideas more important to her teaching. Even though Beth and Wanda began and ended at different places, the experiences during the semester seemed to support them both in thinking about students' ideas.

Trajectories with an intervening event

Some preservice teachers experienced an intervening event during the semester. Something happened that helped them think differently about their students' ideas for the remainder of the semester. Here, two preservice teachers with the same intervening event are presented. Riley and Katya were placed in the same first grade classroom and they experienced a problematic first science lesson. In order to help students make sense of the science in their lesson, Riley and Katya asked their students to copy a sentence off the board or write a sentence describing what happened in the lesson, a practice commonly used by their cooperating teacher. Riley's journal focused almost exclusively on the ineffectiveness of this strategy. Katya's mentioned it, but she focused on the section of the lesson she was responsible for, which involved finding out students' ideas before the lesson. These different perspectives on the same lesson served as divergent points for their different (but both productive) trajectories. Riley began to focus on students as individuals having varied ideas and requiring a variety of teaching strategies. Katya began to focus on how to discover the science ideas of her students and use those ideas in her teaching. Their trajectories in thinking about learners' ideas are described below.

Riley. Initially, Riley did not talk much about students as individuals but rather as a group. When asked in the first interview what strategies she would use to find out

students' ideas, she only offered one. "I kind of envision sitting on …the floor in a group and kind of just having a little discussion." (Interview 1)

In the pretest, when asked how she would determine if her students learned the concept, she answered again with a singular strategy.

> I would use a sort of informal assessment through class discussion to gauge whether or not the students have grasped the concept I listed as my goals. (Pretest)

When Riley and her partner taught their first lesson, they decided to have students copy a sentence from the board or write their own sentence to explain what they learned as their assessment. When Riley reflected on this strategy after enacting it in her lesson, she realized it might not have been effective.

> I don't think I would use this [strategy] again because I don't think it gives a very accurate indication of what they have actually learned. Instead I would have them write as much as they can on their own, and allow time to go around and write down the ideas of each student. This way I can see who needs more scaffolding and what general ideas need to be revisited. (Reflective Teaching Journal 1)

Here, Riley's experience highlighted for her that different students had different levels of understanding. She learned that individual attention was needed for her as a teacher to learn what those ideas are, especially with young students who struggle with writing. After seeing how many students copied the sample sentence and evaluating the sentences others wrote, she knew she needed to think more carefully about her strategy to evaluate their thinking.

In her second reflective teaching assignment, Riley and her partner demonstrated a more varied set of strategies for finding out what their students' ideas were. They led a class discussion, had each student make a product that demonstrated their idea, and asked

students to complete worksheets. This represents more sophisticated thinking about students' ideas than simply asking students to copy or write one sentence.

Similarly, in her posttest, Riley suggested a variety of strategies for assessing what her students learned. When asked how she would know if students learned the concepts in a unit, she said:

> There are several ways that I would make sure my students attained the learning goals… I would do a pre-assessment through a discussion…I would have them [make a] color wheel, then have them do a worksheet that asks questions…to make sure they understand the relationship among colors. (Posttest)

This, especially when compared to simply having an informal discussion as Riley suggested in the first interview, shows growth in terms of thinking about her students as individuals requiring a variety of strategies. Her intervening event provided opportunities for her to examine both the characteristics of students' ideas (by recognizing the diversity of ideas) and how to deal with those ideas (by realizing that multiple strategies are more effective than one).

Katya. Katya's ideas began, not atypically, with an emphasis on making sure students leave a lesson with the correct scientific knowledge. Twice in the pretest, she said that she would deal with misconceptions by telling students the right answer:

> If they answer [questions] incorrectly then I will explain the correct answer to the best of my ability….I would ask them what made them think that red colors were hot and blue colors were cool and then I would explain why that is not the case. (Pretest)

Katya's emphasis was on telling students the correct answer, not on the ideas they brought into the lesson. On one hand, by asking students about the rationales behind their thinking, she was considering factors that contribute to students' ideas. However, her way of dealing with those ideas was to tell them the correct answer with no regard for

how students might be able to make sense of the new information in light of their ideas. In the context of critiquing a specific lesson, Katya's singular strategy for dealing with alternative ideas was explaining the scientific idea to students. However, in the first interview, when Katya was asked about this strategy, she backed off from suggesting that students were told the scientific idea.

> Like the way I have it [in the pretest] it's like, it makes it seem like if they don't, if I feel they don't have the right answer. I don't necessarily have to give them the answer but I want to make sure they're on the right track to at least finding the answer on their own. (Interview 1)

She elaborated on other strategies she would use instead of giving students the answer:

> [I would] at least give them a chance to think about it on their own because if I just give them the answer chances are they're going to forget it. Then they go through the process of coming up with it on their own or at least thinking about it more…so it sticks more with them, I think. (Interview 1)

This was a direct contradiction from her pretest. There, the only strategy suggested was explaining the science to the students. In the interview, she said that if students are told the science, "chances are they're going to forget it". Although the interview was taken somewhat later in the semester (about a week) than the pretest, it seems unlikely that Katya shifted her ideas because of concepts presented in the class. More likely, she was struggling between making sure her students at least hear the scientific idea presented and knowing that this was not the most effective strategy. Katya was not alone in this struggle. Almost all of the preservice teachers had this issue arise in their coursework and it was a constant source of discussion in the class and a topic in the online discussion.

Katya's early struggles suggest that she knew that students' ideas were important, but she did not seem to have traction in dealing with those ideas. She seemed to ignore her students' ideas even though she felt they were important. Katya's first lesson

provided her with strategies and motivation to deal with those ideas. This seemed to allow her to emphasize learners' ideas for the rest of the semester. In the first reflective teaching assignment (which she shared with Riley, discussed above), her part of the lesson entailed finding out students' ideas about the topic of the lesson. She described this process in depth in her first reflective teaching journal and reflected on the effectiveness of this strategy. She was pleased with how this section of the lesson was enacted and seemed to be convinced of the importance of learning about kids' science ideas.

> During our lesson it was my responsibility to get the students to share some of their ideas about the composition and formation of clouds. … The review was one part of the lesson that I think went rather well. The students were quick to tell me all about what happens during evaporation. Almost all of the students seemed to be struggling with the concept of condensation. As soon as I said the word I noticed that some of them looked very confused. With a little scaffolding the students were able to explain that water changes from a gas back to a liquid during condensation. (Reflective Teaching Journal 1)

Most of her journal described the ideas the students had and how Katya helped them express their ideas and explained some of the concepts with which they struggled. There was some mention of the strategy Riley emphasized (copying the sentence to make sense of the science), but Katya did not spend much time reflecting on it, possibly because that part of the lesson was not her direct responsibility.

After the first reflective teaching experience, finding out students' ideas became a focus in Katya's later work. For example, in the second images of inquiry assignment (which was not specifically focused on learners' ideas), Katya centered her discussion on how Eli, the image teacher, learned what his students' ideas were.

> I especially like the way that Eli taught the lesson on density. I like his idea of having the students answer a question or explain what they know about a concept the night before a lesson. This gives the teacher a chance to see what alternative

> ideas the students might have and because he gets this knowledge before he actually teaches the lesson, he also has a little time to modify his lesson so that he can attempt to dismantle these misconceptions. I usually try to get a sense for alternative ideas that students might have by asking questions right before the lesson or by using my teacher sense but I think that Eli's idea could be extremely helpful. (Image of Inquiry 2)

Katya referred to the importance of a teacher finding out ideas before teaching the lesson, the same idea she focused on in her reflective teaching journal. She viewed Eli's image as providing her with another strategy she could use to learn what her students are thinking.

In the posttest, Katya referred to finding out students' ideas in 3 different instances.

> I would also do some type of activity or have a brief discussion which might allow me to get an idea of the students' alternative ideas before the experiment.
>
> If the students held on to their alternative ideas throughout the entire activity I would feel as though I was not completely successful in fostering my learning goals.
>
> Taking these ideas into account is extremely important because the students bring these ideas into the classroom with them. Sometimes these ideas are inaccurate and they can keep the students from gaining a solid understanding of the material that they need to learn. If I did not address these ideas they might never learn the right information. (Posttest)

In the pretest, Katya did not bring up finding out students' ideas even once. This indicates that over the course of the semester, and perhaps due in part to the first reflective teaching assignment in which she was able to focus on it, Katya became convinced that attending to students' ideas before, during, and after instruction was important.

Katya was able to see this development herself. In the final interview, when asked to point out changes she saw between her pre and post tests, Katya said that she became better at finding out learners' ideas rather than just waiting for them to "pop up".

> I would try to pay attention to the students' ideas. In the [posttest] I said I would try to pay attention for, you know I would try to look for those ideas and not just hope that they popped up but I would try to draw them out by asking questions and more questions um, letting the students talk amongst themselves and I just listen so they're not really trying to give me the answers that they think I want, when they're talking to their peers they're more likely to say what they really feel. (Interview 2)

Not only did Katya identify this area of growth in herself, she brought it up again in another discussion in the second interview. Near the end of the interview, the interviewer asked her generally about her student teaching placement in kindergarten and how much science she would be able to teach. Katya immediately commented on her students' potential ideas in science.

> I'm not sure like how much [science] I'll actually be teaching but I noticed that working with those kids just for a couple of hours they are extremely curious and I could see that at least two in particular coming up with those alternative ideas that are like stand up pretty well against [what I'm trying to teach] you know? (Interview 2)

Katya referred to a common discussion held in the course that stemmed from a reading about students with resilient alternative ideas, even in the face of instruction to the contrary. The fact that Katya brought this up without being prompted, and in fact, somewhat out of context suggests that considering her students' ideas became a focus of her thinking about effective science teaching. Chapter 5 discusses two more preservice teachers for whom finding out ideas was important throughout the semester, Leslie and Ella.

Summary of trajectory with intervening event. Riley and Katya experienced the same intervening event. During their first science lesson, they each learned a valuable (but different) lesson about learners' ideas that stuck with them throughout the semester. Riley learned that when looking for evidence of student learning, one strategy, especially one requiring little thought by the students, was ineffective. Throughout the rest of the semester, she focused on how to learn what her students were thinking, employing a wide variety of strategies. Katya initially thought learners' ideas were important but seemed unable to use this knowledge in her teaching. After a successful lesson, she became convinced that finding out what her students were thinking was critical. Throughout the semester, she continued to focus on it, both when prompted and on her own. For both of these preservice teachers, their experience with their science lesson provided a launch pad to take these ideas on as their own.

Trajectories Emphasizing One Area: Considering Learners' Contexts

An important characteristic of learners' ideas is the factors that contribute to those ideas. Preservice teachers, then, need to develop an appreciation for what learners bring to their science class. Past experiences, culture, beliefs, and other aspects all contribute to how a learner comes ready to learn science. While this a crucial aspect of teaching, it was not emphasized by this set of preservice teachers during their coursework. Of the eight preservice teachers focused on in this section of the study, only one, Amber, considered this concept with any depth. One, Wanda, consistently brought it up in naïve ways. The other six hardly addressed the idea at all throughout the semester and then only mentioned it briefly; this was true as well for the rest of the class, as presented in Chapter 5. In this section, I describe the ways in which two preservice teachers considered these

factors. Amber thought about her students' contexts in quite sophisticated ways. This is in contrast to Wanda, who also thinks about the contexts of her learners, but in very different ways.

Amber. Amber was a unique preservice teacher in several ways. First, she did not intend to teach; she wanted to be a school librarian. Second, she lived at home and did not seem to be immersed in college life like most other undergraduates, and many of her examples involved her much younger brother, whom she had a role in raising. Amber discussed factors that contribute to students' science ideas much more than any of her peers. Most preservice teachers in the course only had about one or two paragraphs coded for this concept over the entire semester, but one of Amber's quotes was five pages long (although her interviews in general were much more verbose than her peers). Thus, the quotes in this section are generally longer to more accurately present Amber's style of speaking. Amber also thought carefully about issues related to multiculturalism. She referred several times to a class she (and all other members of this class) had taken and said "I just got it…I felt it in my gut." She closely related multicultural issues with ideas and experiences students' bring into the classroom and how those contribute to learners' science ideas.

In her first interview, Amber showed that thinking about her learners' experiences and backgrounds was important to her. She made an analogy between learning students' ideas and building a house:

> If you were building a house you would not go in, or if you were adding onto a house, you would first go in, you would find out everything that was there. You would find out what kind of soil you had, what kind of cover was in it. If it was house you would find out everything that's already there existing. You find out what you need to fix, what you need to change, what needs to be added on and that's the way it is with many professions. What you do is you find out what you

> have and then you add onto it. And to me teaching students is just like that. You just, you just have a place where you're at and then you build up from there and I know that we have curriculums and a standardized test that we have to, to prepare them for but my philosophy about that was just that, I mean prepare them for, teach, teach it but, but if you're going to be tested on multiplication and if they don't know addition we have start with the addition no matter when the test is coming (Interview 1).

After building a case for the importance of attending to those ideas, Amber talked about relating science instruction to the prior experiences of all students. This concept was in line with the ideals of the course and program in general but was rarely if ever brought up by other preservice teachers.

> So, and as America's growing into much more diverse country and where that diversity is celebrated and, and really fostered by different parts of the community its going to be more and more important for us to be able to teach these students … and we're not going to be able to teach them unless we can tie what we want them to learn to what they already know. Also we have to know what to teach them and I know we're going to have curriculum guides and we're going to have these other things but if you have an [international] student coming to your class and, and they don't, they don't know things that are cultural norms for us then if you are teaching a lesson and you illustrate this point beautifully by, by um the baseball game and the hot dog that, something that every American has been to at least once well there are people who haven't (Interview 1).

Although Amber was not talking in terms of science teaching, even at the beginning of the semester, she was concerned with using culturally relevant representations in the classroom. Clearly, students' ideas and contexts were a cornerstone in her developing PCK from the beginning of the semester. Later in the interview, she mentioned that in order to support all learners, attending to their existing ideas is important, especially for struggling students.

> For the students who are further behind that if we don't teach from where they know I think they will just get further behind because the way I see a class is that you can have a class and you can have a bad teacher and some of those kids will still learn. Most of them will just kind of float through but the ones who are really struggling are just going to stay the exact same level on it. You can have um, a mediocre teacher and some of the kids will still learn and some of them will still

> float through and some of them will still reverse and I think the tendency, I guess what I'm trying to say is I think the tendency in a classroom within a group of students no matter, no matter who you have, you have some that left alone will, some will learn, some will float through and some will just get further and further behind because they just don't understand. And so what, what we have to do is, is find a way to get those lower students to be growing in their knowledge and to do that … it just makes sense to me that you have to know where they're at. (Interview 1)

At the end of the semester, in her second interview, Amber retained this focus. When asked if her students' ideas about a certain science topic would be predictable (a question asked of everyone in both interviews), she said

> I think there is some degree of predictability um, and if I teach in the same school for twenty years and that school, and the surrounding area stays about the same economically and socially then likely the students will have the same answers. (Interview 2)

She was the only preservice teacher to even refer to economic and social factors influencing the predictability of students' ideas. When asked why she believed these factors were important, she responded

> Um, cultural background, the um, the students coming from different social economic groups or different cultural groups or different ethnic backgrounds they, especially if I'm in the earlier grades, so particularly in their earlier grades um, they're coming to school with very different, sometimes um knowledge basis because their, their social groups and their families have put importance on different things. In a middle class way, suburban area there's usually been some talk about um, the things going on in the world like why does the grass grow? Why do trees grow? Because kids ask these questions when they're around them and when they have the, when their, and when their parents are, are open to questions and answering the questions and things. Now a child from the inner city he may not know what a nut tree is. He may not know what a tree is period because if he's never seen one and I guess one example of that is um, I'm reading this book called <u>One Child</u> by Torey Hayden. And this girl in here had never seen flowers before (Interview 2).

In the same interview, when asked what she learned from her placement, Amber said that all students' ideas, even wrong ones, come from experience. Because of this,

she said, she learned that it was important to address their ideas and allow them to think through and talk about them in relation to the science they're doing in school.

> Well I think that what I've learned through this semester, through the science class and what I've then done in placement, is that students' assumptions, whether right or wrong, come from something and in their own way they are quite logical. Um, the logic's not always right but lots of times that's because they're missing a piece of information or many pieces, um, and that they actually really love to learn. They may not like going to school and they may not like doing paper work but they actually are fascinated by real learning (Interview 2).

This concept was an important one in the class, but Amber was the only one who mentioned it outside of class discussions. Throughout the interviews, Amber was attentive to factors that contributed to students' ideas. Recall that because Amber faced significant personal issues during the semester, much of her other work was done at one time at the end of the semester as make up work, so these themes were not found throughout her journals or other work. In addition, Amber seemed to be focused only on this particular idea. For example, she did not bring up ideas related to teaching science and how to deal with students' ideas. Perhaps in part because she did not see herself as a teacher, she did not seem interested in how instruction could impact students' ideas.

Amber, again unlike her peers, consistently brought up the idea of using culturally sensitive examples in science class. She commented that students from urban environments might not have many experiences with the natural world and might not be able to understand some commonly used examples. While her example, that some students may have never seen a tree, seems unlikely, it shows sophistication that she considers this idea. Amber's focus did not change much during the semester; she did not broaden her thinking about how to deal with those ideas in science instruction, although

she seemed to take experiences from methods and practicum as further evidence of her beliefs.

Wanda. Other than Amber, none of the other preservice teachers carefully considered factors that contributed to their learners' science ideas with much depth. Wanda seemed to go a step further; rather than simply not considering factors that contributed to their ideas, she believed that because of their backgrounds, she could quickly assess their capabilities. As discussed earlier, some of Wanda's ideas were more naïve than her peers. This was also the case in relation to thinking about the backgrounds and experiences of her students. Wanda continually made blanket generalizations about her students (which some of her peers did as well), but she made striking conclusions based on those generalizations.

