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# PRESERVICE ELEMENTARY TEACHERS' USE OF A DISCURSIVE MODEL OF MEANING MAKING IN THE CO-CONSTRUCTION OF SCIENCE UNDERSTANDING

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## ABSTRACT

This research investigates how three preservice elementary teachers were prepared to teach science using a Discursive Model of Meaning Making. The research is divided into two parts. The first consists of the nature of the participants' learning experiences in a science methods course within a school-university Professional Development School partnership. This part of the investigation used Constant Comparative Analysis of field notes gathered through participant observation of the methods course. The analysis investigated how the methods instructors employed productive questioning, talk moves, and a coherent research based Teaching Science as Argument Framework. The second part of the study consisted of an investigation into how the participants applied what they experienced during the methods course in their initial science teaching experiences, as well as how the participants made sense of their initial science teaching. Data consisted of teaching videos of the participants during their initial science teaching experiences and self-analysis videos created by the participants. This part of the research used Discourse Analysis of the teaching and self-analysis videos. These inquiries provide insight into what aspects of the methods course were taken up by the participants and how they made sense of their practices. Findings are:

1) Throughout the methods course, instructors modeled how the Teaching Science as Argument Framework can be used to negotiate scientific understanding by employing a Discursive Model of Meaning Making.

2) During lesson plan conferences the Discursive Model was emphasized as participants planned classroom discussion and explored possible student responses enabling them to anticipate how they could attempt to increase student understanding.

3) Participants displayed three distinct patterns of adoption of the Teaching Science as Argument Framework (TSAF), involving different discursive practices. They were,

- Detached Discursive Approach: Use of some discursive strategies without an apparent connection to the TSAF.
- Connected Approach with a Focus on Student Thinking: Intentional use of the Discursive Model informed by aspects of the TSAF.
- TSAF Approach: Priority is given to the TSAF supported by substantial application of the Discursive Model.

4) The evidence participants chose to highlight in their self-analysis videos is reflective of their patterns of adoption of the Teaching Science as Argument Framework and their differing discursive practices.

Analysis led to the formation of the middle theory that when learning to teach science in the elementary school, teacher commitment to the discourse and practices of science is constructed through participation in a learning community where a discursive model of meaning making is the norm. Curricular and methodological implications, as well as implications for future research are presented.

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## DEDICATION

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To my father Greg, I can hear you standing in heaven screaming, "That's my daughter!" I hope I have made you proud.

# Chapter 1

# INTRODUCTION

Studies have examined the challenges preservice teachers face, (E. A. Davis, Petish, & Smithey, 2006, p. 237), how their field experiences do not support them the way science teacher educators would hope (S. K. Abell, 2006), and how they do not have enough content background to teach science effectively (V. Akerson, Morrison, & Roth-McDuffie, 2006). What has been overlooked is what preservice teachers are capable of when prepared to teach science in a way that is grounded in research and coupled with effective modeling. This study documents the nature of what preservice teachers are able to do to support their students when making meaning of science content and practices. It shows how when they are scaffolded to use productive discourse structures and research-based teaching frameworks they can co-construct scientific explanations based on evidence and discursively make sense of science concepts. This study also examines how preservice teachers make sense of their own practices and how they view what they are capable of doing. By challenging the predominant deficit model of preservice teaching I will highlight the potential of the "well-started beginner" (Hollon, Roth, & Anderson, 1991).

## New Proficiencies in Science Learning and their Impact on Preservice Teachers

Learning to teach science is historically difficult for preservice and veteran elementary teachers who are trained as education generalists (E. A. Davis et al., 2006), especially as the expectations of what it means to be competent in science have shifted. New perspectives on proficiency in science learning emphasize scientific discourse and practices in addition to traditionally difficult areas like depth of subject matter and nature of science

(E. A. Davis et al., 2006; NRC, 2011). What counts as knowledge has moved from static recitation of information handed down from teachers to students to collaborative meaning making through dialogue and discussion. How classrooms function must change to account for this shift. Instead of the traditional pattern of classroom talk where teachers ask questions, students respond, and the teacher evaluates the response (Lemke, 1990), these new proficiencies call for teachers to lead discussions that support scientific reasoning and co-constructing understanding while emphasizing a set of Core Ideas and Practices. These Core Ideas and Practices allow students to engage deeply with science content and develop an understanding of how science is conducted while expanding their abilities related to scientific practices. Specific practices students should be engaged in include developing explanations based on evidence, using argumentation to critique and evaluate scientific ideas, asking meaningful questions, obtaining, evaluating and communicating information, and using the language of science (NRC, 2011). Such disciplinary knowledge is constructed and assessed through language (Carlsen, 2007).

The language of science is considered a social language. Social languages are varieties of language that allow people to enact different socially situated activities (Gee, 2008). Language is at the heart of scientific practice, without language there is no science and no discipline encapsulates a social language quite as well as science (B. A. Brown & Spang, 2008; Gee, 2004). Students access science through symbolic sign systems, social practices, and the social language of the scientific community.

Scientific discourse practices in the elementary school classroom are diverse, complex, and related to assumptions about knowledge and how students learn (Kelly, 2008). Nevertheless many elementary teachers are not familiar with the social language of science

because they are prepared as education generalists and not as science specialists. Also everyday vernacular does not typically overlap with the language of science, and so even veteran teachers can find it confusing to negotiate the transitions between everyday talk and science talk. Norms of scientific language give technical meaning to terms used in everyday conversation (Lemke, 1990). For example, the idea of a scientific theory based on a body of evidence versus an everyday theory based on inference. Science textbooks, articles and reports often use conceptually dense and abstract language, which projects the notion that participation in science is reserved for the intellectual elite (Kelly, 2008). With an emphasis on communicating, evaluating and critiquing scientific explanations of natural phenomena, making the language of science accessible to all students is at the core of the new K-12 science frameworks (NRC, 2011). Because science education is made up of language events and social processes, learning science means learning to talk science (Lemke, 1990). To talk science students, preservice and veteran teachers must learn to use the specialized language of science in writing and understand it while reading. Talking science also guides the practical actions of a science classroom, including hypothesizing, explaining, observing, analyzing, arguing, and forming claims (Lemke, 1990). It is often assumed that if teachers design interesting activities then children will talk more about science, but research has shown this not to be the case (Zhang et al., 2010). Elementary teachers must make a point to unambiguously define and model expected classroom norms of discourse and discussion and give students the opportunity to practice talking science using prompts which bridge every day and scientific vernacular (Herrenkohl & Guerra, 1998; Varelas, House, & Wenzel, 2005). But since science is not typically taught in this way preservice teachers must have the chance to practice talking science in their methods courses if they are to scaffold their

students' abilities to do so. There are many benefits to group discussion during science lessons or science talks. Teachers gain a better understanding of their students' misconceptions about a topic and so are equipped to confront those misunderstandings to increase student content knowledge. Science talks are also used to corroborate evidence about student learning from varying sources and can act as pre- and post-assessments for units. Teachers have also reported becoming more reflective about assessment in general and better able to design meaningful assessments (Zhang et al., 2010).