In the first interview, Wanda made a comparison between two groups of students. Maple is the city where Wanda was teaching and where the university is, and Ira is a district in a nearby urban area. Wanda was asked why attending to students' ideas at the beginning of a unit is important.

> W: Even like with the words that you choose to use because use um, bigger words if you know that your class is a little higher. Like even depending on, like the district that you teach in, you know in Maple versus Ira. I don't know if you're familiar with …
>
> I: Yeah, some but talk a little more about why you think that might matter.
>
> W: Like in upper … I don't know (laugh). Its like the school I'm in now [in Maple] has a lot of ed professors' kids and just, it's mostly like Asian and white and um, and their test scores are higher from MEAP [the state standardized test] and everything and Ira is, I think it's pretty much the same in the whole district and we have to focus more there with um, on just like behavior issues and just getting them kind of caught up there. In Maple you can take them a little further because they can handle that.

She brings this issue up in a journal entry later in the semester as well.

> It's really different for me. I grew up in a small town in northern Michigan. We never had kids from other countries unless they were exchange students… There doesn't seem to be an achievement gap between Asian children and white middle class children. Also, these kids are from the middle or upper-middle class, and their parents are professors or doctors so education is heavily stressed in their households! ☺ (Journal 11/4)

In contrast, Wanda claimed that the entire district of Ira was the same and teachers were forced to mostly focus on behavior issues. This is consistent with other work (Meyer, 2004) that found that new teachers believed that urban students had no prior knowledge or relevant life experiences, while expert teachers found a wealth of knowledge in their urban students.

This idea, while troubling for several reasons, indicates that Wanda did not think carefully about her students as individuals. This concept is not unique to Wanda. Recall that initially, Riley, too, thought of her students in a generalized way, although she did not characterize them based on geography. Wanda believed that these different groups of students would benefit from different instruction. Those in one area could handle more advanced vocabulary and more time spent on instruction; those in the other area needed more time spent on behavior. Towards the end of the semester, in one of her non-structured journals, Wanda reflected on how students learn science.

> I'm struggling with the idea of how kids learn. I'm thinking osmosis. It's easier to see in science, we go over and over things until the idea is just a part of the child's knowledge bank, and they can easily explain it. This is usually a pretty easy process because the kids are generally really excited about science (Journal 11/4).

This indicates that Wanda does not have a constructivist view of learning, but one of students as blank slates. Even though the class and entire education program was taught from a very different perspective of learning, Wanda seemed to have retained her ideas about student learning throughout the semester.

One of the most interesting aspects of Wanda's ideas came in the last question of her pre and posttests. This question asked "Why is taking these ideas into account important? How might your students' learning be different if you didn't address their ideas in this lesson?" In both the pre and the posttest (and especially the post test), Wanda had very sophisticated answers about why attending to students' ideas is important (see excerpt earlier in the chapter). This was in contrast to the more naïve ways of thinking she exhibits in other contexts.

Summary of trajectory emphasizing one idea. Amber and Wanda are examples of the wide range of ideas in the members of the class. For Amber, learners' contexts were of critical importance, and in fact, one of the only aspects of science teaching in which she readily engaged. For Wanda, learners' contexts was used as a shortcut to tell her when "you can take them a little further because they can handle that."

However, Amber and Wanda were also similar. Neither seemed to challenge or change their ideas with respect to the factors that influence students' ideas over the semester. For Amber, at least in terms of considering learners' contexts, her ideas were consistent with those in the course. Like Aruna, she continued to retain these ideas but did not push herself in developing them further. Wanda, too, did not change her ideas. Hers were very far from those presented in the course. She believed that students learned through "osmosis," even near the end of the semester, and she had lower expectations for students in an urban area . For both of these preservice teachers, the course did not present sufficient opportunities for them to refine their ideas about attending to the role that context plays in learners' ideas.

Trajectories that shift from certainty to uncertainty

Some preservice teachers had "smooth" trajectories and others did not. Kate's trajectory was one of moving from certainty to uncertainty in how to deal with students' ideas – a sometimes bumpy path. Initially, Kate seemed to believe that doing a hands-on experiment would change students' ideas or "prove" the scientific concept to their students. As the course progressed, these ideas became less prevalent for her; the course emphasized the resilience of students' science ideas, and Kate seemed to adopt this concept. Kate changed dramatically in her opinion of experiments. She began the semester certain that no alternative ideas could prevail against a good experiment, but by the end of the semester, she recognized that this was not always the case.

Initially, Kate had very strong ideas about how to change her students' ideas. In the pretest, she considered dealing with alternative ideas:

> If some students did have this idea during the lesson, I would simply have them conduct their experiment and follow through with the scientific method which would for sure change this preconceived idea (Pretest).

When asked about this response in the first interview, she said that by going through the scientific method, the students would see that the results were "obviously different from what they thought" so their ideas would be changed. On one hand, Kate's thinking was already reasonably complex. She believed that "it is hard to change students' opinions unless you have sound proof (of an experiment) to back it up" (pretest). On the other hand, she was convinced that simply doing an experiment would change all her students' minds. During the first interview, she struggled when pushed to think about what would happen if students still did not understand. I (as the interviewer) quickly described an article that would be read later in the class in which young children

were unconvinced by an experiment about temperature inside different articles of clothing.

> I: … what would you do if that happened? So what would you do if a kid had a particular misconception and they did this experiment and even though the experiment turned out okay, for whatever reason, they sort of explained around it and still kept their idea? Can you … how would you try and handle that?
>
> K: Um, I guess, I guess I would totally deconstruct the wool, like good question. I mean I think I would go as far as to say like, okay well what is a t-shirt made out of, like cotton, you know. …It's just the material. It can't have any temperature really. You know I, maybe I'd go into like the science of body heat …Um, you know I think, you'd have to find someway of getting the students to understand that it's someway around the data because if the data's not convincing them then um, I guess, you'd have to find some other way (Interview 1).

Kate seemed stumped by this question and struggled to think of alternative strategies. The idea that students would remain unconvinced in the face of a successful experiment was not one she seemed to have considered before.

Perhaps one event that shook Kate's certainty was her second reflective teaching lesson. She and her partner worked to create several hands-on activities for their young students. They wanted them to use tools to predict the weather and determine what types of clothing were appropriate. In Kate's post-lesson reflection, she seemed worried that students did not understand the concept.

> Finally, [my partner] concluded the activity by asking, "Who was dressed more appropriately Miss [Kate] or me for this classroom?" The students came up with many different answers but never with the correct answer which was neither. We were worried that they didn't get this concept….I wish that the students could have answered our question at the end of the lesson (Reflective Teaching 2 Journal).

Perhaps this experience helped Kate question her certainty that hands-on activities would "for sure" change students' ideas. Later in the semester Kate participated in a peer conversation that she wrote about in her journal. The consensus of the group seemed to be that not every student would learn every concept, an idea that Kate might have argued

with earlier in the semester.

> Our conversation also touched on the topic of student comprehension. Everyone in the discussion agreed that it is OK if not every student in the class understands what is being taught, because this would be impossible. New avenues should be sought out in order to reach as many students as possible but it is also OK to give students the answer to their questions sometimes instead of having them figure everything out themselves (Peer Discussion Journal 12/12).

In the posttest, Kate showed less certainty than in the pretest. When asked what she would do if students did not understand an idea at the end of the unit (the same question asked in the excerpt from the pretest), she saw students' ideas as more complex than earlier in the semester.

> I would address this idea during my lesson by simply conducting the lesson and hopefully the results would just change their minds. Unfortunately, that does not always work (Posttest).

This shows Kate's progress from thinking that an experiment would "for sure change this preconceived idea" to knowing that even a carefully designed lesson "does not always work." She went on to suggest some alternative strategies, which she did not do in the pretest. These included reading a book, doing an alternate experiment, and trying "all the alternatives I could think of." In the final interview, she acknowledged that it was possible that students might not have met the learning goals despite the best efforts of the teacher.

> So you know um, what you've accomplished um, during the unit. I mean so you know as a teacher um, how much the students have learned from what you taught them. How much they've um, absorbed and um, I just, you know it's important to know if you've accomplished your goals because if you haven't you need to go back and possibly re-teach things in a different format (Interview 2).

Kate seemed to be thinking carefully about students holding on to their ideas in spite of experiences to the contrary. By the end of the semester, Kate was convinced that science teaching was not as simple as providing hands-on experiences. She knew that

multiple strategies might be needed in order to deal with her learners' ideas, and she also knew there was no guarantee that every student with an alternative idea would adopt the scientifically normative one. Developing this "professional vision" is an important aspect of improving practice, and the ability to see aspects of teaching as more complex is evidence of preservice teachers' developing PCK (Cohen & Ball, 1999; Sherin, 2004, 2007).

Summary of trajectory that shifts from certainty to uncertainty. Kate showed considerable growth during the semester. She grew to appreciate the resilience of students' ideas, though it came at the loss of trust in the power of a good experiment. Though her trajectory was one of becoming less certain, she developed more complex and nuanced ideas about her learners. "Muddling though" this difficulty is part of developing PCK. Recall that Wanda also contradicted herself throughout the semester. Kate gradually accepted the idea that teaching is not as clean as presenting an idea to students in the right way and changing their minds; this, while difficult for her, shows that her understanding of learners' ideas grew in sophistication.

Conclusions

In some ways, this chapter presents eight unique trajectories. Each preservice teacher brings her own experiences and ideas to the course and makes sense of the ideas in her own way. Often, literature describes "how preservice teachers learn," and while there are certainly trends, one goal of this chapter was to provide a window into the range of ideas that even a small group of preservice teachers brings to a learning experience. That said, there were trends in the findings presented in this chapter. Three of these are presented below: the importance of experience with learners, the resilience of preservice

teachers' existing ideas, and the "bumpiness" of their trajectories are all described in the following sections. Each of these themes illustrates a path towards developing PCK-readiness.

Experiences with learners

One trend in the findings was the importance of actual experience with learners. For both Riley and Katya, their reflective teaching assignment proved to be a small but powerful experience. While they had some initial ideas about the importance of learners' ideas, seeing these in action (for Riley, a strategy that failed, and for Katya a successful one) brought into focus their learners' ideas. Kate, too, was heavily influenced by her reflective teaching assignment; this experience challenged her initial ideas. Experience with learners is a major part of PCK, and an often cited reason for preservice teachers' lack of PCK (van Driel et al., 2002; van Driel et al., 1998). Providing many of these experiences with learners is logistically difficult in preservice teacher education, but these results suggest that even limited opportunities to teach science to learners can be beneficial in developing PCK about how to attend to learners' science ideas. Through being able to teach and reflect on science lessons, most of preservice teachers in this study were able to develop their PCK-readiness. These experiences with real learners changed the way they thought about learners' ideas.

Resilience of Preservice Teachers' Ideas

One key concept in the course was the resilience of learners' ideas: that learners have ideas for a reason, and sometimes even despite effective instruction, they hold on to those ideas. It should be no surprise then, that the results of this chapter suggest the same is true for preservice teachers' learning. Some preservice teachers were influenced by a

particular event or the course in general and changed their ideas over the course of the semester. Others, however, did not seem to change their ideas much. Amber and Aruna both entered the semester with ideas that were consistent with those being taught in the class; neither of them changed much in their thinking. The course did not seem to provide opportunities for them to push themselves beyond their initial (already sophisticated) ideas. Wanda entered the course with ideas that were very different from those taught in the course: specifically what the context of a school says about individuals and the ways in which students learn science. These ideas were still prevalent for her at the end of the semester, even though she grew in other areas.

It seems as if those preservice teachers who agreed "too much" or "too little" with the philosophy of the course and the program had fewer opportunities to change their ideas. Perhaps Amber, Aruna, and Wanda represent preservice teachers for whom the ideas in the course are outside their zones of proximal development (Vygotsky, 1978). While most preservice teachers' trajectories allowed them to develop their PCK-readiness, Amber, Aruna, and Wanda are exceptions. More thinking should be done about how teacher educators can help those preservice teachers whose ideas are resilient to change. Chapter 5 focuses on the activities that were designed to specifically support preservice teachers in thinking about learners' ideas. This chapter highlights the importance of those opportunities; preservice teachers (understandably) do not consider all aspects of their learners' ideas. Activities that are designed to force them to consider learners' ideas might be beneficial for those preservice teachers who do not push themselves to do so.

"Bumpy" Trajectories

Learning anything is not a smooth process; certainly this applies to something as complex as teaching. Looking at preservice teachers' learning in terms of trajectories rather than snapshots over the course of the semester shows the "bumpiness" of their learning as they develop their PCK-readiness. Preservice teachers contradict themselves. Wanda, who had naïve ideas about many aspects related to learners' ideas, wrote eloquently when asked generally why ideas are important, though almost everything else she said and did throughout the semester contradicted that she thought they were important at all. Katya wrote that if her students did not understand a concept, she would tell them the correct answer. When asked about this response, she contradicted herself and said that she knew telling them would not change their minds. She seemed to know that telling students was not an effective strategy but was not able to offer any others. Kate felt that experiments would "for sure" change students' minds, but waffled in this belief as the semester progressed.

As preservice teachers move from the intellectual work of the methods course to the practical work of teaching real science to real students, they need to assimilate what they are learning. As they do this, it is natural that they contradict themselves. Also, it is understandable that like Katya and Wanda, preservice teachers may be able to talk or write eloquently about a particular aspect of teaching, especially out of context, but struggle more to think about what to do in a real classroom when faced with the many challenges of teaching.

These steps are important as preservice teachers develop the building blocks of PCK. This chapter illustrates how different preservice teachers made progress in

different ways. For some, PCK-readiness slowly and gradually developed over time. Others struggled to gain traction in dealing with learners' ideas and did not change much. Some found that their experiences with learners helped them think about their ideas in richer ways or highlighted how important those ideas were. Several preservice teachers had a "bumpy" trajectory and contradicted themselves or grew less certain of their ideas. However, the results suggest that the course provided opportunities for preservice teachers with a range of initial ideas to develop their PCK-readiness over the course of the semester. The next chapter looks more closely at the methods course and specific activities designed to foster consideration of learners' ideas.

CHAPTER 5

PRESERVICE TEACHERS' EXPERIENCES WITH FAST ACTIVITIES

The previous chapter described the trajectories of individual preservice teachers across the semester. In this chapter, I look more closely at specific assignments designed to facilitate thinking about learners' science ideas across the entire class. This chapter answers the following research questions: How does preservice teachers' use of focused assignments on students' thinking (FAST activities) within the methods course support them in considering student ideas? More specifically, do different FAST activities foster different aspects of thinking about students' ideas? What kinds of thinking does the set of FAST activities as a whole support?

During the semester, the preservice teachers complete eight assignments (which I call FAST activities) with some emphasis on learners' ideas: a content conversation in which a child was interviewed about a particular science topic, two reflective teaching journals following a science lesson enactment, two responses to reading "images of inquiry," two activities in which a lesson plan was critiqued, and a reflection on a conversation with a group of peers. Each of these activities is described in more detail later in this chapter as well as in Chapter 3. Table 5.1 provides a brief description, rationale, and an example of the type of prompt or scaffold that each FAST activity provided preservice teachers.

Table 5.1: FAST activities summary

FAST Activity	Description	Rationale	Example of Prompt or Scaffold
Content Conversation	After interviewing a child, preservice teachers respond to prompts and reflect on the conversation in relation to planning their unit.	Conversations with learners about science topics provide opportunities to develop PCK with respect to their learners' science ideas (Smith, 1999).	What does the student understand about the science topic? What is your evidence for this claim? How will you use this in planning for your unit?
Reflective Teaching	Twice, preservice teachers teach a lesson and respond to prompts and reflect on their teaching.	Planning, enacting, and reflecting allows preservice teachers to develop their PCK (Zembal-Saul et al., 2000).	What went well? What didn't go well? What did students learn? What is your evidence for this?
Images of Inquiry	Twice, preservice teachers read and reflect on vignettes (the first set focused on students' ideas)	Considering others' choices can develop teachers' identity as science teachers (Abell et al., 1998, Smithey & Davis, 2004a).	Do you identify with the teacher? How did they use students' ideas in their teaching? How can you use this in your teaching?
Critique	Twice, preservice teachers create and choose criteria and refine lesson plans based on those criteria.	Critiquing lesson plans supports preservice teachers in learning to make substantial changes to typical lessons, an important skill for teaching (Davis, 2006b).	Preservice teachers are asked how the lesson meets and does not meet the criteria and what changes they would make to the lesson.
Peer Discussion	Face to face discussion based on prompt and written reflection on conversation.	Peer social supports are an important component of teacher learning (Putnam & Borko, 2000); scaffolding allows them to consider key course concepts (Smithey & Davis, 2004b).	How would you handle it when some students don't understand the science you teach?

These activities varied widely in structure, content, and in emphasis on students' ideas. For example, the content conversations were entirely focused on learners' ideas.

Applicable data for this assignment was often multiple pages for each preservice teacher. For the critique activity, the only applicable data was one sentence of a criterion and another short paragraph in the lesson critique. Similarly, in some of the FAST activities, preservice teachers were given a choice about how much emphasis was given to learner's ideas. Often, this meant that there was very little data because most preservice teachers opted for other emphases. Even in those activities where, due to the nature of the task or the choice of the preservice teacher, there is less emphasis on learners' ideas, each data source provides unique insight into how preservice teachers thought about their learners. Throughout the chapter, I point out where the amount or type of data is unusual as I describe the findings.

Overview of Results

The purpose of the FAST activities was to provide an opportunity for preservice teachers to consider their learners' ideas in different ways and with different types of supports. The results suggest that some types of thinking were well supported while others were not. Table 5.2 highlights the expectations and results for each FAST activity. Specific areas of emphasis from the coding key (see Tables 3.4 and 3.5) are in parentheses.

Table 5.2: FAST activities expectations and results

FAST activity	Expectations	Results
Content Conversation	Preservice teachers would be able to describe one learner's ideas, consider the relationship between what a child says and what she understands, and reflect on what this means for their units. (describing ideas, planning for instruction)	Some thought about planning for instruction based on their learner's actual ideas, but others thought in broader ways about how to use what they learned to plan a unit that promoted deep understanding. (describing ideas, planning for instruction)
Reflective Teaching	Preservice teachers would be able to reflect on how their planning and instructional decisions influenced student learning. (plan for instruction, decisions based on instruction)	After the first reflective teaching, they were not self-reflective but did think about how outside sources influenced learning; the second time, they were more self-reflective. In both, they focused on how the lesson did or did not show what students knew. (finding out ideas)
Images of Inquiry	In thinking about which teacher they identified with and how they felt about changes they made, preservice teachers would be able to think about how they would handle the same situations, especially in relation to learners' ideas. (anticipating ideas, importance of ideas, planning for instruction, decisions during instruction)	Most of the preservice teachers were able to not only critique the image teacher but think about their own teaching as well in terms of attending to learners' ideas. (anticipating ideas, finding out ideas, decisions after instruction) In the second assignment, there was not an emphasis on learners' ideas.
Critique	Preservice teachers would learn to make changes to instructional materials that better allowed them to learn and respond to learners' ideas. (finding out ideas, planning for instruction, decisions during instruction)	They made changes that provided more time to focus on learners' ideas at beginning and end of lesson; when given a choice, they did not emphasize learners' ideas. (anticipating ideas, finding out ideas, decisions during instruction)
Peer Discussion	By using social supports, preservice teachers would be able to have an honest discussion about the concerns and conflicts inherent in teaching while also attending to learners' ideas. (importance of ideas, resilience of ideas)	Preservice teachers did not emphasize students' ideas at all. They discussed other issues of importance to them.

FAST activities provided opportunities for preservice teachers to reflect on a range of ideas related to their learners' science ideas. The evidence suggests that these activities encouraged them to focus on aspects that they did not choose to focus on when given a choice. As a group, the FAST activities seemed effective in helping preservice teachers consider issues of anticipating learners' ideas, finding out ideas in teaching, and thinking about those ideas during and after a lesson. They were not effective in helping preservice teachers think about most aspects of the *characteristics* of their learners' science ideas, even though consideration of these ideas was expected.

Furthermore, even though different FAST activities might exhibit similar coding patterns (for example, reflective teachings and critique assignments both support thinking about finding out ideas), the results for each FAST activity highlight that the type of thinking done is quite different in different assignments. This suggests that a range of activities, even if there is some overlap in content, is important in helping preservice teachers consider different aspects of considering their learners' ideas.

Table 5.3 indicates which aspects of learners' ideas preservice teachers focused on while completing each FAST activity. The shaded boxes do not represent a statistical finding, but an indication of which codes, if any, were the primary foci. Certain aspects of attending to learners' ideas were emphasized through the FAST activities, and others were not, especially aspects related to *characteristics* of learners' ideas (see Table 5.3). While these concepts were intended to be a focus of the course, either the assignments did not lend themselves to thinking about them or the preservice teachers chose instead to

focus on other aspects of teaching. Possible reasons for this lack of emphasis are discussed later in the chapter.

Table 5.3: Summary of findings for FAST activities

	Content Conversation	1st Teaching Journal	2nd Teaching Journal	1st Images of Inquiry	2nd Images of Inquiry	Peer Discussion	1st Critique	2nd Critique
Characteristics of Learners' Ideas								
Anticipating Ideas				■			■	
Describing Ideas	■							
Factors that contribute to Ideas								
Difficulty of Idea								
Resilience of Ideas								
Importance of Ideas								
How to Deal With Ideas								
Finding out Ideas		■	■	■			■	
Planning for Instruction	■							
Decisions during Inst.							■	
Decisions after Inst.				■				

This chapter presents results in two parts. First, the findings from each FAST activity are presented. The specific results for each activity provide examples of the kind of thinking preservice teachers were doing in completing each assignment. Second, I discuss how these FAST activities fit together to provide a constellation of opportunities for preservice teachers to think about their learners' ideas and what opportunities might still need to be provided.

Main Areas of Emphasis in FAST Activities

The following section summarizes the types of knowledge of learners' ideas each FAST activity supported.

Content Conversation

The content conversation provided a unique opportunity for preservice teachers to talk extensively with one student about their ideas about a particular science topic on which the preservice teachers' units were based. After the conversation, preservice teachers were asked to describe their conversation, analyze what the student did and did not understand, and evaluate how the conversation would inform the planning of their unit. (See Appendix C for the instructions given to the preservice teachers.)

The content conversation provided unique opportunities to interact with students, and preservice teachers thought about their students' ideas in ways they did nowhere else during the semester (Table 5.3). The first relates, predictably, to how preservice teachers *described* the ideas their students expressed during the content conversation. The second involves how preservice teachers used the results of their conversation to *plan for instruction* as they considered the unit they were planning.

Describing Ideas. A major aspect of the content conversation involved preservice teachers describing and analyzing their students' ideas. When asked to describe the conversation, many preservice teachers simply restated what students said, but some synthesized the set of ideas their students had. Ella's work is an example of reporting her conversation; Carrie's is one of synthesizing her conversation.

Like many of her peers, Ella described her conversation by reporting each turn of talk. Ella did not seem to be thinking about what was said, simply describing it.

> The first question I asked Tom was, "What happens to a puddle of rain water?" He told me that "it evaporates into the air because of the Sun." Then, I asked Tom what he meant by evaporation. He told me that it was hard for him to describe, so I asked him to draw me a picture of evaporation. He drew me a picture of a Sun, Clouds (with raindrops falling from them), and a lake. When I asked him to explain the picture to me, he explained to me that "the water from the lake goes up into the clouds to make rain clouds and when there is enough water in the clouds it rains".

Carrie, too, recounted the conversation but seemed to think more carefully about what the collective statements meant in terms of her students' understanding. While she described her conversation with her student, her description was more than a transcript of the conversation. She seemed to try to piece together the parts of her students' ideas to summarize what he did and did not understand.

> He seemed to have the basic understanding of how clouds work and was able to relate it to the water cycle, but had specific misconceptions and inconstancies. For example, he told me that clouds were made of cotton but that they felt 'invisible,' you would be able to go through them. When I asked him how airplanes fly through them he answered that they need to go very fast in order to break through, inconsistent with his invisible theory. He also knew that puddles evaporate into the air when they 'disappear,' but seemed to believe that it needed to be sunny in order for this to happen.

Carrie found aspects of the science that her student understood and identified misconceptions as well. She even provided an example of him contradicting an earlier theory. While she met the criterion of describing the conversation, she also reflected in ways that are presumably more productive in terms of considering those ideas for teaching.

Preservice teachers have limited experiences with learners. The opportunity to have an in-depth conversation about science with a child is a unique one. Even those preservice teachers who do little more than report on what their student said are having an important experience. However, Carrie's example points to the possibility of a more

in depth reflection. Further consideration of how to better scaffold this kind of thinking is discussed later in the chapter.

Planning for Instruction. Preservice teachers were also asked to think about their conversation in terms of planning for their unit. Some wrote about their class as if they would all have the same ideas as the student they interviewed. For example, Wanda said, "I can probably assume that most of the things that he didn't know, or had misconceptions about, the others will too." Aruna too, generalized the idea of her student, saying, "Overall, based on these ideas I realized that the students may have a very vague understanding as to what electricity is" although she went on to think carefully about how this vague understanding might need to be addressed in instruction. She said, "In order to incorporate these ideas, I think I might pose this as a question and then design an experiment or an experience or exploration in order to learn more about the topic and to help students understand the ideas to a deeper level."

Natalie made two kinds of generalizations: that her student's previous science knowledge was indicative of the class and that the class would have similar areas of difficulty.

> I know from speaking with Lynn that the students have done some in depth work on the water cycle in previous grades. I will need to amend my lesson slightly to make them more difficult and challenging. I can expect more of the students. I also know that condensation is the weakest area for Lynn, and likely many other students as well.

Finally, Jade, who thought carefully about how she could leverage a real-life experience to help her students better understand the science, assumed that just because her (preschool) student had flown in an airplane, her other students would have had a similar experience.

> Because many students will have had the opportunity to fly in an airplane I would try to use this to inform my students thinking about what clouds are really like. Using Yoshki's ideas I would be easily able to build on the ideas of the water cycle (very introductory with preschoolers) and the composition of clouds.

Even though some of these represent simplistic perspectives that all students will follow the example of the interview subject, some preservice teachers did still think carefully about how they might handle these ideas in their instruction. For example, Aruna thought about what specific strategies might give her students a deeper understanding, Natalie recognized the need to challenge her students more than she had initially planned, and Jade thought about how an experience could be used to help students understand a science concept. On one hand, these preservice teachers did not look beyond the ideas their individual student had. However, they were still able to think in productive ways about how to deal with these ideas in their instruction.

Other preservice teachers thought in broader ways when asked what their conversation meant for their unit. Even though the assignment did not ask them to think specifically about these concepts, some preservice teachers reflected on types of representations, curriculum, and assessment of true understanding instead of knowledge of facts. These topics were not directly related to what was said during the conversation. However, the conversations provided inspiration for what kinds of instruction might be productive. As these preservice teachers thought about the struggles encountered by their students and how to deal with them, they ended up reflecting on more general topics. This assignment allowed them to develop their PCK in other areas as well; this was not planned for in the design of the assignment as there are no prompts related to broader issues.

Six preservice teachers are presented below as examples of thinking more broadly regarding their students' ideas. The specific focus of their thinking is different; they consider ideas related to scope and sequence of curriculum, making science applicable to students' lives, and focusing on deep understandings. However, they are also similar in that they branch out from thinking about using the specific ideas their student reported in planning for their unit.

For example, Carrie thought in terms of scope and sequence in terms of how her conversation would impact her unit. She was planning a unit on clouds, and her class was in the middle of a unit on the water cycle.

> Our classroom science focus right now is on the water cycle, and I find this difficult to fit into the unit because not every grade one class will cover the water cycle the way that our class is. How should I fit in clouds with the water cycle, when it seems that clouds are a product of the water cycle? So in some ways the content conversation has confused me because I know that students cannot think of clouds as a separate unit when the water cycle is already being covered.

She seemed to gain an appreciation for how clouds and the water cycle are closely related and that it is not simple to teach one without the other. While she did not resolve this issue, the fact that she was struggling with the specifics of how science concepts relate to one another and how the pedagogical implications of teaching one without the other might impact student understanding shows important PCK development.

Leslie and Ali both realized the importance of making a connection to students' lives after their conversations. Leslie chose to interview two students, and she saw a difference between the two and believed that being able to relate concepts to real world examples was a key factor in the student who understood the ideas in a more usable way.

> Roy seemed to have more book knowledge whereas Tori used her own ideas to relate to the science questions. From this information, I would definitely incorporate real life ideas to the concepts. Roy was not able to give me examples

> but he was able to reiterate what was said in his book. Tori may have had some different ideas but was able to relate them to examples that helped her remember the information.

Ali, too, became intrigued by the fact that her student seemed to be most interested in a concept she could relate to, and she planned to use relatable examples in her unit to "strengthen the concepts being taught" and not only to spark interest.

> I also realized that the topic that sparked the most interest in Laurie was talking about the evaporation of water in her fishbowl. This encourages me to find some sort of experiment or direct connection to the student's lives to strengthen the concepts being taught and get the students excited about this topic.

Even though real world examples of science concepts is not directly related to students' ideas, the students' ideas sparked these reflections, and their focus remained student learning. While Ali's student was merely interested in her fishbowl, Ali thought about how she could leverage this to promote deeper understanding.

Several other preservice teachers thought carefully about promoting understanding as well. Brandi, Kim, and Riley all came away from their conversation thinking about the difference between knowing facts and truly understanding a concept. The student Brandi interviewed seemed to have a grasp on the basics, but Brandi saw the potential for deeper understanding.

> He did not have any of the misconceptions I had thought students his age might have, or any 'alternative ideas' that stand out to me at all. I think he basically needs to learn about things in greater detail, and more of why things happen rather than what happens.

Kim, too, thought about her students' understanding. She recognized that previous instruction about a topic did not guarantee that students would develop a deep understanding.

> Even though our [cooperating teacher] said not to teach the Water Cycle because as fifth graders they've already exhausted the topic, I feel as though it has passed over the head of this student in particular.

Finally, Riley also thought carefully about her student's understanding of concepts versus knowledge of facts. She wanted to look deeper than the facts he knew. She viewed being able to tie ideas together as important and a concept that she needed to build into her lesson through the driving question.

> First, I wanted to see how well Robbie understood what they learned in class. Second, I wanted to find out how he tied them all together in his head. He understood the specific concepts very well, but failed to tie them together, which made me realize that drawing everything together may be a common teaching mistake. Knowing what happens when puddles sit in the sun for awhile is great, but without the connections to many other concepts, it is not very useful. I want to make sure that when I plan or teach a science unit, the driving question guides every lesson toward one broad idea.

When these preservice teachers thought about planning for instruction, they focused on their students' ideas, but they went deeper than generalizing their specific ideas. Even though their topics of curriculum coverage, connecting science to students' lives, and promoting deep understanding differ from one another, there are commonalities in this group. All of them thought beyond their student's specific ideas and considered a larger issue of science instruction.

Summary. The content conversation provided unique opportunities for preservice teachers. First, they were able to interact with a student in ways that are typically difficult for preservice or practicing teachers simply by having a conversation centered around science concepts. Having this conversation alone is productive in promoting PCK-development (D. Smith, 2000). Second, in terms of focusing on learners' ideas, the content conversation allowed preservice teachers to describe actual science ideas and to use those ideas in planning for instruction. These are aspects of learners' ideas that no

other course assignment promoted (see Table 5.3). When describing ideas and planning for instruction, some preservice teachers described their students' ideas by providing a play by play of each interaction rather than reflecting on patterns or synthesizing their students' understanding. This type of over-simplified interpretation has been identified in other work with preservice teachers (Davis, 2006a). When asked to think about their student's ideas in planning for instruction, some predicted that their class would exhibit the same level of understanding as the student they interviewed. Others were able to think about other aspects of instruction and promoting understanding based on what they learned from their interview. This pattern continues in other FAST activities as well. The conclusion section discusses how to better foster consideration of learners' ideas in those preservice teachers who did not engage as deeply as some of their peers. It was encouraging, however, that the FAST activities did seem to provide opportunities for preservice teachers with a range of ideas to engage in thinking about their learners.

Critique Assignments

The data from the critique assignments is very different from that of the content conversation. In the content conversation, the preservice teachers typically wrote several pages focused specifically on their student's ideas. In the critique, however, there was one criterion (usually one sentence) and a short critique based on that criterion (usually a short paragraph). So while parts of the critique activities were very focused on students' ideas, there was very little data to analyze. Recall that there are two critique activities, done at different times in the semester. The results from these two activities are presented separately in this section.

Critique 1. In the first critique assignment, preservice teachers created several criteria by which to critique science materials; one had to be focused on students' ideas. They used these criteria to evaluate a particular lesson plan with a partner. For this section, both the criteria they constructed and their critiques of the lesson were coded for their focus on students' ideas.

The importance of having time to focus on students' ideas emerged from the individual criteria and critiques. Several preservice teachers thought it important that the lesson build in time for teachers to focus on learning or dealing with their students' science ideas and provide them with resources to do so. For example, Kelly's criterion suggested that there should be "time to deconstruct misconceptions. The plan [should] also give information on what prior knowledge the students might or might not have." Riley emphasized that there should be time for the teacher to find out students' ideas at the beginning and end of a lesson. Brandi and Wanda also suggested that time should be devoted to students' misconceptions. Ella's critique criticized the lesson for not providing the teacher with the opportunity to address common misconceptions or find out students' prior knowledge.

The issue of time was important for these preservice teachers. They felt that the teacher should be given time and guidance for finding out what students' ideas might be. They believed that finding out those ideas was important for effectively teaching, but they also felt that they needed guidance and time in order to do so. This theme continued in the group critique.

In the group portion, partners chose three criteria from a class-generated list and critiqued the lesson together according to their new criteria. They were not required to choose criteria related to students' ideas, and only six groups did so.

Beth's individual criterion was that a lesson should "allow students to ask unexpected questions about possible misconceptions." Three groups chose to evaluate this lesson based on this criterion. All three felt that the lesson did not provide time for students' questions. One group said the lesson was too "packed with activities" to allow for this kind of questions, one felt that the lesson should open each day with time for students' new questions, and another felt that the lesson left "no room for error."

Like the criteria generated by the individuals, time continued to be an important factor in the group critiques. This shows that considering students' emerging ideas was important to them and that they recognized the need for time and structure built into curriculum materials to support them in attending to those ideas.

Three other groups chose a different criterion related to learners' ideas; the lesson "allows students time/opportunity to explore their prior ideas and compare them to what they learned." Again, none of the groups were pleased with the lesson they critiqued in terms of this criterion. One group suggested adding a KWL (listing what students know/want to know/learned from the activity) to the lesson to better address students' misconceptions. Another suggested having a closing activity where students individually reflect on what they learned and compare their final ideas to their original predictions, and the third group suggested a similar final comparison activity.

While the idea of comparing initial and final ideas had not been a focus of discussion or course assignments, it appears to have found traction as a way for teachers to gauge how their students' ideas did or did not change over the course of a lesson.