In addition to the proficiencies discussed above, preservice science teachers must also learn to explicitly scaffold student thinking using discourse patterns to engage with the practices and language of science as well as the process of argumentation (K L McNeill, 2011; J. Osborne, Erduran, & Simon, 2004). Teaching scaffolds are supports aimed to extend a students' abilities (Bransford, Brown, & Cocking, 2000). These scaffolds include talk-moves and productive questionings, as well as prompts for making ideas public and challenging the claims of others (Chapin, O'Connor, & Canavan Anderson, 2009; Elstgeest, 2001; Kelly, 2008; Robertson, 2009). These are traditionally a challenge for preservice teachers (E. A. Davis et al., 2006). To achieve these goals preservice teachers need to adopt a new classroom discourse (Gee, 2008) that assimilates the Core Ideas and Practices and foregrounds the discourse of argumentation in their classrooms (NRC, 2011; Simon, Erduran, & Osborne, 2006).

However preservice teachers often utilize simple, authoritative talk patterns and there is not always a correlation between talk type and the content and objectives of the lesson (Viiri & Saari, 2006). This pattern is not specific to preservice teachers and has also been identified in experienced in-service teacher talk ("Trends in International Mathematics and

Science Study (TIMSS, 2007). Choice of talk type is typically based on coping with the classroom situation rather than on planning or reacting to student talk (Viiri & Saari, 2006). When teachers sense a deficit in their subject matter knowledge they will default to a closed classroom discourse where they control the flow of conversation and utilize the traditional question-response-evaluation (Lemke, 1990) pattern to assess students' content knowledge (Carlsen, 1993). To change this pattern it is important for teachers to explicitly plan talk types in accordance with lesson objectives but also be willing to change talk types in reaction to student ideas and contributions (Viiri & Saari, 2006).

Regular practice talking about science has been shown to increase student-student interaction, improve students' ability to listen to each other and build off of others' thinking. Students have been shown to be better able to ask questions and have developed better content knowledge, enhanced self-efficacy, and increased understanding of the "Big Ideas" of the unit along with improved assessment scores. Science talks also help to cultivate scientific habits of mind at an early age (Zhang et al., 2010). Because children benefit from opportunities to practice learning to talk about their scientific observations, findings, explanations, and claims preservice teachers must also have the chance to practice using the language of science and to become comfortable leading investigations and science talks. The ability to guide classroom discussion and control the flow of discourse is the hallmark of effective science teachers (Leach & Scott, 2003; Viiri & Saari, 2006). Thus preservice teachers must learn how to use the language of science in order to effectively mediate their students' adoption of scientific language for the purpose of participating in scientific practices such as inquiry and the social construction of scientific concepts (C. W. Anderson, 2007). This needs to occur in both their methods classes and in their internship placements,

but because they do always see such practices in their placements (S. K. Abell, 2006) science teacher educators must equip preservice teachers with tools for learning from practice (Santagata & Guarino, 2011).

**Good Teaching vs. Good Science Teaching**

Productive Discourse is a hallmark of all good teaching but what differentiates good science teaching from other disciplines is the centrality of evidence-based claims used to inform explanations. Good science teaching does not push one single "scientific method" but instead presents a way for students to ask and answer questions about the world around them. Science is empowering for young students because it can equip them with an arsenal of problem-solving tools that contribute to their abilities to reason critically and communicate effectively (Zembal-Saul, McNeill, & Hershberger, 2013).

Early in their science education, students should be making observations of scientific phenomena, encouraged to ask questions of the phenomena, constructing explanations of what they observe and communicating their explanations to their peers and others. An often-overlooked step in this process is the critique and evaluation of their own and other's explanations based on evidence. Teachers need to support their students in going beyond making simple claims to include reasons and evidence in their arguments (NRC, 2011). Elementary students can productively engage in these practices when they participate in learning communities where this is the norm and teachers explicitly model and critique scientific argumentation (K. L. McNeill & Krajcik, 2008). Instruction can be designed in ways that foster productive participation along with positive orientations to science by beginning with a deep understanding of how scientists investigate problems and

communicate their findings (Allchin, 2011). Teachers can also develop meaningful tasks that challenge students in developmentally appropriate ways and give students authority over their own learning through a commitment to social negotiation of meaning through argumentation (Zembal-Saul, 2009).

**Preservice Teachers Learning from Practice**

Most teacher education programs succeed at preparing future teachers for the everyday work of teaching, but reflection and ongoing learning from practice are often vague (Zeichner & Liston, 1996). If preservice teachers are to continue to grow and improve as practitioners they need to be equipped with the knowledge and skills to do so. They must be able to attend to important aspects of instruction, reason about and make sense of these elements, and propose alternative instructional strategies. When video is used as an artifact of practice it has proven effective at supporting preservice teachers' ability to learn from teaching (Santagata & Guarino, 2011).

**Significance of the Study**

Scientists use language to challenge, validate, and advance knowledge. Science teachers use language to make thinking public, to assess their students' understanding, and to communicate the norms of science. Science learners use language to make sense of concepts, process ideas and reflect on their developing scientific understanding. Language is the means by which science teaching and learning is accomplished, and so it is important to understand *how* science teachers use language to accomplish these tasks. Often even veteran elementary teachers do not utilize science talks and scientific discourse in their practice (S.

K. Abell, 2006) and so this study uses video as a primary data source to inform how preservice teachers make sense of their own practice and aims to describe how preservice teachers learn to use discourse to support science learning during their initial science teaching experiences. The specific research questions this study addresses are:

1) What is the nature of three preservice elementary teachers learning experiences in their science methods course?
2) In what ways do the preservice teachers attempt to support students in making sense of science ideas and practices in their initial science teaching experiences using productive discourse strategies? How else do they attempt to do this?
3) How do the preservice teachers make sense of their initial science teaching experiences through video based analysis of their practice?

These are important to study because much research has been done on argumentation (Erduran, Simon, & Osborne, 2004; J. Osborne et al., 2004; Simon et al., 2006; von Aufschnaiter, Erduran, Osborne, & Simon, 2008) and science literacy (DeBoer, 2000; Feinstein, 2011; Roberts, 2007), but less work has been done on the importance of how teachers can use the social language of science to help their students make meaning of science concepts – specifically how preservice teachers learn to use the social language of science through participation in teaching and learning communities. Also at a time when there is a strong push for standardization and homogenization of education, this study further documents the social nature of science learning and elucidates the need for preservice teachers to participate in productive discourse communities in their methods classes and preservice placements.

# Chapter 2

## REVIEW OF LITERATURE

*Talking Science: Language, Learning and Values* by Jay Lemke was published in 1990. It has become a seminal piece for the role of talk and discourse in science teaching and learning. Because of the importance of this piece, it was hypothesized its publication could have been a critical point in time spurring research on talk in the science classroom, specifically how preservice teachers learn to use productive discourse to help students co-construct meaning of science concepts. But a search of the three main professional journals on science education – the *Journal of Research in Science Teaching*, *Science Education* and the *Journal of Science Education* – between the years 1990 and 2012 returned 335 articles on preservice teachers. Only ten of these focused on talk and/or discourse, and none of them examined how preservice elementary teachers actually implemented science talks in their teaching. So while this section discusses relevant research on talk and discourse in relation to elementary students, preservice, and in-service teachers there are some notable gaps, which this study will begin to fill.

This sections begins with a discussion of elementary science learners, it then goes on to examine elementary teachers in relation to teaching science (with an in-depth introduction to talk moves and productive questioning), the epistemic aspects of science teaching, and scientific argumentation in the elementary classroom. Finally the use of video for preservice teachers to learn from practice is reviewed.