Critique 2. For the second critique activity, done later in the semester, preservice teachers were given 7 criteria generated by the instructors. They were asked to select 3 of these to use in evaluating a lesson plan (different from the lesson from the first critique assignment). Most groups only had time to complete their critique using two criteria. One of the seven criteria was focused on students' ideas. It stated:

> The lesson incorporates ways of helping the teacher identify and/or anticipate students' prior knowledge and alternative ideas, before, during, and after the lesson. The lesson does not try to simply replace these ideas with more scientific ones, but instead tries to build on those ideas constructively—for example, through asking probing questions, providing scaffolding, incorporating relevant experiences, and minimizing technical vocabulary.

Four groups consisting of seven preservice teachers chose to critique the lesson using this criterion. Even though nothing specifically about predictions was stated in the criterion, three of the groups brought up the fact that the lesson does not ask students to make predictions. All three suggested that this would be a way for the teacher to identify their learners' initial ideas. Again, finding out ideas, though this time in the form of predicting, emerged as a focus for how to deal with students' ideas. A related critique voiced by three of the four groups was that there should be more probing questions throughout the activity and in the final discussion. Beth and Holly, for example, were concerned that the lesson did not identify or anticipate prior knowledge and therefore "does not build on students' ideas constructively because student ideas are not present". They suggested probing for students' ideas initially and building on those ideas throughout the lesson.

Summary. The critique activities did not provide opportunities for preservice teachers to reflect extensively on learners' ideas. However, preservice teachers were able to identify aspects of attending to learners' ideas that were important to them. On the one hand, there was not much data to analyze, but the work the preservice teachers did was unique from the work they did in other assignments and had different foci. In addition, these activities also showed what emerged as salient for preservice teachers because they had a choice on what their criteria said and which criteria of their peers to chose. The issues of time to attend to ideas, allowing students to explore their own ideas and emerging questions, and allowing the teacher to learn students' initial ideas in order to deal with them during the lesson are all sophisticated examples of how the critique activity encouraged them to think about students' ideas.

Reflective Teaching Journals

Twice during the semester, preservice teachers taught a lesson in their placement classrooms. One lesson pertained to the unit they were planning, the other integrated what the elementary class was currently studying in science. The preservice teachers could choose which lesson to teach first and which to teach second. After the lesson, they completed a reflection in which they were asked to recount the lesson, including what went well and what did not go well, what the students learned, and what they would change next time (see Appendix B). Those who followed the format of the reflection guidelines reflected more about students' ideas than those who reflected generally. The structure seemed to be an important scaffold in helping them think critically about their practice.

Differing Perspectives. One of the findings from analyzing both reflective teaching assignments was how prevalent differing perspectives were regarding the same lesson. Even though preservice teachers planned and taught a lesson in pairs (or groups of 3), often, their reflections about their experiences were quite different. Below is one such example from Naomi, Wanda, and Shelby's first teaching experience. Emphases are added to some of the quotes.

Naomi felt strongly that the lesson was not successful. She was frustrated with the actions taken by her partners, and her concern seemed to be centered around the students' learning.

> *This lesson did not go so well for many reasons*….I was also frustrated because we had the students predict which glass would have the highest pitch, and after asking the first two tables (everyone knew the answer), I was ready to move on because it was obvious that the class understood, but my partners wanted to continue on and ask the entire class the same question and get the same answer. I think that was a waste of time. I think that we wasted a lot of time during this lesson….*This particular lesson wasn't that rich in science content.*

Her conclusion at the end of her reflection was that one of the major problems was that the lesson was not rich in science content. This was salient for Naomi, as she referred back to this during her second reflective teaching journal later in the semester (she believed her second lesson went better because there was more content to focus on.)

Wanda agreed with Naomi that the lesson was not successful, but their assertions as to why were totally different. While Naomi was concerned that the lesson lacked an emphasis in science content, Wanda worried that they looked bad in front of their cooperating teacher and principal.

> Everything would've been fine, if the children didn't know everything already!…Since the kids knew everything about the lesson, we finished about 15 minutes early. So, we asked the CT what we should do next, and she told us that this was our lesson and we needed to figure it out. So, we did 3 read-alouds. (Did

> I mention that the principal was there!) If I was the real classroom teacher, I would've just gone on to the next lesson, or the next subject, etc. Instead, we tried to drag out the lesson, and ended up just looking stupid!

Unlike her peers, Shelby felt that the lesson was successful.

> Overall, *I found the lesson went very well.* For example, during the discussion many students gave correct answers. The worksheets revealed that the students were engaged in the lesson through their ability to follow directions….. I felt this was an important step because following directions prevented the opportunity for misconceptions to form….The students came to the front of the class as groups. However, they played their songs individually upon the glasses of water. To encourage their efforts of composition I gave positive reinforcement through clapping and verbal comments.

While Naomi and Wanda found it problematic that the students already knew the answers, Shelby found this to be encouraging. She felt that because students were following directions, misconceptions would not form. She focused on more superficial aspects like being engaged, following directions, and encouraging students rather than their learning of the science content.

These three perspectives on the same event are important because they highlight the importance of the experiences and beliefs that preservice teachers bring to the methods classroom. If different criteria for success are used, then the same event can be perceived in vastly different ways. In addition, these reflections highlight how different individuals thought about attending to learners' ideas. For Naomi, student understanding of science content was important; she chose to focus her reflections on how this goal was not met. Wanda and Shelby chose to focus on other aspects; attending to their learners' ideas was not an emphasis for either of them. These serve as a reminder that even though assignments might attempt to foster thinking about students' ideas, in the end, it is the preservice teachers who decide what they will think about when reflecting on their own experiences.

The next two sections describe more general trends that emerged from the class during the first and second iteration of the reflective teaching journals.

Reflective Teaching 1. In the first reflective teaching journal, several preservice teachers were able to identify weaknesses in their teaching materials, specifically in finding areas where they did not effectively attend to students' ideas. In general, these comments were limited to weaknesses in the materials, however, and did not extend to the preservice teachers' own teaching strategies. Usually, when the preservice teachers were trying to evaluate what students learned or did not learn, they realized that their assessment was not adequate to determine their students' ideas (Zembal-Saul et al., 2000). Four preservice teachers are presented below as examples of this type of thinking.

Ali was frustrated with the content of the worksheet; she felt that it did not allow her to see whether her students truly understood the content of her lesson.

> I did not like this worksheet that was part of the original lesson for a few reasons. First, it did not correspond with the book and the steps in the cycle. I should have and, if re-taught, would rewrite the worksheet. Second, it tells me nothing of what the students learned. I know what information they may have heard and caught in time to write down, but it tells me nothing of what they understood.

Leslie, too, thought the worksheet she used during her lesson was not a sufficient assessment. She wrote that she felt pressure to use the materials her cooperating teacher wanted her to use, but that next time, she would supplement with having students ask questions about their observations.

> I really enjoyed the lab but didn't think the worksheet was beneficial to the students. I liked how the students had to write down their observations but it did not show what they learned.

Riley had the same frustration. After having her students write or copy a sentence from the board, she realized she could not say what they learned from the lesson.

> It is hard to tell exactly who learned what with such a young age, because few of them were able to write their own sentence about what happened. …Since they are used to doing drawings and writing (or copying) a sentence for science, this is the format we took, but I don't think I would use this again because I don't think it gives a very accurate indication of what they have actually learned.

Recall that this excerpt was discussed extensively in Chapter 4 because it became an important event in Riley's PCK development over the semester. Her ability to criticize the strategy allowed her to realize what kinds of strategies would be more effective in finding out learners' ideas.

Riley, Leslie, and Ali all showed important signs of PCK development. Identifying weaknesses in materials, especially where they do not support students in developing understandings, is part of the work of teaching.

Ella, like Riley, Leslie, and Ali, had problems with the assessment, but unlike her peers, she was critiquing an assessment she designed.

> The main thing that I would change next time is my assessment of the students. I would have them answer a more structured question. The structured response I would have them complete is "to draw a picture of the penny and label where cohesion, adhesion, and surface tension occur on the penny." I would also provide them organized worksheets (especially for predictions and conclusions) to help them better follow the lesson and understand the significance of what is happening during the lesson.

So Ella, too, found problems with the assessment but pointed the finger at herself. She used this experience to think carefully about what kinds of assessments she would design in the future.

In general, during the first reflective teaching, preservice teachers showed some important PCK development in that those who were looking for evidence of student learning often had problems finding it. This caused them to look critically at the materials they were using. Many found specific instances of how the materials did not

support student learning and were able to think through how they might modify them to better reflect their students' ideas. Other than Ella, though, the preservice teachers generally did not think about their own roles in enacting these materials or in facilitating understanding in general. However, this began to change in the second reflective teaching assignment.

Reflective Teaching 2. In the second reflective teaching assignment, preservice teachers seemed to be more aware of what they did not know. They were able to look beyond finding problems only in the materials and look at themselves as well. In addition, they discussed in more depth changes they would make in their own teaching were they to teach the lesson again.

For example, Ali again focused on the worksheets, but in this reflection, she emphasized the misunderstandings that she noticed and took responsibility for not making the concept clear in the discussion.

> The questions were tough, but I think the students did very well with them, at least when we talked about the questions afterwards. …However, when looking over their lab sheets, there are some common misunderstandings. …This is something we talked about and tried to clear up when going over the lab sheet, but I am not certain it was made clear to the students.

While she discussed the worksheets as she did in the first reflective teaching assignment, the tone is different. In her second reflective teaching, she emphasized student understanding and the aspects of the lesson that impacted it, including her own instructional decisions rather than just the design of the worksheet.

Natalie was concerned that her students still had a particular misconception at the end of the lesson. She felt pressure to move on before she was ready, but she seemed to regret her decision:

> The kids' main misconception was about the location of water vapor (that it is not constantly part of the air). They talked about water vapor evaporating directly from the cup and forming the condensation on the side. I tried to get at this misconception, but I didn't want to take up too much time (from Ella and Kim) and I also wanted to leave something for them to discuss.

Leslie found evidence for student learning and her lesson was successful by her own report. However, she found many things to improve in her teaching.

> At the same time, there are many improvements to be made in the future. I definitely need to lengthen my 'wait time' when asking questions. For some of the questions I would have the same students raise their hand so my natural instinct was to call on them instead of waiting.…I also need to relax a little because once I start moving into exciting labs I forget to ask things that I wanted to ask. I wanted the students to predict the percentage before doing the experiment but I completely forgot. Predicting is always a learning experience in science. Once of the last things I would change is my closure of the lesson. I need to connect it more with their prior knowledge by asking more real life questions. It could lead to discussions on fire, small or large spaces, or just about living. I was caught up in the discussion of the worksheet as well as the calculations and didn't have a solid ending to the lesson.

Each of these changes Leslie suggested pertains to students' ideas: attending to every student during class discussion, asking probing questions, and finding closure at the end of a lesson. Leslie was self-reflective and even though she taught a successful lesson, she still was able to identify aspects of her instruction to improve upon.

Like Leslie, Ella found herself calling on the same students repeatedly and reflected on why she made this choice.

> One thing I thought did not go well was that not many of the students were raising their hands to participate in the whole class discussion.… I would have called on people who did not raise their hand, but I was not close with the students because we taught the lesson in Natalie's classroom. I felt like I called on the same students that had been called on during Natalie's and Kim's part of the lesson and I did not like that feeling; I wanted everyone to participate.

Ella was also not happy with her assessment. "In addition, I would have made up a worksheet like so to help the students better organize their thoughts, observations, and

newfound knowledge." In the earlier reflective teaching journal, Ella found flaws with the assessment, although she spent more time considering how to handle the class discussion in a more equitable way.

Sam felt that leaving time for closure in his lesson was important (he was not left enough time to do this in the first lesson and wrote about its impact on the lesson). In doing so for the second lesson, he worried that a particular representation he used was not well understood by his students. In fact, throughout his journal, he returns to this three different times.

> I went a little too fast through the definition of the water molecule. I used little circles as substitutes for the oxygen atom and two hydrogen atoms and the students didn't immediately make the connection between the circles and the molecule…. One thing I would change next time is the emphasis on the water molecule. I would make sure that the structure of the molecule is understood and that atoms make up the molecules….This was not a huge problem, but some students definitely did not make that initial connection.

Sam carefully attended to his students' ideas. His reflection was centered around a specific problem he noticed with a representation he used. Like his peers, he was able to pinpoint areas of his teaching that he would improve upon.

Summary. During the first and second reflective teaching journals, preservice teachers focused on anticipating students' ideas and dealt with those ideas during and after instruction, in talking about decisions they made during the lesson, and especially what they would do differently next time (see Table 5.3). Based only on patterns in the coding, there seemed to be little difference between the first and second journals.

However, there were some key differences. After teaching their first lessons, some preservice teachers struggled to find evidence of student learning. They pinpointed

the materials as the problem with showing students' understanding. Very few preservice teachers found problems in their own instruction.

By the second iteration, some key changes emerged with respect to students' ideas. The most obvious was the ability of the preservice teachers to think about how their own instructional techniques could have improved. From general ideas like wait time to specific ideas such as particular instructional representations, they were able to focus on how their own choices impacted their students' learning. Rather than pointing to outside sources like the curriculum, they took more ownership of the outcome of their lessons. Another change was that they were able to look beyond the assessment's role in learning. In the second set of journal entries, they evaluated the lesson's assessments, representations, teacher questioning, and whole class discussions.

Images of Inquiry

Images of Inquiry were fictional narratives embedded within lesson plans on the CASES website. Each "image teacher" had a particular focus such as attending to learners' ideas, teaching science to young students, or teaching inquiry in a school environment focused on standardized test scores. Preservice teachers read about how an image teacher taught each lesson in a particular unit. For the first images of inquiry assignment, preservice teachers were asked to read about two image teachers, Nancy and Emily. The focus of both Nancy and Emily was attending to their learners' ideas. These images were embedded in the weather unit (the focus of the course), so for each lesson, preservice teachers could read about how Nancy, a third year teacher, and Emily, a preservice teacher, taught the same unit. For the assignment, they were asked to reflect on these images and discuss whether they related to Nancy or Emily. For the second

assignment, later in the semester, preservice teachers were able to select any image teacher and reflect on their response to those images, so they had a choice about whether or not to focus on learners' ideas. See Appendix D for the instructions given to preservice teachers for both image assignments.

Recall from Chapter 3 that for assignments where preservice teachers had a choice in whether to focus on learners' ideas, the assignment was scored from 0 to 3, with 0 representing no discussion of students' ideas and 3 representing a document entirely focused on it. These scores did not judge quality or sophistication, only the amount of emphasis on learners' ideas.

First Images of Inquiry Assignment. Nancy and Emily's images were written with an emphasis on attending to learners' ideas. Not surprisingly, the preservice teachers' reflections also focused on students' ideas. Five preservice teachers' reflections were scored as a 1 with very little discussion of students' ideas. The other 15 were scored either a 2 or a 3, so for the most part, their reflections were centered specifically on students' ideas. Most of those who had a 1 merely commented on specific changes Nancy or Emily made to the lesson that may not have centered around learners' ideas.

Some of the preservice teachers did not think about Nancy and Emily's images in terms of how well they related to one or the other but instead merely judged the decisions they made. For the most part, these were the preservice teachers who did not emphasize students' ideas. Kim's work is an example of this type of reflection. She was critical of Emily because she did not have a good understanding of her students' previous instruction, and she did not make an effort to relate these experiences to her own.

> It was nice that Nancy's class already had previous knowledge to build off of such as reviewing the concepts of "revolution, rotation and axis" from before however

> finding out what Emily's class already knew would have been key to the way her lesson should have been taught and the length of time she needed. Had she found this information out from the teacher before hand maybe there would of been some previous knowledge she too could have built off of.

The majority of preservice teachers engaged in more thoughtful reflection. Two important and related findings emerged from this group. First, the content of the reflection centered around anticipating students' ideas. Some of the preservice teachers were critical of Emily's inability to anticipate her learners' ideas, but many identified with her for this reason. The second, related finding, was that this assignment enabled preservice teachers to not only critique someone else, but to think about their own teaching, especially when discussing why they identified with Emily. Those presented below all thought they, too, might have difficulty anticipating learners' ideas. So while the discussions center around anticipating students' ideas (see Table 5.3), perhaps the more interesting finding is the ability of preservice teachers to reflect about their own practice and areas for improvement. Five examples of this type of thinking are presented. All five of these preservice teachers were able to use the images to think about their own teaching.

Leslie felt that although Emily did not anticipate her students' ideas, she handled the lesson relatively well. Leslie also worried about her own ability to predict her students' ideas.

> Even though she did not predict some of their responses, she quickly used extra tools to see if they could come up with a correct answer. I definitely don't know what to expect in my class because I don't know what the students know about the information. … If Emily's situation happened to me, I would stop and try to think of ways I could get the class to understand what happens to the puddle.

This leads to an interesting observation of Leslie's ideas about her own weakness in this area.

> She really picked up on how the students were relating the information. I don't know if I would be able to observe as much as she did. I would need a teacher to watch the students and take notes on what they see are the problem areas. I feel when I teach, it is hard for me to know if the students understood the lesson.

Leslie seemed to struggle with her own ability to assess her students and would need "a teacher" to help her do this. Leslie was open with her struggle to think of herself as a competent teacher. As in the reflective teaching assignment, discussed earlier in this chapter, Leslie was a preservice teacher who consistently found opportunities to be reflective of her own weaknesses and thought about how she would handle difficult situations.

Like Leslie, Naomi identified with Emily and she, too, worried about dealing with students' ideas as a lesson progresses.

> I identify with Emily because like her, I sometimes forget to anticipate lessons or students' understandings not going according to plans. It is important to keep lesson plans flexible because it is not certain how the students are going to respond to the lesson or activity.

Ella is another example of a preservice teacher who struggled when thinking about attending to her learners' ideas. Thinking about how she related to Emily helped her identify this in herself.

> I identify with Emily more than Nancy because like Emily, I would be worried about whether I was effectively addressing my students' prior knowledge when teaching a lesson.

Kate felt that, like Ella, she would struggle if unanticipated ideas surfaced during a lesson.

> I feel that I would also be stupefied if an experiment did not turn out the way I had planned or if students were making comments that I had not thought of, and I worry that I would not come up with quick modifications to remedy these issues in the classroom environment.

The ability to admit that she would be baffled if something unexpected happened in the classroom is an important development. For preservice teachers to recognize what they are and are not able to do is a key initial step in developing PCK. Leslie, Naomi, Ella, and Kate all worried that they would not be able to effectively anticipate and attend to their learners' ideas. Leslie worried that she would not measure up to Nancy, and Naomi, Ella, and Kate all identified with Emily's struggles. Either path opens the door to self-reflection and engaging with a key concept about learners' ideas.

Shelby also identified with Emily. It was unusual for her to engage so thoughtfully with an assignment; typically, Shelby wrote very little and was not particularly reflective about her own teaching.

> I read through the lessons and found that I had a close connection with Emily. I found this person to stand because she is going through the same steps I am at the present time. For instance, she has some ideas about how to teach a lesson and so do I. Yet, we both lack the experience that only comes through actually teaching. The lack of experience leaves open the opportunity to overlook certain misconceptions in our students during planning.

Shelby seemed to feel an attachment to Emily (the phrases "close connection" and "our students," for example). After this excerpt, she wrote that the image gave her ideas about specific misconceptions her students might have since she was planning a unit around the topic of the lesson she evaluated. This assignment, probably more than any other during the semester, provided Shelby with the opportunity to reflect about her own weaknesses and think about planning for her unit with respect to learners' misconceptions.

The first images assignment provided unique opportunities for preservice teachers in several ways. First, they engaged in talking extensively about anticipating their learners' ideas. While some were critical of Emily's inability to do this, more identified with Emily for this reason. This allowed them to reflect about their own ability to predict

their learners' ideas in ways that were not seen in other course assignments. Specifically, this assignment seemed to provide opportunities for personal reflection for preservice teachers at all points on the continuum of PCK-readiness. For example, Ella, for whom learners' ideas surfaces in much of her work, and Shelby, who was rarely self-reflective, were both able to engage in thinking about their own abilities to predict their learners' ideas.

Second Images of Inquiry Assignment. Recall that for the second images of inquiry assignment, preservice teachers were able to choose any image teacher. So unless they chose to focus on Nancy or Emily again, the emphasis of the image was not on attending to learners' ideas. Not surprisingly then, only three reflections showed a strong focus on students' ideas (scoring a 2 or a 3). Two of these three chose to reflect on Nancy and Emily again; the third brought her own focus of students' ideas. Many other important topics were discussed by the rest of the class, such as how to help students provide evidence for explanations or how to teach complex scientific concepts to emergent readers.

Two responses are briefly described below. They are certainly not typical of their peers' responses, but show how two preservice teachers (Leslie and Ella) maintained a focus on students' ideas.

Ella chose to focus on Nancy (her first image assignment focused more on Emily). Like in the first assignment, she emphasized the importance of anticipating her students' ideas.

> Within the teaching of science, I have not really had a dilemma as of yet on how my lesson did not go well because I did not pre-think out what misconceptions could happen well doing a science lesson. However, this is definitely one of my

> fears as being teacher. The fact that I did not plan on addressing certain issues because I did not think they would be a problem for students.

This is one more piece of evidence that attending to students' ideas was an issue of importance for Ella. Throughout this chapter, her work demonstrated how she chose to focus on her learners' ideas, even when, like in this assignment, she had a choice over what topic on which to reflect. While Ella's attention to learners' ideas was not typical, she does demonstrate how each assignment provides traction in different areas of a particular issue of importance.

Leslie, who was also reflective about her role in anticipating students' ideas during the first images assignment, chose to focus on Eli. The focus of this image was teaching under pressure of standards and testing. Leslie thought about this issue in terms of balancing this with also attending to learners' ideas.

> Sometimes it is necessary to have the students go through steps and change their ideas to the correct idea. … If the students have strong alternative ideas sometimes it is necessary to change the procedure of the lesson. At the same time, the student need to learn the concepts for the standardized tests. Eli could have based the lesson off of the alternative ideas but also tied other parts of the lesson in order to get the conceptual understanding of the topic.

Like Ella, Leslie was a preservice teacher for whom learners' ideas were of importance. Even though a reflection about preparing students for standardized tests could have gone in many different directions, Leslie chose to juxtapose attending to standards and to learners' ideas.

The second image of inquiry assignment allowed preservice teachers to choose their area of emphasis. Only three chose to think about learners' ideas in depth. Two of those did so by choosing to read more about Nancy and Emily (whose images were written to emphasize attending to students' ideas) and Leslie brought the focus in on her

own. While most of the class chose to emphasize other aspects of science teaching, it seems that those for whom attending to learners' ideas is especially important, continued emphasis was something they found helpful.

Peer Discussions

Recall from Chapter 3 that the discussion assignment changed during the course of the semester. Initially, the preservice teachers were to respond to a prompt related to learners' ideas using the online discussion tool they had previously used. However, the previous online discussions were not particularly interactive and the preservice teachers complained about the format. So as the instructor, I offered an option for this assignment. Preservice teachers could respond to a prompt (see Appendix A) either via the online discussion or through having a conversation with a small group of peers from the course and writing a reflection about that conversation. All but two in the class chose to have a conversation. Even though this activity was designed to encourage preservice teachers to focus on their students' science ideas, in fact the discussions centered around other topics. In general, the preservice teachers had interesting, thoughtful conversations around ideas central to teaching in general and science teaching specifically. Several wrote how encouraging it was to have informal conversations with their peers and how valuable a resource they found their peers to be. While topics varied, several groups discussed particular teaching strategies (such as using centers), student versus teacher directed inquiry, depth versus breadth in science curriculum, and creating a comfortable learning environment. While this activity seemed to foster important conversations, there was very little focus on students' ideas. In fact, only one preservice teacher emphasized learners' ideas in her journal.

Ella tended to emphasize students' ideas in earlier assignments as well, and this pattern continued during her reflection about the conversation. Ella was the only preservice teacher who emphasized students' learning in the written reflection of the face to face conversation. In fact, the first sentence of her journal reads, "The big topic covered was how to maximize students' learning." Of course, Ella was summarizing the same conversation that her group members summarized in their journals, but she brought out the emphasis on students' ideas in her reflection. While her peers listed pros and cons of particular strategies, Ella did the same but included comments like "Students need to be challenged so they can grow" and "This conversation made me realize again that science teaching is more than just knowing the facts about science; it's about making sure that students feel both comfortable and challenged in their learning environment." Ella's reflection was not drastically different from those of her peers, but she did seem to be adding her own emphasis on students' ideas where her peers did not.

Overall, this assignment was an important addition to the course. Topics that were not covered in class were discussed and perhaps more importantly, preservice teachers were able to share their own worries about becoming science teachers. However, there was almost no discussion directly related to attending to learners' ideas, despite a prompt focused on this topic. This, like the second critique activity and the second images activity, is further evidence that preservice teachers, while able to focus on learners' ideas, typically did not do so when given a choice of other aspects of teaching. For this reason, it is important to have assignments where they are required to think specifically about how to attend to their students' science ideas and assignments where they can feel a greater sense of ownership and choose to think about issues of

importance to them. The next section discusses this balance and how these activities worked together to provide a range of opportunities for the preservice teachers.

FAST Activities: How do the pieces fit together?

Each individual FAST activity fostered different kinds of thinking related to students' science ideas. The following section describes the unique contributions of each activity and discusses how the activities worked together to form a set of experiences to foster a rich set of ideas for preservice teachers as well as what aspects were not especially well-fostered.

What did each individual FAST activity contribute?

Content Conversation. The content conversation supported preservice teachers in emphasizing describing ideas and planning for instruction. This assignment provided the only opportunity for preservice teachers to interact with individual students about their science ideas. This assignment had very specific foci. It is not surprising that preservice teachers emphasized describing ideas and planning for instruction; this is exactly what they were asked to do in reflecting on their conversation. Nowhere else in the FAST activities did preservice teachers emphasize describing ideas, indicating that this assignment provides a unique opportunities for the preservice teachers. Recall that when preservice teachers were emphasizing planning for instruction, some were able to think beyond their student's specific ideas and consider ideas like curriculum or focusing on understanding rather than fact accumulation. Perhaps with tweaking, this assignment could foster this kind of connection more explicitly.

Reflective Teaching. Preservice teachers emphasized finding out students' ideas and decisions during and after instruction in both reflective teaching assignments. Like

the content conversation, the reflective teaching assignments are important because they represent the only time preservice teachers actually teach science to their students. Even though the areas of emphasis were the same in the first and second activities, there were some changes in the way the preservice teachers were thinking about learners' ideas. In the first assignment, they pointed to outside sources such as the materials for ways to improve the lesson. In the second, they identified aspects of their own teaching they would change. Thus, in the second reflective teaching assignment, preservice teachers seem to have developed more PCK in that they were able to look at their own practice critically. This is a good example of PCK-readiness because even though preservice teachers were unable to make changes as they teach, they were able to reflect effectively on what they wish they had done. Schön (1982) describes this distinction as reflecting *on* action and reflecting *in* action. Reflecting *in* action requires the ability to think while teaching and make adjustments in the moment; a complex skill. However, reflection *on* action is being able to think back and reflect on changes that might have been productive, an easier first step and one that was accessible to these preservice teachers. Because of the stark change between the first and second iterations, the redundancy is an important piece of this assignment. More work should be done to explore to what extent the change is a product of time and experience, simply teaching and reflecting multiple times, or a combination of the two.

Critique Activities. During the first critique activity, preservice teachers emphasized anticipating ideas, decisions during instruction and finding out ideas; during the second, they emphasized finding out students' ideas. The critique activities were very structured. Thus, perhaps more than any other FAST activity, they support preservice

teachers in thinking in depth about a particular aspect of dealing with students' ideas in ways they had not before. Having them create a criterion related to learners' ideas provided an opportunity to see what aspects they chose to focus on, and many emphasized that time and resources (such as example questions) to find out students' ideas should be built into the lesson plan. Even though there were very few preservice teachers who focused on learners' ideas in the second activity, those who did said that while they believed the teacher's role in asking questions was important, they wanted those aspects built into the lesson plan for them. It is a sign of developing PCK that they were able to recognize their own need for more support in these areas. The recognition of what kinds of thinking a teacher needs to do and that they need support to develop that thinking shows a growing understanding of what it means to teach one's students.

Images of Inquiry. In the first images of inquiry assignment, preservice teachers emphasized anticipating and finding out students' ideas and decisions after instruction. In the second, they focused on areas other than learners' ideas. In the first assignment, preservice teachers had to consider issues directly related to students' ideas. Not only were they critiquing the actions of other (fictional) teachers but many of them were able to think about their own teaching in relation to the image teacher. This shows important development: thinking 'I, like Emily, might have trouble anticipating ideas' is a more complex reflection than the judgment 'Emily never anticipates ideas'. This assignment allowed preservice teachers to examine their own ideas about what weaknesses they might have in ways they did nowhere else in the course.

But the second image assignment shows that without guided focus, preservice teachers chose a wide variety of (often productive) areas not related to learners' ideas. If

the goal, then, is to have them focus on students' ideas, it is not enough to have the opportunity there – it needs to be specifically scaffolded. However, in the second image assignment, some preservice teachers chose to emphasize learners' ideas on their own, like Leslie and Ella. These preservice teachers found ways to bring it in regardless of the presence of scaffolds, but this was exception, not the rule.

Peer Discussions. Even though the peer discussion was intended to support preservice teachers in thinking about learners' ideas, it did not. However, two interesting findings emerged from these reflections. The reflections on these conversations, like the reflective teaching journals, demonstrate that multiple reports of the same event can show very different perspectives. This was best seen in Ella choosing to emphasize students' ideas when her group members did not. Second, this assignment also shows that, perhaps especially in an unstructured environment such as an informal conversation, it is difficult for an instructor to determine the focus.

How could FAST activities be improved?

Each FAST activity provided a different type of opportunity for the preservice teachers taking in the methods course. Even though they were designed to allow preservice teachers to consider their learners' ideas, this was not always the outcome. Table 5.4 highlights some changes to each activity based on the results. For example, recall that during the content conversation, some of the preservice teachers merely described the ideas their students had. Those who thought in deeper ways point to the possibility of deeper reflection through this activity. Perhaps more focused scaffolds might support more preservice teachers in considering issues beyond their individual student (like instructional sequencing, factual knowledge vs. deep understanding, etc.)

With more focused design changes informed by these results, preservice teachers in future elementary science methods courses might benefit even further from these activities.

Table 5.4: Potential changes to FAST Activities

FAST Activity	Changes to make based on results
Content Conversation	Provide prompts to help them move beyond only describing ideas (such as asking whether the student only knows facts or has a deeper conceptual understanding).
Reflective Teaching	Provide more support in class in between iterations. Provide prompts that ask them to reflect on their instructional decisions (such as asking them to link instructional decisions they made to student learning or how other decisions might have better supported student learning).
Images of Inquiry	Prompts that encouraged attention to learners' ideas could be added to the second assignment; this would help them think about learners' ideas even if the image was written to focus on something else.
Critique	Provide opportunities for them to reflect about their rationales for the changes they made to the lessons and how they can apply the criteria related to students' ideas in their units.
Peer Discussion	This activity was productive in its own way; perhaps an additional in class small group discussion more carefully focused on learners' ideas could be added.

In general, the FAST activities need to have more focused prompts and other scaffolds to guide preservice teachers' thinking. This study shows that with support, preservice teachers are able to think in sophisticated ways about their learners, but without it, they focus on other things. If attending to the characteristics of learners' ideas is important, it needs to be scaffolded in a more focused way in these FAST activities. Additional implications based on the results are discussed in Chapter 6. The following section describes conclusions about elementary preservice teacher learning and how methods courses can support their PCK-readiness.

Conclusions

Each FAST activity provided unique opportunities for the class of preservice teachers to develop their PCK-readiness in terms of their learners' ideas. In the next section, I move beyond the individual activities and look at what kinds of thinking the group of FAST activities supported and failed to support.

What kinds of thinking were fostered by the set of FAST activities?

While it is interesting and important to evaluate what types of thinking each activity fostered, it is also important to look at the set of activities together. When evaluated as a whole, how did the FAST activities support the development of PCK-readiness? Certain aspects of *dealing with students' ideas* were emphasized (see Table 5.3) throughout the semester. For example, finding out ideas was a focus in both reflective teaching journals, both critique assignments (although the second critique only involved a few preservice teachers), and the first images of inquiry. More than any other, this aspect of dealing with ideas seemed to resonate for preservice teachers. This seemed to be a natural first step; as the preservice teachers began to realize that attending to learners' ideas was important, they recognized that it was difficult to do if they never learn those ideas in the first place. It was a concrete step they could identify, more so than what to do when certain ideas persist past instruction or how to attend to those ideas during instruction. PCK-readiness is about acquiring the building blocks of rich, usable PCK, and it seems that finding ideas is a building block that many preservice teachers are able to add to their repertoire of ideas.

One of the important findings of this study is the ways in which particular ideas are fleshed out in different ways across different assignments. For example, *decisions*

during instruction is an aspect of dealing with students' ideas that was emphasized in both reflective teaching assignments and the first critique activity. In the reflective teaching assignments, the preservice teachers were reflecting on a lesson they actually taught, so they were talking about thoughts or decisions they made while in the midst of a lesson. In the critique activity, they did not teach a lesson; they were evaluating an existing lesson plan. So in this instance, when they referred to decisions during instruction, they were writing about decisions they would like to make and things they would want to think about were they to teach this lesson. Both types of thinking are important. Without actual experience and reflection upon it, preservice teachers would not have the opportunity to realize how difficult attending to learners' ideas in the moment is and reflect back on how they did or did not do this in the moment of teaching. However, this is understandably difficult for preservice teachers; they are balancing management, teaching with a partner, sticking to a lesson plan while attending to emerging ideas, and teaching science for the first time. Assignments like the critique and images activities provide them with the ability to evaluate the decisions of others or to write about what they would do with a given lesson plan while removing the real time pressure and other stressors of actual teaching. This allows a more thoughtful, considered reflection on specific aspects of teaching. Both types of consideration build preservice teachers' PCK; without practice in the act of teaching, the knowledge will never be usable, but carefully building that knowledge while in a calmer, more structured activity is also important.

What was not well-fostered by these FAST activities? Why?

When evaluated as a whole, the FAST activities certainly left "holes" in what preservice teachers considered pertaining to learners' science ideas, especially related to the *characteristics of learners' ideas*. The aspects of characteristics of ideas that were emphasized, describing and anticipating learners' ideas, were more concrete. Those that were not emphasized, factors that contribute to ideas, difficulty of ideas, resilience of ideas, and importance of ideas are all more theoretical aspects of learners' science ideas. Merely describing an idea a student has is less complex than reflecting on why a particular idea is important or difficult for a student. Perhaps the complexity of these concepts explains why preservice teachers never focused on them. It would make sense that as PCK develops, more concrete aspects are easier to think about initially, and in fact, perhaps are necessary before more complex ideas can be tackled. For example, it is difficult to imagine that a teacher who is unable to anticipate a learner's idea can reflect extensively on how particular ideas are resilient even after instruction.