**Elementary Science Learners**

In 2011 the National Research Council published a new Framework for K-12 Science Education (NRC, 2011). This framework builds on the work of previous studies that have sought to identify major ideas for K-12 science education. These projects include *Science for All Americans* (Rutherford & Ahlgren, 1991), *Benchmarks for Science Literacy* (AAAS, 1993), the *National Science Education Standards* (NRC, 1996), and *Project 2061* (AAAS, 1989). The framework integrates the understanding of science concepts with the practices of science and is designed to build these understandings through each year of a child's schooling. By the end of 12th grade all students should have developed an understanding of the major practices, concepts, and core ideas of science. They should also be able to engage in productive discussions about, and make informed decisions on, science-related issues as well as be "critical consumers of scientific information" (NRC, 2011) and to continue to learn about science in their everyday lives.

The framework identifies eight scientific practices students should be immersed in across their K-12 science education (NRC, 2011). These are:

- Asking questions
- Developing and using models
- Planning and carrying out investigations
- Analyzing and interpreting data
- Using computational thinking
- Constructing explanations
- Engaging in argument from evidence

- Obtaining, evaluating, and communicating information

Each of these practices is embedded in and co-constructed through language. Language is the medium through which questions are asked, explanations are constructed, arguments are made, and information is communicated. Without language making sense of models, interpreting data, and planning investigations would be impossible. Language is central to the practices of science (Carlsen, 2007).

Though a common thread through the K-12 science progression is language, how children use language and make sense of the practices of science vary greatly from kindergarten to twelfth grade. Children often differ from adults in how they generate and evaluate hypotheses and make predictions, with children under ten years of age typically proceeding without any consideration of hypothesis whatsoever (Penner & Klahr, 1996). Both children and adults are likely to focus on variables they believe to be causal and hypotheses that predict expected results are proposed more frequently than those predicting unexpected results, highlighting the importance of the consideration of prior knowledge when designing investigations (Kanari & Millar, 2004). Critiquing and evaluating evidence is a defining feature of scientific thinking and even young children understand what it means to test ideas and to differentiate between hypothetical beliefs and evidence (D. Kuhn & Pearsall, 2000; Sodian, Zaitchik, & Carey, 1991). In the context of investigations children tend to default into making causal inferences during their initial explorations (Schauble, 1996) and are likely to selectively record data, distort or reinterpret data to support their hypothesis (Kanari & Millar, 2004). Students struggle with data that seems to not influence the system under investigation, as well as with data that needs to be collected and considered over the course of multiple investigations because they tend to lack the memory and

recording skills to do so. Children also tend to terminate their search for new information once they find evidence to support their hypothesis and are likely to refer to the most recent data gathered. Only with additional exposure to investigations and evidence evaluation do children begin to make inferences of noncausality and indeterminacy (Kanari & Millar, 2004).

In general children are not able to design appropriate investigations without teacher scaffolding and are more likely than adults to duplicate their efforts when considering multiple variables. They also do not naturally record their data, have trouble understanding the limitations of their own memory, and do not foresee the relationship between inscriptional practices and future reasoning (Carey, Evans, Honda, Jay, & Unger, 1989). Even so it has been shown that with the proper support children can be successful in co-constructing their understanding of science concepts (Lehrer & Schauble, 2005; Metz, 2004).

In order for children to be able to plan and carry out scientific investigations they cannot merely be shown what to do during investigations. Their actions must be explicitly scaffolded by teachers; tools teachers can use to do this are talk moves and productive questioning. Student thinking during investigations can be prompted with questions such as, "What are you going to do next?" "What outcome do you predict?" "What did you learn?" and "How do you know?" These forms of questioning-in-action prompt students to explain their reasoning behind their investigating, which helps facilitate the integration of newly learned and prior knowledge especially when prompts are related to the negotiation of knew understandings or the meaning behind observations (Chi, De Leeuw, Chiu, & Lavancher, 1994). But preservice elementary teachers do not typically hold strong commitments to the notions that their classroom practice should push student construction of deep understanding

of science concepts but that rather it should be student-centered, hands-on, and enjoyable (S. Abell, Bryan, & Anderson, 1998).

**Preservice and Inservice Elementary Teachers and the Teaching of Science**

Teachers must be able to understand and account for their students' ideas as learners in order to help all students develop an understanding of science and participate in scientific learning communities. However, preservice elementary teachers do not typically have sophisticated ideas about their students' thinking and do not know what to do with those ideas in practice. There is typically a mismatch between how preservice teachers view teaching and what they are able to accomplish in the classroom and they have shown to be concerned with keeping their students interested, motivated, and physically involved in learning activities rather than focusing on understanding science content (E. A. Davis et al., 2006).

In a study of preservice elementary teachers enrolled in a science methods course (S. Abell et al., 1998), researchers integrated various written and discussion based reflective tasks for use with integrated media cases of science teaching to understand participants' examination of personal theories about science teaching and learning, their personal histories and visions of science, and how they frame science problems. Participants discussed student interest and motivation about science in their responses, but typically did not include student understanding of science concepts as a goal for their teaching. Activity-based lessons were valued and "teacher as guide" was often discussed, this was thought to be because they also held negative views of themselves as science learners and so seemed to feel more comfortable as a guide rather than alternative images of science teacher as authority figure.

In addition to these vague notions of science teaching they also held naïve views of their students, believing that elementary students would lack the cognitive ability to perform science investigations. The participants strongly believed that elementary school science should be simple and fun in order to motivate and engage their students (S. Abell et al., 1998).

Teachers must also be able to conceptualize the purpose of investigations in their classrooms (Hart, Mulhall, Berry, Loughran, & Gunstone, 2000) – why investigations are important and the specific learning outcomes of investigations. Scientific experimentation in elementary classrooms has historically been an exercise in following directions, where students are given a lab notebook and asked to follow procedures leading to a given outcome. Not only does this method not encourage higher order thinking, it does not align with the work of scientists and leads children to believe that science is all about learning to control one variable and follow directions rather than the development of evaluative skills to reflect on and manage strategic knowledge in relation to task goals (Hart et al., 2000; D. Kuhn & Dean, 2005). Ideally investigating should be seen as a means to gather evidence and observations to be used in the formation of claims, explanations, and arguments leading to increased understanding of the natural phenomena under investigation. When teachers make this purpose explicit, students are better able to make conceptual links between what they are doing and why they are doing it (Hart et al., 2000).

Elementary school students collect evidence through participation in scientific investigations. When designing investigations it is important for teachers to understand the abilities and limitations of their students. But this is not a typical practice of preservice teachers (Zembal-Saul, Blumenfeld, & Krajcik, 2000). Even after conducting concept

interviews of student ideas and being asked to integrate their findings into their lesson plans, participants in one study still did not utilize student ideas and preconceptions in their teaching (Zembal-Saul et al., 2000). Other studies indicate that preservice teachers have unsophisticated and underdeveloped knowledge and skills related to scientific practices themselves and need further exposure to such practices in their teacher education coursework in order to be able to effectively lead scientific investigations in their classrooms (Bowen & Roth, 2005; Lawson, 2002; Windschitl, 2003).

These scientific practices include questioning, predicting, explaining and making sense of data, as well as communicating findings (NRC, 2000). In one study, preservice teachers were asked to formulate a hypothesis about what causes differences in the swing speeds of pendulums – the length of the pendulum or the weight of the bob. Ninety-four percent could set-up a test to determine the correct answer and could provide evidence to support their argument. But when these same students were asked to predict why water rose inside an inverted jar placed over a burning candle only 21% were able to do so. According to the researcher, it is relatively easy for students to use observable evidence to explain phenomena, but when the evidence is unobservable it is difficult to conceptualize the relationship to the phenomena and so the majority are unable to construct arguments to back-up their predictions (Lawson, 2002).

In a comparative case study of how preservice teachers' perceptions of inquiry are influenced by their own inquiry experiences, six preservice students were studied as they participated in an inquiry based science methods course, as well as in their student teaching classrooms. After a short introductory period the students were given six weeks to complete their own independent inquiry project. Students were asked to complete unstructured journal

entries chronicling their experiences with inquiry and how they felt it could be useful (or not) in their future classrooms. The independent inquiry was also coupled with in-class activities to complement the inquiry experience. Participants were aware that they were using substantial background knowledge throughout their inquiry and several suggested that considerable input from them as teachers would be needed to create a successful learning experience for their future students. All participants had trouble formulating testable questions and believed this would also be an issue for their students. Participants were excited during data collection, but that excitement was not enough to prompt them to want to use inquiry in their own classrooms. This study showed that inquiry projects are not sufficient to ensure that preservice teachers will feel confident in using inquiry in their own classrooms, and writing about inquiry without structured reflective prompts is inadequate to encourage substantive reflection by preservice teachers (Windschitl, 2003).

In another study designed to understand preservice teachers' practices relative to data interpretation and representations, participants were asked to design a study, collect data, interpret the data and communicate their findings. After participating in several guided inquiry experiences preservice teachers began their own inquiry projects. The participants' inquiries were scaffolded to include two focus questions based on measurable variables and to report their methods, data, and claims. Participants had trouble structuring testable questions for their projects and had trouble operationalizing variables to be able to make claims from their data. Data tables were often unorganized and seemed to be viewed as a presentation tool and not as a way to make sense of data. Graphs were often poor representations of the data, using bar graphs when the data called for line graphs and vice versa, as well as many missing labels and titles. Only two of the twelve who completed

research reports stated claims that clearly stemmed from the collected data, and only seven were related to the original research questions. Participants did not know how to structure questions, gather data needed to answer their questions, organize and make sense of collected data, or choose and utilize adequate representations of the data in order to make accurate claims. This suggests that preservice teachers need to engage in open inquiry projects more than once and/or to be guided through reflection on their practices with opportunities to revise and revisit their methods and reporting strategies (Bowen & Roth, 2005). Overall these studies indicate that preservice teachers tend to have unsophisticated and underdeveloped knowledge and skills related to inquiry and need further experience with inquiry in their preservice classes.

**Participating in Scientific Practices through Talk and Discourse**

Elementary students are expected to participate in the practices of science yet the typical elementary preservice and inservice teacher does not have a strong understanding of or experiences with such practices. Talk and discourse are tools to bridge this gap. Argumentation is the central activity of scientists (Bazerman, 1988) yet true argumentation is rarely seen in elementary classrooms. Most talk originates from teachers and consists of teachers explaining the science concept to their students (Ogborn, Kress, Martins, & McGillicuddy, 1996). When talk does involve students it follows a pattern where the teacher asks a student a question with a known answer, the student responds and the teacher evaluates what the student said. This is called the I-R-E pattern for Initiation – Response – Evaluation (Mehan, 1979). What this talk pattern implicitly teaches students is that knowledge resides within the teacher and that they need to rely on the teacher for validation

of their thinking. This is contrary to the expectations for science learners outlined in the a new Framework for K-12 Science Education (NRC, 2011) where students are expected to be asking questions, interpreting data, forming explanations and engaging in scientific argumentation. Teachers can shy away from the practice of argumentation when they do not understand how the language of science defines argument, which rests on evidence and has the goal of shared understanding versus an argument in everyday life (Duschl & Osborne, 2002).

In order for talk and argument to be successful in the science classroom teachers must make explicit interventions to emphasize the construction of arguments based on evidence, and tolerance for others' ideas. Articulating ones' ideas and communicating them with others differentiates science from other school subjects. In science students must form an evidence-based explanation to a question and support their ideas with data. Since this process is unique to science teachers must provide scaffolds to support student success. Without such scaffolding students do not spontaneously adopt the social norms or the epistemic aspects of argumentation for conducting productive classroom discourse (J. Osborne, Erduran, Simon, & Monk, 2001). Because the language of science is abstract and unfamiliar to students, all students can be considered "non-native" science speakers. To accommodate such a perspective, this review draws from the literature on teaching science to diverse students to outline practices for teaching science in the elementary school classroom. First teachers must unambiguously define the norms, expectations, and patterns of thinking that constitute the "rules of the game" of the science classroom (O. Lee, 2002). Students must then have the opportunity to use these norms in a challenging yet balanced manner while participating productively in the practices of science. Productive participation in

science refers to students making intellectual progress in understanding science concepts, while actively engaging in tasks related to the discipline of science (Engle & Conant, 2002). As defined in the new Framework for K-12 Science Education, these tasks include asking questions, developing and using models, planning and carrying out investigations, analyzing and interpreting data, using computational thinking, constructing explanations, engaging in argument from evidence and obtaining evaluating and communicating information (NRC, 2011). Changing the typical I-R-E talk pattern is essential to increasing productive participation in science lessons (Herrenkohl & Guerra, 1998). This talk pattern is not typical of conversations outside of the classroom where the person asking a question does not already know its answer and is not testing the respondent's knowledge (Lave & Wenger, 1991). In order to productively engage students in discourses beyond the I-R-E talk pattern, teachers must adopt discourse that supports children in publicly explaining their perspectives to their peers while developing scientific understandings (Herrenkohl & Guerra, 1998). Two tools to help achieve this goal are productive questioning and talk moves.

Productive questions do not require mere recall; they are problems to be solved. A good question jump-starts students' thinking, it stimulates curiosity and leads to where the answer can be found. Productive questions do not even need to be answered with words, children can show rather than say their response (Elstgeest, 2001). Talk moves are conversation prompts that are effective at supporting student thinking and learning. The use of talk moves allows students' scientific thinking to be discussed, dissected, and understood while simultaneously building and supporting a community of learners (Chapin et al., 2009).

**Productive Questioning.** Asking questions and formulating hypothesis is often considered the hallmark of scientific investigation, but how teachers ask questions and

encourage thinking around a problem is directly tied to how they conceptualize the role of questioning in the classroom. While it is often said, "There is no such thing as a wrong question." there can be in the context of a science classroom. Wrong questions stem from a teachers' "testing reflex" and typically manifests as purely verbal questions requiring no problem solving on the part of the student with answers housed in textbooks, on the white board, or embedded in PowerPoint™ slides. These forms of questions follow the I-R-E pattern. This model has been found to be the default questioning strategy in most classrooms, yet it does not support complex reasoning or encourage students to elicit or justify claims (Mehan, 1979). A good question opens the door to investigation, stimulates thinking and invites students to find out where the solution lies. Good questions are referred to as "Productive Questions" because they stimulate productive thought and encourage action (Elstgeest, 2001). Productive questions call for explicit responses, not just memorized answers, to indicate whether or not a student *really* understands. They bring attention to details that students might overlook. These questions encourage students to deepen their understanding by exploring further into the science concept under investigation (Elstgeest, 2001; Norton-Meier, Hand, Hockenberry, & Wise, 2008; Robertson, 2009). Examples of productive questioning strategies, as well as suggestions for use, are located in Table 2.1 (used with permission – see Appendix A).