Another possible explanation for the lack of focus on these areas is that the set of FAST activities did not provide sufficient or appropriate opportunities for consideration of these concepts. For example, the content conversation supported thinking about describing learners' ideas by specifically asking preservice teachers to report on those ideas. The issues of resilience, importance, difficulty, and factors that contribute to ideas were all central to the course; many discussions during the semester centered on these issues. However, in a careful examination of what preservice teachers were asked to consider in the FAST activities, these concepts were not directly scaffolded. In the images of inquiry assignment, when many preservice teachers were criticizing Emily for

not anticipating her students' ideas, one could imagine that a natural reason for this assumption is that they believed that attending to these ideas was important in helping students construct new understandings. However, reflecting on this was not prompted and few if any preservice teachers wrote about why they thought she should be anticipating those ideas.

The balance of freedom versus structure is central to this issue. These results suggest that without very specific prompting, preservice teachers will choose to focus on other areas (as in the images assignment, where they did not elaborate on why they held particular opinions, or in the peer discussions, where they opted to consider issues not related to learners' ideas). So if a particular aspect of learners' ideas (or any other concept) is deemed important, very specific scaffolds need to be folded into the assignment in order to facilitate preservice teachers' consideration of these ideas. Even when concepts seem to be related (like anticipating learners' ideas and the importance of those ideas), preservice teachers in this study did not make these connections without prompts to do so. However, this approach is not without cost. First, it is hard to imagine a specific scaffold for every concept deemed important related to learners' ideas, much less the multitude of other aspects of learning to teach science. Second, giving preservice teachers freedom to choose their focus is also an important aspect of building preservice teachers' identities as science teachers (Britzman, 2003; Smithey & Davis, 2004b). Several preservice teachers commented in their reflections about their peer conversations that they appreciated the opportunity to talk about issues of concern to them with their peers. So while some focus was lost on attending to learners' ideas, perhaps strength was built in other areas.

Because this course aimed to support preservice teachers in taking ownership of their teaching, many of the assignments gave them some degree of freedom in the area of focus. So even though these FAST assignments were designed to encourage preservice teachers to focus on students' ideas, in reality, so much freedom was given that often they did not. The content conversation, reflective teaching journals, first images of inquiry, and first critique assignments were all designed so that preservice teachers considered aspects of learners' ideas. That is reflected in Table 5.3. Each of these assignments has multiple areas of focus. The second images of inquiry, peer discussions, and second critique activities all gave preservice teachers options for foci; one of these options had to do with learners' science ideas, but they could also choose other, important areas of emphasis, and as the table indicates, they did this. None of these assignments sufficiently supported preservice teachers in considering the characteristics of their learners' ideas. So even though in design, these were focused assignments on students thinking, in reality they were not.

In developing PCK-readiness, preservice teachers need to learn to attend to their learners' ideas, specifically the characteristics of those ideas and how to deal with them in instruction. The FAST activities were designed to guide preservice teachers in thinking about specific aspects of their learners' ideas in different types of assignments. The success of this was mixed; some fostered more careful thought than others. Preservice teachers need to consider how closely to scaffold important ideas while still allowing room for choice. Finally, they need to think about how course activities might better foster thinking about more abstract aspects of PCK-readiness, such as the resilience

of learners' ideas. The next chapter addresses conclusions and implications that can be drawn from these findings.

CHAPTER 6

DISCUSSION AND IMPLICATIONS

This chapter begins with a discussion of the contributions this study makes to the field of science teacher education and the limitations of the study. A summary of findings is presented, organized by the two sets of research questions. Within this summary, I describe how each finding is relevant to the construct of PCK-readiness. PCK-readiness is then discussed in more depth. Specifically, I describe the reasonable expectations for preservice teachers in terms of developing PCK-readiness and how this contributes to the work done by others. In addition, I begin to outline how PCK-readiness might develop into rich, usable PCK over time.

Next, I discuss additional conclusions that can be drawn from the results of this study. I highlight the role that different experiences with learners plays in PCK-readiness development and discuss the role that structure and choice might play in preservice teacher education.

I then make suggestions for future research directions with respect to teacher learning and designing teacher education experiences. Finally, I conclude with a brief summary of how the findings from this study contribute to the greater body of work about preservice teacher learning.

Contributions and Limitations of Study

This study contributes to the findings and theory in the field of teacher learning. Of course, it also has limitations to the conclusions and implications that can be drawn. Both of these are discussed in the following section.

Contributions

This study builds on work others have done, both in study design and learning theory. Much research about preservice teachers, and teachers in general, includes only a small number of participants; this study is no exception. However, one goal of the dissertation was to describe how different preservice elementary teachers make sense of thinking about their students' ideas. Other work has taken this approach (Anderson et al., 2000; Trumbull, 1999); this study builds on those ideas and methods. The eight preservice teachers who were the focus of the first set of research questions and results presented in Chapter 4 were selected because they were representative of the range of initial ideas in the class. In answering the second set of research questions, I evaluated how the entire class made sense of the FAST activities. Even though the number of participants in this study is still small, I tried to make choices that would allow me to provide a rich description of different kinds of preservice teachers.

This study followed a class of preservice teachers through an elementary science methods course. The purpose was to look for evidence of PCK-readiness with respect to learners' ideas. The concept of PCK-readiness is a new one. Some studies have suggested that with scaffolding, preservice elementary teachers can develop aspects of PCK (Anderson et al., 2000; Davis, 2004; Davis & Petish, 2005; Zembal-Saul et al., 2002). This dissertation builds on this work by further exploring what the very

beginnings of PCK might look like and how a methods course can support preservice teachers in developing this beginning knowledge for science teaching. The construct of PCK-readiness is further discussed later in the chapter.

Most teacher elementary education programs require a science methods course. This study strove to explore how the methods course might be able to support preservice teachers in developing their understanding about their learners' scienceideas. Previous work suggests that scaffolding experiences in methods courses can support preservice teachers in thinking about the concepts presented in the course, even in the midst of other topics and pressures (Mitchell, 2003; Smithey & Davis, 2004b). Others have thought in terms of developing frameworks for further PCK development (Zembal-Saul et al., 2000). My work adds to this area of research. Rather than focus on how difficult it is for preservice teachers to develop PCK with their limited experiences, here, I ask how the experiences they do have might best be leveraged so that they can develop PCK-readiness. Thinking about teacher learning in terms of PCK-readiness allows teacher educators to focus on the knowledge and skills that preservice teachers are able to develop. There are many things preservice elementary teachers can think about with respect to their learners' ideas, as the results from this study show. Even with limited experiences, the preservice teachers in this study were able to push beyond the typical set of expectations set forth in the literature. Perhaps these new ways of thinking will form building blocks that will allow them to develop usable PCK more easily as their experiences with learners grow.

Limitations

There are several limitations to this study that constrain the generalizations that can be made based on the results. First, as noted, the study included a small number of participants. While I attempted to select focus preservice teachers who represented the range of ideas in the class, they still represent case studies. Therefore, I use caution when generalizing them as exemplars of "types" of preservice teachers but rather describe them as individuals from whose experience we can learn. It is important to note that the class was a relatively homogenous group taking the same class in the same program, so wide generalizations about all preservice elementary teachers are not warranted. For example, an important factor in development of PCK is a teacher's subject matter knowledge. This was not addressed at all in this study, and thus, limits what I can know and say about each individuals' ability to develop rich PCK.

Learning to be a teacher is messy. This can be problematic for designing research looking at influences on preservice teacher learning. Because I wanted to see the impact of particular assignments, my claims are tempered by the fact that preservice teachers were engaging in many different activities during the semester, including other assignments in my course, another methods course, and field experiences. Therefore, it would be difficult to establish a causal link between a particular learning outcome and a particular activity within the course. Rather, I try to say what kinds of thinking preservice teachers engaged in during an activity and compare that to other instances of their thinking at different points in time.

A third limitation of the study relates to the nature of learning. There are limits to how much a particular intervention can change thinking. Especially in the chapter about

the focus preservice teachers, the results indicated that some ideas are resistant to change. So while overall, the results from this study are encouraging in terms of the kinds of thinking a methods course can support, it is also important to note that like children, preservice teachers are individuals, and for some, they will not be ready to change their thinking, even with supports. This is an area for future research. Determining the limitations on how much change a methods course can be expected to facilitate and why some preservice teachers' ideas are resistant to that change would contribute to the field of teacher learning.

Summary of Findings

The findings from this study are divided into two sections based on each results chapter and set of research questions. The first looks carefully at how the trajectories of eight focus preservice teachers changed over the course of the semester with respect to their learners' ideas. The second looks at the influence of a set of activities designed to help preservice teachers learn to consider their learners' ideas.

Preservice teacher trajectories

The first set of research questions asks: How does preservice teachers' PCK-readiness develop over the course of a semester with respect to thinking about and using students' ideas? Specifically, what characterizes the development of understandings of learners among preservice teachers with different initial ideas? How does the preservice teachers' treatment of students' ideas change over the course of the semester? The results are presented through themes that emerged from the data. However, each subquestion is addressed in each theme. I summarize several types of trajectories: consistent, those

influenced by an event, those that move from certainty to uncertainty, and other types. In addition, I highlight themes that emerged across trajectories and individuals.

Consistent trajectories. Two of the preservice teachers, Beth and Wanda, showed consistent growth during the course. They began and ended the semester in different places from each other; Beth began and ended with more sophisticated ideas about attending to learners' science ideas than Wanda, but both made progress along their own trajectories. Beth built on the cornerstone of PCK-readiness she already had - that attending to learners' ideas was a critical part of science teaching - and continued to refine her ideas based on this belief. During the semester, Wanda acquired more of the building blocks of PCK as she grew (in a sometimes "bumpy" trajectory) to appreciate the importance of her learners' science ideas.

Trajectories influenced by an event. Riley and Katya were partners in their first grade classroom, and their first science lesson influenced both of their trajectories, though in different ways. After their reflective teaching journals, Riley began to look more carefully at different instructional strategies to foster understanding, and Katya focused on finding out what her students' ideas were.

Trajectories moving from certainty to uncertainty. Kate began the semester convinced that hands-on experiences would change students' ideas. As the course progressed, she became less sure of herself, and by the end of the semester, she suggested multiple strategies and allowed that there were no guarantees for changing students' ideas. Even though she contradicted herself and was more unsure at the end of the semester, she had a greater respect for learners' ideas.

Other types of trajectories. The methods course did not seem to influence some preservice teachers' ideas. Two preservice teachers, Lara and Aruna, did not choose to focus on their learners' ideas. These two did not challenge themselves, either during interviews or coursework, to think in different ways about their learners' ideas. The course, even those aspects specifically designed to do so, did not influence their resilient ideas.

Wanda and Amber both had strong ideas related to the factors that contribute to students' ideas (though opposite of one another). However, neither Wanda nor Amber changed over time in how they thought about this issue. Like Lara and Aruna, who rarely considered their learners, having such strong opinions seems to be another type of thinking that is resistant to change. Conclusions that can be drawn from these findings are discussed later in this chapter.

FAST Activities

The second set of research questions asks: How does preservice teachers' use of focused assignments on students' thinking (FAST activities) within the methods course support them in considering student ideas? More specifically, do different FAST activities foster different aspects of thinking about students' ideas? What kinds of thinking does the set of FAST activities as a whole support?

First, I summarize the results in terms of what the FAST activities were able to foster, specifically how to deal with learners' ideas. Second, I show what the FAST activities did not support, specifically thinking in terms of the characteristics of learners' ideas. I then discuss possible reasons for this lack of emphasis by the preservice teachers.

FAST activities fostered consideration of how to deal with learners' ideas. In completing certain FAST activities, preservice teachers considered multiple aspects of how to deal with learners' science ideas. In the content conversation, preservice teachers described learners' ideas and thought (in different ways) about how to use those ideas in planning for their unit. This FAST activity seemed to support a wide range of thinking about learners' ideas. Some thought only about their individual interviewee's specific science ideas while others thought about broader instructional issues such as fostering deep understanding. Even though there are differences in sophistication, this particular FAST activity supported preservice teachers with a range of ideas in thinking about how to deal with their learners' science ideas in their instruction.

Other FAST activities also supported preservice teachers in thinking about how to deal with their learners' ideas. In both reflective teaching assignments and the first image of inquiry and critique assignments, they considered using learners' ideas in instruction and finding out ideas. The concept of finding out ideas seemed to resonate with preservice teachers; through the scaffolding provided in the activities, they realized that there was little they could say about what students learned if they as teachers did not discover their ideas in the first place. Focusing on finding out learners' ideas seems to be an important building block as preservice teachers develop their PCK-readiness.

Several FAST activities supported preservice teachers in thinking about using ideas before, during, or after instruction. While these are all different ways of considering learners' ideas, each represents a type of thinking typically not attributed to preservice elementary teachers because it deals with attending to learners' ideas in instruction. Contrary to literature that suggests that preservice (or new) elementary

teachers are unable to deal with learners' ideas (Abell et al., 1998; Anderson et al., 2000; D. Smith & Neale, 1989), the results from this study suggest that at least the beginnings of this type of thinking are possible. This will be further discussed in the conclusions section.

FAST activities did not foster sufficient consideration of characteristics of learners' ideas. While the ability of preservice teachers to consider how to deal with their learners' ideas is encouraging, their consideration of the characteristics of those ideas is not. There are only three instances of preservice teachers focusing on the characteristics of learners' ideas. In the content conversation, they describe ideas; this is hardly groundbreaking, as they are asked specifically to describe their learners' ideas. The other two instances of focusing on characteristics of ideas were in the first image of inquiry and critique FAST activities. In each of these, preservice teachers focused on anticipating learners' ideas. Both of these assignments lent themselves to thinking about this aspect of learners' ideas.

The other aspects of characteristics of learners' ideas - factors that contribute to ideas, difficulty of ideas, resilience of ideas, and importance of ideas - were never emphasized by the preservice teachers in any of the FAST activities. There are two possible explanations for this. The first is that the FAST activities did not specifically support this type of thinking. For the other instances described above in which preservice teachers thought about characteristics of learners' ideas, there were either specific questions asking them to do so or other aspects to the assignment that led them in that direction (for example, the ways in which the image of inquiry teachers did and did not anticipate their learners' ideas were central to the outcomes of their lesson). Although

there were certainly opportunities where preservice teachers could have considered characteristics of learners' ideas, specific questions were not asked about those aspects that were never emphasized. The results (across the entire study) suggest that without specific scaffolds, preservice teachers are unlikely to consider particular aspects of learning to teach. If thinking more carefully about the characteristics of learners' ideas was deemed important, more scaffolds should have been in place to support that thinking.

The complexity of the characteristics of learners' ideas is another possible reason that preservice teachers seemed unable to focus on those aspects. The areas in which they focused, anticipating and describing ideas, were both relatively straightforward. Thinking about why ideas are important, factors that contribute to those ideas, or the resilience of them is more complex and abstract than simply describing them. It makes sense that preservice teachers first need to be able to describe and anticipate ideas. Perhaps later, they can think more carefully about the more nuanced concepts of what makes an idea difficult or resistant to change. Preservice and new teachers struggle to think about learning in complex ways, and this influences their ideas about the nature of students' ideas (Meyer, 2004). In much the same way that finding out ideas is a logical first step in thinking about how to deal with ideas, anticipating and describing are logical first steps in considering the characteristics of learners' ideas.

What do the results say about preservice teachers' development of PCK-readiness?

Each of the two results chapters illustrates different perspectives on PCK-readiness. Chapter 4 addressed how eight individuals made sense of the methods course. Each person had a unique trajectory, and each made progress towards PCK in her own way. For example, even though Riley and Katya both had trajectories that were

influenced by an event, they made sense of this experience in different ways. Both were productive, and both developed PCK-readiness, but Riley was able to integrate what she learned about the characteristics of learners' ideas with how her instruction should change as a result. Figure 6.1 illustrates where each preservice teacher could be placed in her development of PCK at the end of the semester. This does not represent the dynamic nature of their trajectories, only the areas they tended to emphasize by the end of the semester.

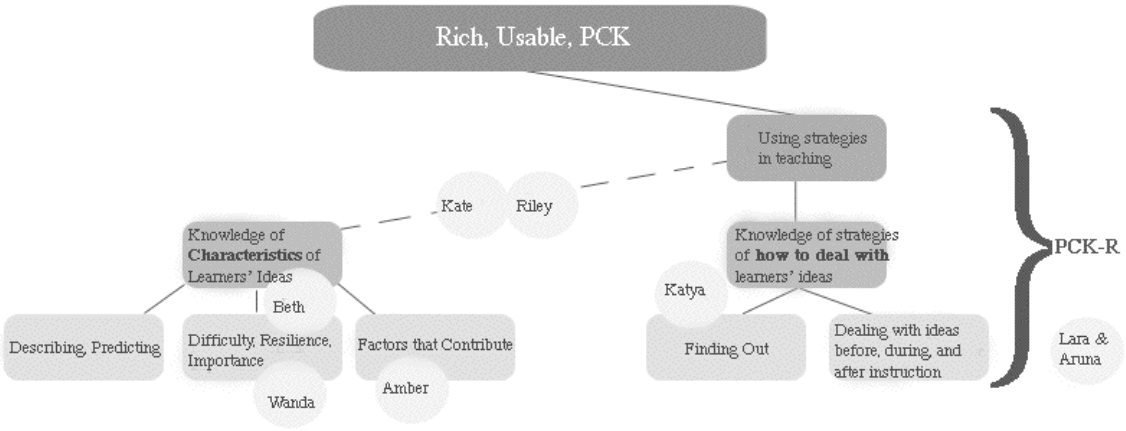

Figure 6.1: PCK-Readiness in Focus Preservice Teachers

Note that within PCK-readiness, there are two areas; knowledge of characteristics of learners' ideas and knowing how to deal with them in instruction. A preservice teacher can progress from focusing on a singular strategy or characteristic (as Amber did) to integrating different ideas within an area (like Beth did with characteristics of ideas and Katya did with how to deal with ideas) to integrating knowledge of both characteristics and how to deal with them into a beginning understanding of how to use students' ideas in instruction (as Kate and Riley did). Over time and with experiences, teachers progress from holding knowledge in pieces (diSessa, 1988) to integrating knowledge within an

area (Linn et al., 2004) to finally having integrated, rich, flexible knowledge that can be used while teaching (Ball & Bass, 2000). The trajectories described in this study show only the beginnings of this process; few trajectories emphasized integrating their ideas about characteristics of learners ideas and how to deal with them in instruction.