Productive questioning can individualize instruction when teachers choose the type of question to ask to suit a child's experience in relation to a particular inquiry (Elstgeest, 2001). Productive questioning also encourages curiosity and engages students in critical thinking crucial for the negotiating meaning, which leads to better student understanding and achievement (Norton-Meier et al., 2008). But because the I-R-E recitation pattern has been

the default mode of questioning in most classrooms, students have come to expect it and often show resistance when teachers press them with productive questions. Some subtle and not-so-subtle discourse repertoires have been developed to help teachers facilitate effective classroom science talk.

**Table 2.1:** Productive Questions

| Forms | Examples | Suggestions for Use |
|---|---|---|
| Attention Focusing | Can you see …? Do you notice …? | Helps to encourage children to take note of details. Useful at the beginning of an investigation. |
| Measuring and Counting | How many …? How long…? | Nudges students from purely qualitative to quantitative observation. |
| Comparison | Is it stronger, heavier, longer than ….? | Helps children order observations and data |
| Action | What happens if …? | Encourages experimentation and the investigation of relationships |
| Problem Posing | Can you find a way to …? | Use when children are able to set-up investigations on their own |
| Reasoning | How do you think …? Why do you think that …? | Use cautiously, only after students have had the experience necessary to answer. |

adapted from (Elstgeest, 2001) (used with permission)

**Talk Moves.** Structured talk-moves are one way to support teachers in attending to scientific talk in their classrooms. They extend classroom discourse beyond the traditional I-R-E talk pattern (Chapin et al., 2009; Lemke, 1990; Simon et al., 2006) and encourage students to expand their reasoning and arguments while fostering student-student interaction and debate. While using talk-moves, as seen in Table 2.2 (used with permission – see Appendix B), teachers could revoice a students' reasoning, or prompt other students for participation by asking for agreement/disagreement, as well as ask students to explicate their reasoning with prompts for evidence (Chapin et al., 2009). Revoicing serves several purposes. At a minimum it repeats a student's contribution and rebroadcasts it back to the group, giving it added importance and attention. Teachers may reformulate the utterance in the process of restating it to give it greater clarity, more complex conceptualization or a more

specialized register. The teacher can also maintain the student's right to evaluate the correctness of the teacher's restatement by introducing the revoiced utterance with phrases such as, "So let me make sure I'm saying what you meant …" or "So you're suggesting …." The teacher can encourage further discussion between students by contrasting divergent statements or comparing similar ones. In these ways teachers can use this talk-move to build a community of learners (Cazden & Beck, 2003). A teacher could also ask a student to revoice what another student said using his or her own words. This encourages purposeful listening while highlighting the need to listen to each other's use of evidence. Rather than having students talk at each other, purposeful listening sets the ground work for meaningful argumentation in the science classroom (Simon et al., 2006). By utilizing talk moves and effective questioning, teachers are communicating to their students that productive classroom science talk is challenging, intellectual work that takes time, effort and persistence (Chapin et al., 2009).

**Table 2.2**: Talk Moves

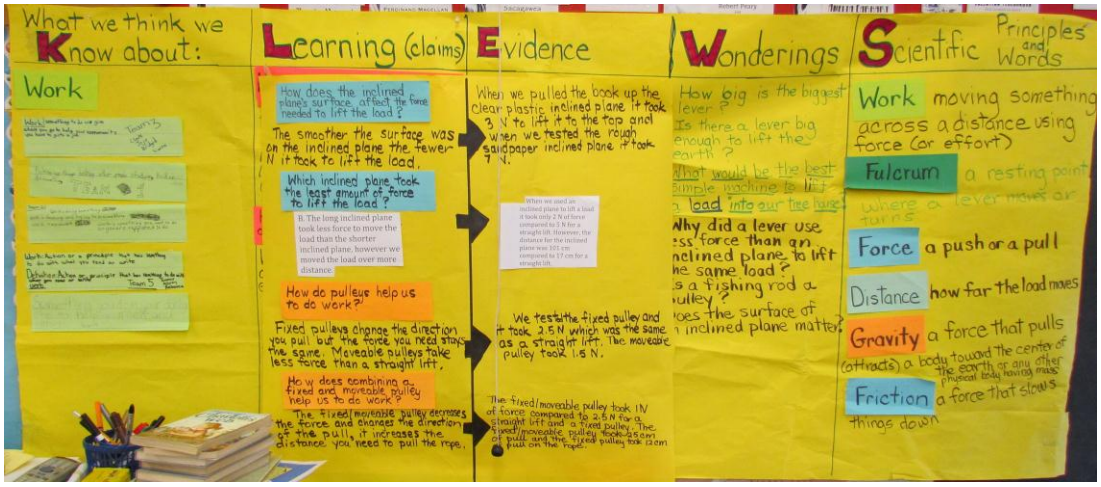
| Forms | Examples | Suggestions for use |
|---|---|---|
| Revoicing | "So let me see if I've got your thinking right. You're saying _____? (with space for student to follow-up) | Clarifying student thought and reinforcing ideas for the rest for the class. |
| Asking students to restate someone else's reasoning | "Can you repeat what he just said in your own words?" | Allows students to reflect on what they do and do not understand. |
| Asking students to apply their own reasoning to someone else's reasoning | "Do you agree or disagree and why?" | Make students more aware of discrepancies between their own thinking and that of others (including the scientific community. |
| Prompting students for further participation | "Would someone like to add on?" | Allows students to reflect on, participate in, and build on scientific thinking |
| Asking students to explicate their reasoning | "Why do you think that?" or "What evidence helped you arrive at that answer?" or "Say more about that." | Improve students' ability to build scientific arguments and reason logically. |
| Using wait time | "Take your time…. We'll wait." | Increase participation in a discussion by allowing students to think about their ideas. |

adapted from (Michaels, Shouse, & Schweingruber, 2008) (used with permission)

**Other Scaffolds: KLEW(S) charts**. A KLEW(S) chart is a modification of the KWL chart for reading comprehension (Ogle, 1986). It was originally published as a KLEW chart (Hershberger, Zembal-Saul, & Starr, 2006) consisting of four columns, one for each letter of the acronym KLEW. The K column is used to document prior knowledge and is framed as What WE *THINK* WE **KNOW**. The L column is framed as WHAT ARE **LEARNING**? and is where claims are recorded throughout the learning sequence. The E column directly links to the claims with examples of evidence the students collected to support their claims and is framed as WHAT'S YOUR **EVIDENCE?** The final column is for **WONDERINGS** and used to record student questions that arise during instruction (Zembal-Saul et al., 2013). But a fifth column was recently added (Zembal-Saul et al., 2013) for **SCIENTIFIC** PRINCIPLES making it a KLEW(S) chart, which addresses the importance of science concepts when developing claims based on evidence. In science a KLEW(S) chart is a tool used to map explanations over the course of a lesson or series of lessons with emphasis placed on the connections between claims and evidence. It was developed to highlight the essential features of inquiry and to counter the perception that inquiry takes too much time to pursue in the elementary school classroom. The KLEW(S) chart emphasizes direct observation and the use of evidence to support the formation of scientific claims (Zembal-Saul et al., 2013). KLEW(S) charts help organize student ideas and what they have learned during investigations. They also provide a visual scaffold for students to refer to during science talks. By situating the LEARNING and EVIDENCE columns next to each other, students can see the direct connection between claims and the data used to support them. In practice students often, "refer to the KLEW(S) chart to explain what they learned, and they used specific observations as evidence to support their claims" (Hershberger et al., 2006, p.

53). KLEW(S) charts can also serve as visual reminders to preservice and inservice teachers to prompt students to support their claims with evidence. The S column on SCIENTIFIC PRINCIPLES was added after data collection for this study was completed so all references are to KLEW charts. An example of a KLEW(S) chart can be seen in Figure 2.1.

**Figure 2.1**: KLEW(S) chart created by a third grade class




## Epistemic Aspects of Science Teaching

Preservice teachers also have difficulty understanding some of the epistemological commitments necessary to help their students form a deep appreciation of science concepts and practices. Epistemological commitments, from a practical standpoint, can be understood as the socially shared production and reproduction of knowledge and truth (Lidar, Lundqvist, & Ostman, 2006). Understood this way, important epistemic aspects of science teaching include comprehending the nature of science (NOS), scientific knowledge construction, including the sources of such knowledge (Sandoval, 2005), the difference between classroom science and the actual practices of scientists and acknowledgement of the constraints of

authentic science practices in the classroom including designing investigations, gathering evidence and forming explanations based on that evidence.

The first step in building a strong epistemologically based orientation to science teaching involves understanding the Nature of Science (NOS) and how scientific knowledge is constructed. NOS is concerned with the values and epistemological assumptions underlying scientific activities. Understanding NOS is no small task considering the scientific community has had much disagreement on what constitutes it (Allchin, 2011; Lederman, 2007; J. Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003). What has emerged from the literature are general themes which should be used as frameworks for understanding NOS. Students should understand how science works, be able to analyze scientific information, form functional understanding of scientific practice, and comprehend its relevance to decision making. Foremost students need to be able to analyze the reliability of scientific claims and understand what forms of scientific communication are credible in order to interpret scientific practice in particular cases, not abstractly (Allchin, 2011). "NOS includes the whole spectrum of features that affect the reliability, or trustworthiness, of scientific claims" (Allchin, 2010, p. 591) including the development of a claim from, "experimental controls, through the revision of theories, to publishing in journals and communicating science in the public media" (Allchin, 2010, p. 591). Elementary teachers are charged with developing their students' understanding of the NOS (NRC, 1996) yet they typically do not have an understanding of it themselves (V. Akerson et al., 2006; V. L. Akerson, Abd-El-Khalick, & Lederman, 2000).

Teachers must also understand that scientific knowledge is constructed by people and does not simply reside somewhere out in the world waiting to be discovered (T. S. Kuhn,

1996). What must be understood about this notion is that scientific knowledge is not accepted because of its "truth" but because members of the scientific community are persuaded of its value, through argumentation, as an explanation of natural phenomena (Sandoval, 2005). This implies that what counts as scientific truth is in embedded within language and discourse practices (Lidar et al., 2006).

By focusing on the reasoning and discursive skills of scientists and developing an understanding of how scientists evaluate and apply evidence, the dialectic relationship between disciplinary knowledge and epistemic commitments is brought to the forefront. This entails beliefs about what counts as evidence leading to the designing of investigations which can generate such evidence (Sandoval & Reiser, 2004). When children understand this connection they are more able to successfully engage in scientific investigations, form scientific explanations and defend their explanations through argumentation.

**Scientific Argumentation in Elementary Classrooms**

Scientific argumentation is a central activity of scientists and is a social product resulting from involvement in a community of practice whose members generate explanations of natural phenomena based on gathered evidence and persuade each other on the validity of their ideas (Bazerman, 1988; Newton, Driver, & Osborne, 1999; J. F. Osborne & Patterson, 2011). Argumentation is an authentic practice of scientists that can also be implemented in the science classroom. Scientific argumentation is defined as a "knowledge building and validating practice in which individuals propose, support and refine ideas in an effort to make sense of the natural world" (Sampson & Clark, 2008b, p. 8). When students engage in argumentation they compare explanations and use evidence (Aikenhead, 2006) to

decide which explanation best describes a given phenomenon, (Berland & Reiser, 2009) whether it succeeds in pushing understanding and whether it does so better than other explanations (J. F. Osborne & Patterson, 2011). An explanation is a statement which describes how or why natural phenomena occur, and explains why the natural world works in a particular way. Explanations and arguments are complimentary practices with arguments necessary for justifying the validity of explanations (Berland & Reiser, 2009; K. L. McNeill & Krajcik, 2008; J. F. Osborne & Patterson, 2011). Using evidence to build explanations and support arguments is an important practice of the discourse of science (K. L. McNeill, 2011). Because of the dialectic relationship between scientific truths and the epistemic commitments proposed in this paper, scientific claims cannot be grounded in observation alone but rather in arguments where links are made between evidence and scientific conjecture, "the *raison d'eˆtre* of the scientist is to determine which conjectures present the most convincing explanations for particular phenomena in the world" (Newton et al., 1999, p. 555). Arguments are the basis on which new ideas are judged and made sense of, as well as how students gain insight into the practices of the scientific community (Newton et al., 1999; J. F. Osborne & Patterson, 2011). Learning to argue scientifically is not innate and needs to be explicitly taught though instruction, scaffolding, and modeling (K. L. McNeill, 2011). This process requires teachers to shift classroom discourse from an authoritative or closed questioning model to an open dialogic format associated with negotiation (Elstgeest, 2001; J. Osborne et al., 2004). Yet this change is often difficult for teachers to make (K. S. Davis, 2003). Teachers must then let go of certain aspects of classroom control and allow students to openly interact around, debate, and discuss competing ideas (Lemke, 1990; J. Osborne et al., 2004) in collaborative groups (Jimenez-Aleixandre, Rodriguez, & Duschl, 2000;

Sampson & Clark, 2008b) because the social structure of classrooms is a major determinant of the nature of classroom discourse (J. Osborne et al., 2004). Engaging students in scientific argumentation has many potential benefits including learning to support claims with evidence, participating in scientific discourse, and learning science concepts (Jimenez-Aleixandre, 2008).