Chapter 5 investigated how a set of FAST activities did or did not foster consideration of PCK-readiness with respect to learners' ideas. Figure 6.2 highlights what kinds of thinking each activity supported.

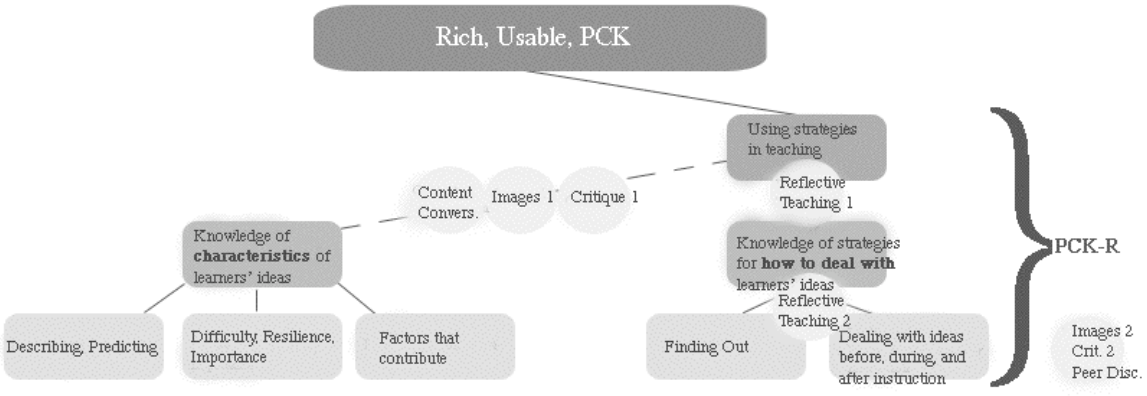

Figure 6.2: PCK-Readiness emphasis within each FAST activity

None of the FAST activities supported preservice teachers in thinking only about characteristics of learners' ideas. However, the content conversation, first image assignment, and first critique assignment, did foster thinking about both the characteristics of learners' ideas and how to deal with them in instruction. In the reflective teaching assignments, the preservice teachers were able to integrate their ideas about how to deal with learners' ideas. In the second iteration, they were even able to think about and critique their own instructional decisions.

The construct of PCK-readiness allows for an unpacking of the knowledge that is not yet PCK. The results of this study show two different perspectives on developing PCK-readiness: how individuals develop deeper understandings as they progress towards PCK and what pieces of PCK a set of course activities can foster. The next section discusses PCK-readiness in more depth, including conclusions that can be drawn based on the results of this study.

PCK-readiness

In this section, I discuss how the results from this study can be viewed through the lens of PCK-readiness and how this new construct might inform our understanding of how preservice teachers can be put in the best position possible to develop usable PCK once they are practicing teachers. I first discuss how the idea of PCK-readiness builds on the work of others and makes a contribution to the existing field of teacher learning. Then, I describe how a preservice teacher might navigate from having PCK-readiness to developing rich, usable PCK.

How does the construct of PCK-readiness build on the work of others?

Over the course of the semester, preservice teachers showed that with scaffolding, they were able to consider their learners' ideas in depth. This builds on the literature that suggests that with supports, preservice teachers can think about their learners' ideas (Lemberger et al., 1999; Tabachnick & Zeichner, 1999) but goes a step further because they were also able to think about using those ideas in instruction. Six of the eight focus preservice teachers made substantial progress in their thinking about learners' ideas throughout the semester. And most of the FAST activities (though not all) supported the class in thinking about how to deal with learners' ideas in science instruction.

The ability of preservice teachers to consider how to deal with their learners' science ideas is an example of developing PCK-readiness. Other work suggests that preservice teachers are not well-positioned to do this (Meyer et al., 1999; D. Smith & Neale, 1989). However, these studies were not looking at preservice teachers' development in terms of their trajectory *towards* PCK. The preservice teachers in this study were not thinking about dealing with their learners' ideas in instruction the same way an experienced teacher would. However, the extent to which they were able to do so, even "baby steps" like finding traction with the idea of learning what those ideas are in the first place, are crucial pieces of PCK-readiness, much like learning the alphabet is to reading readiness.

This study contributes both a finding and a lens with which to view the finding. The results suggest that with support, preservice teachers are, in fact, able to think in sophisticated ways about how to deal with their learners' ideas. This knowledge does not represent usable PCK (which is as far as other studies go), but it does show a building block of it. It is the development of PCK-readiness. Armed with these building blocks, perhaps preservice teachers will be well-started beginners (Hollon et al., 1991) and in a good position to develop their PCK when they are teaching.

Moving from PCK-readiness to PCK

What are those building blocks with respect to learners' ideas? A teacher with rich usable PCK knows what likely science ideas are, has an appreciation for the impact of learners' ideas on their sense-making, knows how to find out what learners' actual ideas are, and understands how to deal with them in instruction. Each of these is

fundamental in knowing how to teach science to particular learners. Preservice teachers in this study demonstrated all these examples of PCK-readiness to some extent.

How might PCK-readiness develop into usable PCK? One example of a building block is using learners' ideas to plan for instruction. One could imagine a preservice teacher who used the content conversation about evaporation to naively assume that all students in her class would assume that the water "disappears" like the student she interviewed. Through her scaffolded reflection, she would be forced to think about how to take her student's ideas into consideration before moving ahead with her unit plan on the water cycle. Then, perhaps during student teaching, she would enact a version of the unit she planned during her elementary science methods course. Remembering her experiences in the methods course, she might give a pretest a few weeks before she begins her unit that included a question about where the water from a puddle on a sidewalk went on a sunny day. Later, as a practicing teacher, she would begin to develop a repertoire of ideas that she expected students would bring to a unit on the water cycle. Seamlessly, she would take these ideas into account as she planned her instruction for the unit. As these measures were successful, she might even use the same strategies (such as pretests) when she begins to teach a different unit in order to learn what her students' ideas are. Her early experiences in the form of interviewing one student and answering questions about how to use those ideas in her unit plan might have given her the leg up to be more attuned to the importance of those ideas and taking them into account when planning instruction as she developed into a practicing teacher.

A major goal of this study was to evaluate how preservice teachers with different initial ideas about learners make sense of the same set of course activities. The results

from both sets of research questions show that preservice teachers with a range of ideas can make progress in their thinking about learners. For example, Beth began and ended the semester with relatively sophisticated ideas about learners and Wanda had somewhat naïve ideas, especially in the beginning of the semester. Even though Beth and Wanda were in very different places in terms of their ideas about learners, each was able to take different events and activities from the course and challenge their own thinking about learners' ideas. In addition, Kate and Riley started out the semester with very different ideas about learners. Even though their trajectories were different from one another, they both ended up with some degree of integration between characteristics of ideas about how to deal with them during instruction (see Figure 6.1). Similarly, each preservice teacher was asked to describe their student's ideas after participating in the content conversation. Some preservice teachers merely reported what the student said while others were able to think more deeply and synthesize the conversation. Both of these kinds of thinking demonstrate considering the characteristics of learners' ideas, but this FAST activity provided opportunities for preservice teachers at different stages of PCK-readiness.

There are limitations to this, however. Recall that in Chapter 4, several preservice teachers had areas in which they did not change. Each of these preservice teachers either initially agreed wholeheartedly with the philosophy of the course or had initial ideas that were opposite of those presented in the course. Perhaps those preservice teachers who fall on the very edges of the range of typical ideas are less able to make use of learners' ideas. Other work supports the idea that those who fall very far from the course philosophically have trouble making progress (Anderson et al., 2000; Trumbull, 1999)

and that some congruence between personal beliefs and the program must be in place in order for their ideas to develop (Mahlios, 2002).

This study found that the same set of course experiences can be productive for individuals with different "starting places" in terms of their initial thoughts about learners. Like a classroom of young children, a group of 20 preservice teachers represents 20 different sets of experiences and ideas with which to make sense of the methods course. The building block one preservice teacher needs to develop her PCK-readiness might be different from what another needs or is ready for. However, the results indicate that through scaffolded experiences designed to provide opportunities to think in depth about learners' ideas, preservice teachers with even a very wide range of initial ideas are able to take what they need and develop their own trajectory towards PCK-readiness.

Additional Conclusions

Below, I discuss two additional conclusions based on the results of this study. The first focuses on the importance of experiences with learners and how teacher educators can create more of these experiences as well as make the most of the typically limited experiences preservice teachers do have. Next, I describe how a methods course should attempt to find a balance between structure and choice, both in terms of individual assignments and the direction of the course or program as well.

Experiences with learners are important

Preservice teachers struggle to develop pedagogical content knowledge. One major component of PCK for science teaching is knowledge about learners (Magnusson et al., 1999). It makes sense, then, that the limited experiences preservice teachers have

with learners contributes to their lack of PCK. This is a frequently cited reason for why it is unreasonable to expect that preservice teachers are able to develop usable PCK (Magnusson et al., 1999; Meyer, 2004; van Driel et al., 2002; van Driel et al., 1998). While this study does not dispute that, it instead asks how best to leverage the experiences preservice elementary teachers do have and the extent to which those experiences can help them develop PCK-readiness.

Clearly, the experiences preservice teachers have with learners are limited and quite different from those of a practicing teacher. However, the results of this study suggest that even these limited experiences can be powerful in supporting preservice teachers in developing their ideas about their students. For example, in Chapter 4, the "intervening event" for trajectories that changed was teaching and reflecting on a science lesson. This experience, though a small one, proved to be powerful. In different ways, both Katya and Riley struggled when they were asked what students learned after their lesson; this clarified for them the importance of attending to their learners' ideas while teaching. These realizations influenced their trajectories for the rest of the semester.

The results from Chapter 5 indicated that the reflective teaching and the content conversation provided rich opportunities for preservice teachers to think about their learners' ideas. Both of these experiences with learners were limited, but both had scaffolded reflection questions or prompts that guided preservice teachers to think about their learners' science ideas. Through reflecting on their content conversation, preservice teachers were able to describe learners' actual science ideas and think about planning for those ideas during instruction. Through the reflective teaching assignments, they thought about finding out learners' ideas and dealing with them both during and after instruction.

These unique opportunities to interact with and make sense of experience with learners helped to develop preservice teachers' PCK-readiness. In addition, the growth that preservice teachers showed between the first and second reflective teaching assignments (described in detail in Chapter 5) indicates that multiple instances of interacting with learners are important and can provide even richer opportunities for growth. This includes different kinds of experiences, such as the content conversations, and similar experiences multiple times, such as the reflective teaching experience. Other work has found that through multiple opportunities to reflect on teaching experiences, preservice teachers are able to focus more on their learners (Zembal-Saul et al., 2000).

The finding that preservice teachers benefit from experiences with learners is supported by the literature (Bryan & Abell, 1999; Lederman, 1999; Trumbull, 1999; Zembal-Saul et al., 2000). However, this study adds nuances to what the field already knows. For example, while most preservice teachers will not have the extensive exposure to learners that practicing teachers do, this study finds that even very limited experiences, such as a guided conversation followed by a scaffolded reflection, can prove helpful in supporting them in thinking about their learners' ideas in sophisticated ways. A range of different experiences, such as observation, informal teaching, guided play, and focused conversations might all be productive interactions that are also feasible within a typical teacher education program. So while one goal of teacher education is to leverage other experiences that preservice teachers *do* have in abundance, the findings point to the importance of providing as many interactions with learners as possible and guiding preservice teachers in thinking about those experiences in terms of attending to their learners' ideas in instruction.

Structure is important, but so is choice

One of the challenges of studying preservice elementary teachers within a methods course is evaluating what they know about a particular aspect of the course when they have countless other topics on which to focus. I hoped that the FAST activities would focus the preservice teachers into emphasizing learners' ideas. While this was certainly true in some cases, in others, they simply went in other directions. This was especially true when the preservice teachers were given a choice about the focus of their work. Almost without exception, they did not choose to focus on students' ideas. From a research perspective, this is disappointing because it did not provide additional insight into their thinking about learners' ideas. Nevertheless, there are conclusions to be drawn.

In most cases, when preservice teachers were given a choice, it was a limited one. For example, during the second images of inquiry assignment, preservice teachers selected from image teachers focused on learners' ideas, promoting inquiry in young students, teaching inquiry in a high stakes testing environment and other topics designed to be helpful to the preservice teachers. Likewise, the critique activity asked preservice teachers to evaluate a lesson plan based on several criteria of their choosing. The criteria, like the set of image teachers, were all focused on critical aspects of learning to teach. So when preservice teachers were not focusing on their learners' ideas, they were still considering other important aspects of learning to teach science. With limited choices, preservice teachers can choose valuable criteria on their own (Davis, 2006b), but other work suggests that preservice teachers who are not focused on learning focus instead on just making science fun or engaging (Anderson et al., 2000; Trumbull, 1999). Providing

limited choices for preservice teachers keeps them focused on important ideas but gives them some control over their learning as well.

During the semester, the preservice teachers participated in one relatively unstructured assignment, the peer discussion. Although they had specific guidelines for this discussion (see Appendix A), they chose to branch off and discuss topics of concern to them (although still related to teaching). While there was virtually no discussion of learners' science ideas, several preservice teachers reported that these conversations were helpful and that it was encouraging to be able to share their concerns with their peers. While this was certainly not the intended goal of this FAST activity, it was an important outcome. One goal of preservice teacher education is to support preservice teachers as they transition from thinking like a student to thinking like a teacher. By giving preservice teachers more ownership over their experiences and opportunities to make choices in their work, teacher educators support them in learning to wear their "teacher hat" more often (Britzman, 2003; Smithey & Davis, 2004b).

Implications

The results from this study have implications that are relevant for those involved in teacher education as well as research about teacher learning. Ideas for each are presented in the following sections.

Implications for teacher educators

Those who work with preservice and new teachers can take away several implications from this study. First, as noted above, many aspects of this dissertation point to the importance of providing experience with learners. Second, teacher educators should make careful decisions about which ideas to scaffold. Finally, teacher educators

should provide opportunities for preservice teachers to develop their PCK-readiness. Each of these is discussed below.

Provide experiences with learners. One obvious implication for teacher educators is to provide many opportunities for preservice teachers to interact with learners. The more time preservice teachers can spend actually teaching children about science, the more developed their thinking will become about their learners' science ideas (Lederman & Gess-Newsome, 1999). However, this study also points to the productivity of other types of experiences as well. The content conversation lasted only a few minutes for most preservice teachers, but it was helpful for most of them in thinking about how to plan for instruction using learners' ideas and simply being exposed to those ideas in the first place. Therefore, teacher educators might think more broadly about the kind of experiences they are able to provide. For example, a preservice teacher might instigate a game during recess where young children act out the water cycle or conduct informal conversations with groups of children during lunch or transition times in the classroom. None of these might be as productive as teaching, but there are potentially many opportunities for these kinds of interactions with learners.

In addition, teacher educators should consider carefully scaffolding those experiences. While the literature suggests that it is often difficult for preservice teachers to focus on learning rather than other aspects such as engagement or management (Abell et al., 1998; Anderson et al., 2000; Trumbull, 1999), this study found that they were able to consider their students' learning in generally sophisticated ways. While both iterations of the reflective teaching journals certainly included preservice teachers' thoughts about management and student interest, they also were rich with their thinking

about how to deal with learners' ideas during and after instruction. The specific questions they were asked to answer focused their thinking in these areas (see Appendix B). Similarly, the questions they responded to in the reflection following their content conversation asked them specifically how they might use what they learned about the student's understanding in planning for a unit of instruction (see Appendix C). Participating in and reflecting on conversations with learners can be useful in developing PCK (D. Smith, 2000). While preservice teachers might not be able to focus on learners' ideas without scaffolds (and this study certainly supports the need for scaffolds), this does not mean they cannot consider these concepts. By providing guiding questions and other supports, teacher educators can greatly influence the kinds of thinking about learners their preservice teachers are able to consider.

Scaffold the most important ideas. Teacher educators should not assume that preservice teachers will consider concepts just because there are opportunities to do so, even when those concepts are a focus of the course. Therefore, thinking about those ideas deemed most important by teacher educators should be scaffolded. This study shows that with those scaffolds, preservice teachers can consider learners' ideas with sophistication; other work has highlighted the importance of scaffolding as well (Lemberger et al., 1999; Tabachnick & Zeichner, 1999). Without it, however, they rarely choose to focus on learners' ideas (Abell et al., 1998; Trumbull, 1999). This does not mean that every experience in preservice teacher education should be closely guided or scaffolded, however. There is value in providing preservice teachers with choices. Doing so allows them to explore areas of interest or concern that they may have about

becoming science teachers. Both providing limited choices and the occasional open-ended assignment can be beneficial for preservice teachers.

Balance should be considered at the course level as well. Finding a balance between carefully scaffolding each concept that is important and providing options for preservice teachers is difficult. On one extreme, an elementary science methods course could be focused on a single idea around which preservice teachers engage in depth, such as the nature of science. While this would give them ample opportunity to think carefully about one aspect of learning to teach, it would be at the loss of considering the many other facets of teaching. On the other extreme, preservice teachers could be given so much choice and variability in what they choose to focus on that they would have little guidance and perhaps never choose to engage in depth some of the most crucial aspects of learning to teach. There is certainly no easy solution to this issue. In the methods course for this study, there were three areas of emphasis that we deemed critical for elementary science teachers: engaging students in inquiry, attending to learners' ideas, and critiquing and adapting instructional materials. We designed activities with specific scaffolds for each of these foci (Davis & Smithey, in review). This solution covered many of the most important concepts the preservice teachers would need as they entered student teaching.