Tracing how students negotiate meaning through classroom argumentation is an ongoing area of interest with varying outcomes. A variety of video and discourse based studies have been designed to investigate whether students are able to learn new content through argumentation. Many have focused on the impact of argumentation around socioscientific issues (Dawson & Venville, 2008; Driver, Newton, & Osborne, 2000; Duschl & Osborne, 2002; J. Osborne et al., 2004; Sadler & Donnelly, 2006; Simon et al., 2006) and/or have used Toulmin's Argument Pattern (TAP) as a central framework (Driver et al., 2000; Erduran et al., 2004; Newton et al., 1999; J. Osborne, 2001; J. Osborne et al., 2004; Simon et al., 2006). TAP considers the rhetorical elements of arguments and their function, including claims, data, warrants, and backings. Someone states a claim, essentially an assertion, then should follow that up with data or evidence in support of that claim and may also pose a warrant based on theoretical presumptions or backings (Toulmin, 1958). TAP places emphasis on the patterns and features of argument rather than the content of arguments. In one such study, groups of eighth grade students were video recorded as they explored and posed arguments for and against the building of a zoo at the beginning the school year. Teachers then taught a minimum of eight lessons where argumentation using TAP was central in both a scientific and socioscientific context. At the end of the school year the same groups of students were video recorded during an identical discussion of

building the zoo. Researchers sought to explore the development of argumentation patterns by elementary students. Notably, argument patterns were seen more often during discussions of socioscientific issues than scientific ones, indicating a need for knowledge of evidence to engage in argument about scientific phenomena. To determine the quality of the students' arguments, researchers determined whether an argument contained any reasons or grounds, such as data, warrants or backings, as well as the inclusion of rebuttals. The scientific nature of the arguments was not a focus of the study, rather the development of argument patterns (J. Osborne et al., 2004). In a follow-up study aimed to determine the relationship between argumentation and the development of scientific knowledge, researchers once again video recorded discussions between groups of eighth grade students and assessed the quality of their argument patterns as described above. To understand the development of students' scientific knowledge several verbal and non-verbal activities were used, each student was followed and his or her thinking was analyzed sentence by sentence. Each student's arguments were assigned a level based on the quality of the argument pattern and the scientific content of the argument. Students typically used personal experience to back-up their claims, such as details of their own visits to zoos, indicating that students were not constructing new knowledge throughout the process but simply drawing on already assimilated knowledge. When students were unfamiliar with the concepts of the lesson they were unable to generate quality arguments and did not understand what was presented to them. Researchers concluded that students could only engage in argumentation using TAP when they previously knew the topic and that argumentation was not a valid method for constructing new knowledge. TAP-based argumentation is however useful in improving

students' thinking and supporting them in making connections across familiar contexts (von Aufschnaiter et al., 2008).

These studies have mostly examined the impact of content knowledge on the quality of argumentation and have found that content, level of abstraction, and time are probable markers of students' conceptual development. They have classified student learning as an increasing ability to integrate concepts and thematic focus, apply individual observations to understand general rules and laws and to use these developing understandings to more quickly solve problems (von Aufschnaiter et al., 2008; von Aufschnaiter & von Aufschnaiter, 2003). As demonstrated by their immediacy, tone and level of conviction, evidence has shown that students mainly rely on prior knowledge when arguing rather than incorporating new knowledge to support their claims. This indicates that instead of enabling learning and changes of opinion, students actually become more secure in their existing knowledge while engaging in socioscientific argumentation activities. But through this process students can learn how to defend their ideas in a precise streamlined manner (Sadler & Donnelly, 2006; von Aufschnaiter et al., 2008). Considering the previously presented definitions of explanation, argument, and argumentation (K. L. McNeill & Krajcik, 2008; Sampson & Clark, 2008a) teachers must facilitate students' exploration of natural phenomena through the gathering and evaluation of evidence as an integrated aspect of argumentation and not simply focus on socioscientific arguments in and of themselves. When science concepts rather than socioscientific issues were used as the framework for building arguments, it was found that content knowledge is not an indicator of argument quality. Six teachers were asked to implement a standard chemistry curriculum that included lessons focused on an explanation framework with opportunities for students to formulate arguments on science content. It was

found the students of the teacher who made the most significant modifications to the focus lessons on explanation and argument showed the least progress in constructing strong explanations of phenomena. At the same time, they earned similar scores to the other students on a content assessment leading researchers to conclude that making claims and explaining phenomena requires more than just an understanding of science content (K. L. McNeill, 2009).

Another study had fifth grade students collecting evidence to determine how many different habitats were in an outdoor space near their school. After collecting the data the students were asked to write an argument addressing the question. The students were then introduced to the constructs of using claims, evidence, and reasoning to support strong arguments and charged with revising their previously written arguments based on the new criteria. Additional lessons were also taught with strong written arguments as a consistent goal and the researchers interviewed the students to understand how they conceptualized argumentation. Even with argumentation as a consistent goal of the lessons, students conceptualized argumentation as a disagreement between scientists, though by the end of the study they reported that such disagreements did not mean the scientists were fighting or having a physical encounter. They thought evidence was collected in order to support an answer to a question and that explanations were exchanges between people on how or why a phenomenon occurs. Over the course of the study the students' abilities to construct arguments improved, pointing to the need to explicitly address and teach argumentation over an extended period of time to support students' abilities and understanding of this complex process (K. L. McNeill, 2011).

When preservice K-8 teachers were studied in a physics class for teachers, bridges needed to be built between the social language of teaching and the social language of science. The course was taught by a physics professor who self-reported the belief that it was important to use science talks as ways for students to explain their understandings of physics concepts. Yet he controlled most of the dialog in the class and often became frustrated when the students did not display ownership of the discussion. In essence the students were expected to use the language of science without participating in the practices of science, which proved not to be an effective combination. When the course instructor collaborated with a teacher educator, he began to understand the discourse of education, including the need to employ the practices of science before being able to effectively talk science. This border crossing led to an improvement in student achievement and success using the language of science to demonstrate their understanding of physics (Briscoe & Prayaga, 2004).

A middle and secondary science methods course was studied to understand preservice science teachers' abilities and perceptions of argumentation. The class was physically organized into small groups and the groups were expected to participate and interact with one another every class period. Two full class sessions were devoted to explicitly teaching the norms of argumentation using TAP as a framework (Toulmin, 1958). Prior to these sessions students were asked about the place of discourse in the science classroom. Most participants agreed that argumentation was fundamental to the practice of science, but that in the science classroom it was simply a pedagogical strategy to aid with the acquisition of science content rather than an important aim of science education. These perceptions did not change significantly during the course of the study, though they maintained a positive stance toward

using argumentation strategies in their teaching. When formulating their own arguments most participants showed improved argument complexity after explicit instruction; it is not known if this complexity remained after leaving the course (Sadler, 2006).

In view of the fact that the central activity of scientists is the construction of arguments based on evidence (Bazerman, 1988) and considering all students are expected to gain experience with argumentation, (K. L. McNeill, 2011; NRC, 2011) yet learning to argue in a scientific manner is not innate, it stands to reason that the tools of argumentation needs to be explicitly taught though instruction, scaffolding and modeling (K. L. McNeill, 2011). In order to do this teachers must shift classroom discourse from an authoritative or closed questioning model to an open dialogic format (Elstgeest, 2001; J. Osborne et al., 2004), which is often difficult for teachers (K. S. Davis, 2003). It is reasonable to expect the dialogic processes associated with argumentation be advanced in the preservice methods class. How elementary students construct arguments using various interventions has been studied (Berland & Reiser, 2009; Cavagnetto, 2010; Clark & Sampson, 2007; K. L. McNeill, 2011; K.L. McNeill, Lizotte, Krajcik, & Marx, 2006). Teaching strategies to promote student argumentation have also been studied (K. L. McNeill, 2009; Simon et al., 2006). How preservice teachers construct arguments has even been investigated (Haefner & Zembal-Saul, 2004; Sadler, 2006). But how preservice teachers are taught to be effective users of the dialogic tools associated with argumentation and how preservice teachers implement dialogic practices associated with argumentation in their initial teaching experiences has not been examined. This is the gap in the literature that this study aims to fill.