Foster PCK-readiness. Perhaps the most important implication for teacher educators is that developing PCK-readiness is possible. Instead of assuming that fostering PCK in preservice teachers is a lost cause, teacher educators should instead consider which building blocks might be most helpful for preservice teachers in their own programs. These needs might be different depending on the population of preservice

teachers, children in the schools in which they teach, or emphasis of the teacher education program. For example, it seems that learning about the importance of learners' ideas (which the preservice teachers in this course struggled to focus on) might be one of the critical building blocks on which rich PCK is built. PCK-readiness, like PCK, is not a "generic" kind of knowledge, but rather one that is rich in its specificity to learners, context, and content. However, perhaps there are ideas, such as characteristics of learners' ideas, which might be emphasized throughout preservice teacher education. For example, one could imagine a preservice elementary teacher thinking (like Kate in this study) about the resilience of learners' ideas and the role evidence through experimentation and other instructional strategies might play in student learning. In the same program, that same preservice elementary teacher might think in similar ways about using primary sources in a social studies methods class. For example, she might struggle with the idea that reading about a historical account through a historical document might be more persuasive (though not certain) to change students' ideas than reading a summary in a textbook. Through these specific activities, preservice elementary teachers can develop PCK-readiness about the resilience of their learners' ideas. These types of ideas could be emphasized through elementary and secondary and in all subject areas, even if the knowledge about these concepts is specific to a given context or concept.

In thinking in terms of PCK-readiness, expectations are high; preservice teachers can (given ample opportunities and scaffolds) consider learners' ideas in depth and beyond what previous work suggests they can. Certainly, they will not develop complex, usable PCK as preservice teachers, but they can be poised to do so when given the opportunity.

Thinking about the characteristics of learners' ideas proved to be difficult for the preservice teachers in this study. It is difficult in this context to say whether this is due to the design of the FAST activities or because the concepts are too complex given how most of the preservice teachers were thinking about their learners' ideas or for other reasons. This ambiguity provides an opportunity to design further research. First, are there supports that could be designed to help preservice teachers think more critically about the resilience, difficulty, and importance of their learners' ideas? Alternatively, is there a sequence of concepts that proves most helpful for preservice teachers? Recall that Katya, one of the few preservice teachers who did think carefully about the characteristics of learners' ideas, first had a "light bulb moment" during her reflective teaching. From that point on, she focused extensively on finding out her learners' ideas. As the semester progressed, however, she began to bring in more about the resilience of those ideas. This sequence makes sense: once a teacher begins learning more about what students' ideas are, she might notice that they are resistant to change. Certainly, the trajectory is not as neat as developing concrete ideas first followed by more abstract ones. However, more work to learn about how best to support the development of more complex thinking might help the field learn more ways to provide opportunities for PCK-readiness to develop even further than it did in this study.

Implications for future research

This study opens many doors for research on preservice teacher learning. First, we need to know more about what kinds of experiences with learners are productive for preservice teachers. Second, more work should be done regarding how to better provide

choice and structure in teacher learning environments. Finally, there is much to be learned about PCK-readiness and how it relates to rich, usable PCK.

What determines a helpful experience with learners? This study finds that preservice teachers benefit from even a limited set of experiences with learners, especially when they are carefully scaffolded. More work should be done to see the influence of these experiences, and teacher education in general, as it is not clear how much preservice teachers are able to take with them into teaching (Richardson, 1996). For example, how much benefit can be gained from limited opportunities with learners? Is there a threshold of experience that is needed to be useful, or is any scaffolded exposure helpful? What constitutes an "experience" with learners? For example, would watching a good science teacher with a scaffolded observation and reflection be helpful for preservice teachers? What about more informal experiences like leading a nature walk during recess? Finally, one way to dig deeper into the influence of experiences with learners would be to compare preservice or new teachers' PCK with respect to learners' ideas based on the types of teacher education programs from which they graduate. Some promising work has been done that suggests that programmatic support can support preservice teachers in thinking about their learners (Lemberger et al., 1999). More can be done to build on this work. Do those whose programs emphasize time in the classroom and teaching experiences along with guidance to help them make sense of those opportunities have more developed PCK about their learners' science ideas than those in more typical programs? Looking into the outcomes of different types of programs is one way to cast a wider net into the influence of experiences with learners.

How are structure and choice important in learning to teach? Not much work has been done on the impact of choice versus structure for preservice teachers in elementary science methods courses. The results from this study suggest that further research is needed to see what benefits they can gain from choice and how structure helps them develop their understanding. For example, specifically, how does having a choice or ownership over activities in the methods course affect preservice teachers? What, specifically, do they chose to focus on when they have a choice? How effective is providing options compared with giving open-ended choices? Does having a choice have an impact on their developing identities as science teachers?

A major finding of this study is that PCK-readiness can develop when concepts are specifically scaffolded. Consistently, preservice teachers were able to think in sophisticated ways when there were specific scaffolds to support them in doing so. Without those scaffolds, however, they rarely chose to focus on learners' ideas. An important aspect of scaffolding is that the scaffold fades over time, allowing the learner to gradually do the activity without the support (Pea, 2004). However, in a one semester course, there is insufficient time to fade scaffolds. Preservice teachers only taught and reflected on two science lessons; it is unreasonable to think that if the guiding questions had been dropped for the second lesson, they would have been able to think as carefully about their learners' science ideas. More work should be done to evaluate at what point fading scaffolds is appropriate. Perhaps one way to study this would be to examine teacher education programs that provide systematic supports across the entire program (Zembal-Saul et al., 2002). Over the course of the entire program, scaffolds might be

added and taken away while still supporting preservice teachers in considering their learners' ideas (or whatever concept the program was attempting to support).

How can the construct of PCK-readiness help preservice and new teachers? The concept of PCK-readiness also has implications for further research on teacher learning. This study explores the very beginnings of PCK-readiness. More work should be done to further flesh out how the initial building blocks progress to rich, usable PCK. How do student teaching and the first few years of practice build on the foundations laid during teacher education? What types of scaffolds could best support this development during these initial teaching experiences? What types of programmatic support best foster PCK-readiness development? Would a more systematic program allow for fading scaffolds that might give teachers more of a leg up as they begin teaching? Are some building blocks more important than others? Is there a learning progression that best supports the development of PCK-readiness? Do those teachers who develop PCK-readiness go on to become effective elementary science teachers? Do they stay in teaching longer than their peers? How do the building blocks of PCK-readiness support new teachers in developing usable PCK? This area is full of potential for future work.

Concluding Remarks

Preservice teachers are in a unique position. On the one hand, they are surrounded by support through university and field experiences. On the other hand, they are unable to interact with learners in many authentic ways, thus limiting their ability to develop PCK. This study looked at how the experiences they do have, namely those in an elementary science methods course, could be best leveraged to help preservice teachers develop an aspect of their PCK-readiness related to their students' ideas. While

they are unable to develop the kind of PCK a practicing teacher has, the results indicate that preservice teachers, given careful supports, were able to think about their learners' ideas in ways previously not thought possible. As teacher educators and researchers further explore the idea of PCK-readiness, we can provide even richer opportunities for preservice teachers. Then, as they move through the professional continuum towards becoming experienced teachers, they can use the building blocks attained in methods courses and other experiences to develop rich, usable PCK for science teaching.

APPENDICES

Appendix A: Peer Conversation and Online Discussion Prompt

Online Discussion Directions

Below are the expectations for participating in the online discussion for the rest of the semester.

1. You must post 3 times over the next 8 weeks (the remainder of the semester). You should post no more than once per week.
2. At least one of these posts must be in response to your instructor's thread called: **Inquiry Discussion 2**. The others may be in response to others' threads or you may start your own thread (or you may respond further to the Inquiry Discussion 2 thread)
3. Remember to link your ideas to others' posts and ideas.
4. All posts should be completed by the last week of class.

Alternate Assignment

If you would prefer not to participate in the online discussion, you may discuss your science teaching with your peers in a face-to-face forum. Below are the expectations for this option.

1. Each group needs between 3 and 5 people.
2. Find a time to meet as a group for 20 - 30 minutes. During this time, discuss what you're struggling with in terms of your science teaching. Use the following prompt to start your discussion:

   > One of the hardest things about being a science teacher is making sure you cover all the benchmarks and concepts you need to while still making sure each individual understands the science you're teaching. How do you let kids have some control over what goes on in the classroom and still cover everything you need to? How would you handle it when some of your students still don't understand the science after you taught? Is it OK to just give students the right answer and move on, or should you spend more time investigating it further?

3. You don't need to limit your conversation to this prompt—this is just to get you started!
4. After the discussion, write a short synopsis of the conversation and what was helpful in thinking about your own science teaching. Each person should do this individually. This can be relatively short and informal. Submit this as a journal entry on CASES. Note: This is in addition to your regular journal entry for the week.
   THIS SHOULD BE COMPLETED BY THE LAST WEEK OF CLASS.

Appendix B: Reflective Teaching Reflection

Note: this is from a handout that also gives directions on planning and enacting the lesson.

Reflecting on Your Enactment:
In your CASES journal, reflect on your lesson. Make sure you cover all the following aspects:

- What happened during the lesson? (What did you do? What did the students do?)
- What went well? What didn't go so well?
- What did the students learn (or not learn) during the lesson? (Use student work as your evidence for this)
- What would you change next time?

Appendix C: Content Conversation Reflection

Note: These directions are on a handout that also gives directions on planning and enacting the content conversation.
Your analysis should focus on 4 main aspects (Parts 1, 2, and 3 are equally important. Part 4 is less important).

First, describe the conversation. Who did you talk with? Why did you select that student or students? What happened during the conversation? You do **not** need to turn in a full transcript, but you do need to provide me with enough of a sense of what happened to be able to make sense of your analysis.

Second, analyze the student's responses to your questions. What do you think the student understands about your topic? What do you think the student does not understand? What evidence do you have for your claims? Think about how your child's responses match or do not match what you expected, based on the alternative ideas you identified earlier.

Third, discuss how you would/will use this information to inform your thinking as you work on your unit plan. How will you try to build on students' ideas, given what you know now?

Fourth, reflect on the conversation itself. How did your questions work? What would you try next time? How did you do as the person asking the questions? What did that feel like? How will this experience with talking with a child in depth inform your teaching?

You'll turn your analysis in on CASES as a journal entry. You'll then be able to build on these ideas as you work on the "alternative ideas" section of your investigation plan for Phases 1 and 2.

Appendix D: Images of Inquiry Reflection

Images of Inquiry Journal Assignment #1

"Images of Inquiry" are stories of how different teachers modify lessons on CASES to better meet their own teaching style and the needs of their students. These are intended to help you think about how you can make productive changes to lessons you find – a major focus of this course.

The purpose of this assignment is to help you a) become familiar with the CASES weather unit as a resource for your own investigation plan b) begin to think about how you can make changes to lessons you find that foster inquiry and attend to learners' ideas.

1. Go to CASES: http://cases.soe.umich.edu
2. Click on Unit List and select the Weather unit
3. Browse around the weather lessons. At the bottom of each lesson, you will see the QEC (questioning & predicting, explanations & evidence, and communicating & justifying) graphic and 2 images of inquiry. Read Emily's and Nancy's images. Click on their names to learn more about them. Try to "get to know" either Emily or Nancy and the kinds of activities included in the weather unit.

In your journal entry for this week, focus on at least one of the images of inquiry that you read. You can react to the image or images in whatever way seems productive to you. If you'd like, you might think about some of the following questions:

- Who do you identify with (Nancy or Emily)? Why?
- What do you think of the changes Nancy or Emily made to the lesson or lessons you're focusing on?
- How did Nancy or Emily learn about and use their students' ideas in their teaching?
- How might you use these images of inquiry to help you figure out changes you'd make to the lesson or lessons you're focusing on?

If you want to read about other teachers who've modified CASES lessons or read images from different units, visit the "Images of Inquiry" section of CASES – select it from the top menu bar at any time.

Images of Inquiry Journal Assignment #2

"Images of Inquiry" are stories of how different teachers modify lessons on CASES to better meet their own teaching style and the needs of their students. These are intended

to help you think about how you can make productive changes to lessons you find – a major focus of this course.

Earlier, you read Images of Inquiry related to the Weather unit. Now, you will choose another teachers' images to read and react to.

1. Go to CASES: http://cases.soe.umich.edu
2. Click on Images of Inquiry. Read the summaries of the teachers. Choose one who looks interesting to you and read through their images (by clicking on the lesson plans). You'll need to skim through the lesson plans to make sense of the images.
3. Read all the images for your teacher of choice, and then reflect on them in your journal entry.

You may reflect in whatever way you wish. The questions below might help you get started:

- Why did you choose this teacher?
- What did you think of the decisions he or she made?
- Have you had similar dilemmas in your teaching or planning?
- In what ways are you similar/different from this teacher?
- How might these images help you in thinking about your own science teaching? Be as specific as possible.

Appendix E: Critique Assignment

Note: This is from critique assignment #2. For critique assignment #1, the activity is basically the same, but preservice teachers use criteria that they or their peers generated.

We've talked about different criteria for critiquing instructional materials. Some of the criteria you've identified have included:

1. *Questioning and Predicting:* The lesson expects students to answer relevant and challenging scientific questions, and students may ask their own questions, as well. The lesson involves students in making predictions about phenomena and providing reasons for their predictions.
2. *Making Explanations based on Evidence*: The lesson allows students to experience real scientific phenomena; collect, analyze, and transform data; make inferences; and revise their thinking. The lesson expects students to use evidence in their explanations and to ground their explanations scientifically. Sometimes, students may plan their own investigations, with guidance from the teacher.
3. *Communicating and Justifying Findings*: The lesson supports students in reflecting and productively discussing ideas with each other and with the teacher. The lesson expects students to communicate their findings clearly and creatively, applying their explanations to new situations and providing justification for their reasoning.
4. *Coherence, Instructional Goals, and Assessment:* The lesson sets a limited number of clear and worthwhile goals for learning and engages students in understanding authentic, challenging science concepts and in developing scientific inquiry abilities. The pieces of the lesson (objectives, activities, and assessment) all hang together, and the lesson supports students in making connections among different parts of the lesson, among the science ideas addressed, between this lesson and the rest of the unit, and between this lesson and the students' prior knowledge. The lesson includes a plan for assessing whether the objectives were successfully met.
5. *Using scientifically and pedagogically relevant and appropriate instructional representations:* The lesson makes connections to appropriate real world examples of the scientific ideas. The lesson represents the science content in scientifically accurate ways, and will not promote alternative ideas.
6. *Attending to learners' ideas:* The lesson builds off of students' initial ideas about a concept and allows students to revisit these ideas at the end of the lesson, and/or takes into account alternative ideas students might have.
7. *Equity:* The lesson supports *all* students in engaging in and learning from the experiences.

Review the lesson plan you've received.

Based on what you see in the lesson plan, as a pair, decide on one criterion that you'd like to focus on today. You may choose something from the list above, or a different one. (Select a criterion that you think this lesson plan will allow you to go into depth on.)

As a pair, apply the criterion you're focusing on to the lesson plan. Describe how the lesson plan meets or doesn't meet the criterion. Identify both positives and negatives, and focus on crucial aspects of the lesson, not superficial ones. Then, describe how you might change the lesson plan to better meet the criterion. Be as *specific* as you can be.

As a pair, decide which of the changes you've identified to the lesson plan is most important, in terms of making the lesson plan better meet your criterion. Put a star by that change. Why is this such a critical change? (If you prefer, you may identify which aspect of the lesson plan is most crucial to keep as it is currently written.)

What do you think could or would have come before this lesson, in a unit on weather? Think about science concepts, scientific inquiry abilities, experiences, etc.

What do you think should come after this lesson, in a unit on weather?

Appendix F: Pre/Post Test

Imagine that you are teaching a unit about light in your third grade student teaching placement. As you're planning for this unit, your cooperating teacher gives you[a lesson plan based in color and temperature] to use in your unit, though you can modify it before you teach it. As you consider the lesson, answer these questions:

1. What would be your specific goal for students' learning?
2. If you would make changes to the lesson, briefly describe them.
3. Why would you make the changes you've described?
4. How would you determine if you were successful in fostering the learning you set as your goal?
5. What would you do if some students didn't attain your goal by the end of the lesson?
6. One common idea third graders have about color and temperature after doing this activity is that they think red colors are "hot" and blue colors are "cool." How would you find out if any of your students had this idea?
7. If some of your students had this idea, how would you address it during your lesson?
8. Why is taking these ideas into account important? How might your students' learning be different if you didn't address their ideas in this lesson?

Appendix G: Interview Protocol

How do you think you as a teacher might know or find out the ideas students have in your everyday teaching? (Probe to include both prior knowledge and alternative ideas)

Why is considering the prior knowledge of your students important in science class?

What might influence your decision of how to handle misconceptions (alternative ideas in second interview) of your students?

In your Seeing the Light assignment, you said you would do _____ if the students thought that red was hotter in temperature than blue. Why do you think your ways of dealing with the hot/cold idea (from #4) would help students develop the correct idea? Why do you think this would work?

What would you do if one child had this idea? Why? What if half of the class had this idea? Why?

What if you did [whatever they mentioned] and about half the class still had an alternative idea? What would you do then? Why?

Is there anything else from your pre/post test you thought was interesting or important or that you struggled with?

What [still – in second interview only] confuses you about using students' ideas in your science teaching?

(Second interview) What experiences in the methods class helped you think about students' ideas in science? What about in your placement and teaching?

(During second interview): You completed this assignment during the first week of class, and at that time you said you would ____. Can you tell me about the changes from this first assignment? How have your ideas changed about this idea? What changes do you think are important? Why?

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