**Learning from Practice**

If teachers are expected to expose their students to argument and discourse during science lessons, then they need to be prepared to do so. This instruction should span their methods courses and preservice placement experiences, but the majority of preservice teachers do not see structured opportunities for students to practice talking science in their placements (Duschl & Osborne, 2002). As such much learning takes place "on-the-job" once they begin leading their own classrooms. It should thus be a goal of teacher education programs to equip graduates with the knowledge and skills to continue to learn and improve as professional educators. Preservice teachers need to be provided with opportunities to reflect on their practices in disciplined and structured ways so they are well prepared to continue to grow through their own practice (Santagata & Guarino, 2011).

Preservice teachers must also situate the language of science teaching within embodied experience (S. K. Abell, 2006; Lave & Wenger, 1991). That is preservice teachers have to "see" the meaning of language as a pattern located in their own experience (Gee, 2004). Preservice teachers must believe they can be successful in the field of education where these language practices are being used and see themselves as a valued member of the community of practice. They must be positioned in such a way as to bridge their university classroom experience with the reality of a public school classroom so they can see the utility and value of the academic social language of science teaching.

Unfortunately, because of the limitations of field experiences, preservice teachers rarely have the opportunity to observe let alone have continued interaction with more advanced users of reform minded science teaching (S. K. Abell, 2006). Through such interaction newcomers would be able to internalize how more experienced others use and

apply the academic social language of science teaching and so begin to see how they themselves can use the language in similar ways.

**The Use of Video to Learn from Practice.** The written word does not sufficiently encapsulate the multifaceted interactions of classroom life, so researchers have turned to other media to investigate and learn from teacher practice. The utilization of tools to capture the complexity of social interactions occurring within a classroom space is not new; researchers have used film, audio, and video recordings to gather rich data sets for many decades, but until recently it has been quite awkward and time consuming to use these tools in an efficient manner. The widespread availability and comparative low-cost of digital video equipment has led many educational researchers to adopt video recording as a primary data collection method (S. K. Abell, 2006).

Video is a situated learning tool that depicts images of authentic practice (J. R. Anderson, Reder, & Simon, 1996; Beck, King, & Marshall, 2002; Brunvand & Fishman, 2007; Lave & Wenger, 1991). The affordances of video may increase teachers' ability to make sense of the details of classroom action, enhance their ability to notice, and make connections with prior knowledge (S. K. Abell et al., 1996; Beck et al., 2002; E.A. & van Es, 2005; M G Sherin & Han, 2004; Star & Strickland, 2008). Video captures the richness of classrooms (Bryan & Tippins, 2006) and allows teachers to explore teaching and learning dilemmas in a risk-free environment (Beck et al., 2002).

Teachers have much to attend to throughout the day; watching videos gives insight into this complexity because of the detail that can be shown (Beck et al., 2002; Brunvand & Fishman, 2007) and affords teachers the opportunity to observe alternative teaching styles and strategies within the confines of demanding teaching schedules (M. G. Sherin, 2007).

Teachers need to be able to think on their feet and react in-the-moment to classroom action. Slowing down to contemplate decisions is a luxury not afforded to elementary school teachers. Analyzing videos of classroom practice allows teachers the opportunity to replay action, pause, and revisit particular moments. Such examination of practice can be useful to clarify what took place or to listen in on small group discussions. Video takes teachers out of the immediacy of the classroom and permits reconsideration of comments, decisions, and outcomes of pedagogical dilemmas (E.A. & van Es, 2005; M. G. Sherin, 2007; M G Sherin & Han, 2004). "Watching video affords the opportunity to develop a different kind of knowledge for teaching – knowledge not of 'what to do next,' but rather, knowledge of how to interpret and reflect on classroom practices" (M. G. Sherin, 2007, p. 14).

One way to examine differing aspects of practice is to edit and compile strings of associated clips. Video can be edited and reorganized in configurations different from the original chronological order, permitting focused scrutiny and detailed analysis. Digitizing video means that teachers no longer have to watch an entire lesson to take advantages of these affordances but can directly access desired segments. Digitized video can be linked to student work and captioned, directly capturing teacher reflections (M. G. Sherin, 2007). Video provides the chance to selectively choose specific features of classroom interaction such as questioning strategies (Crooks & Gifford, 1992) or non-verbal messages (Gwyn-Paquette, 2001). Video is also a social artifact and allows multiple viewers to collectively negotiate meaning, determine the significance of events (Bryan & Tippins, 2006; M. G. Sherin, 2007; Star & Strickland, 2008), and engage in critical examination of practice (McGraw, Lynch, Koc, Budak, & Brown, 2007). This is of critical importance to preservice teachers who have spent many years observing classrooms from a students' perspective, but

lack a teachers' eye-view of classroom action (Barnett, Harwood, Keating, & Saam, 2002; Bencze, Hewitt, & Pedretti, 2001; Brunvand & Fishman, 2007).

As preservice teachers edit, compile and construct cases they must continually review their video recordings to choose what to include, what to discard and what is useful footage. This process helps to solidify "complex and stable mental representations of their teaching—learning observations" (Beck et al., 2002, p. 350), as well as to link what they observe in the field to what they encounter in their coursework thus providing a bridge between theory and practice (Beck et al., 2002). Several projects investigating video editing as a tool for teacher education have shown the method to be a promising means of scaffolding reflection and influencing practice.

Rosaen et al. (2008) had preservice teachers write a reflection on a lesson they had taught based solely on memory, then asked them to view video of the lesson, select excerpts for analysis, and write commentary on them. No specific scaffolding was provided either time to allow the researchers to understand what pre-service teachers noticed and if video could alter their noticings. The preservice teachers' reflections from memory differed in several ways from their reflections based on video. Their reflections from memory focused on classroom management, made general comments on instruction and was not grounded in specific evidence, while the video-based reflection displayed a shift toward specific observations focused on children. Such findings seem to support the notion that editing video of one's own practice affords preservice teachers the opportunity to look more closely at the content of a lesson and how that content influences children, that reflection and analysis of their own practice based on video artifacts is more productive, accurate and useful than reflection based on memory alone, and that preservice teachers can use video to "make a

case" for some aspect of their teaching and back-up their claims with evidence (Rosaen, Lundeberg, Cooper, Fritzen, & Terpstra, 2008).

Calandra, Gurvitch and Lund (2008) asked preservice candidates to use iMovie™ to edit three 45-minute segments of lessons they had taught and to justify why they had chosen them. Prior to working with the video the preservice teachers reflected on the lessons and reported if they felt the lesson was successful. The researchers examined the preservice teachers' raw footage, initial reflections, edited video and justifications to determine whether digital video editing is a productive strategy to enhance preservice teachers' ability to think more deeply about their own practice. Results indicated that 90% of the chosen clips focused on the preservice teachers' behavior rather than on their students, which was concurrent with their initial reflections; that the majority of the clips were of classroom management and teachers' verbal instruction; and that 85% of the clips represented positive teaching examples. What was of note was how some of the participants changed their initial positive opinion of certain clips when they saw how their students responded to their instruction leading researchers to conclude that digital video editing can produce shifts in preservice teacher thinking and can provide insight into their existing and developing notions about teaching and learning (Calandra, Gurvitch, & Lund, 2008).

Yerrick, Ross and Molebash (2005) utilized digital video editing within the frame of a science methods course where preservice teachers were charged with exploring changes in their own thinking and beliefs about science teaching. Using desktop video editing software, preservice teachers examined video of their own teaching to identify children's preconceived notions of science topics, and reflect on their own pedagogical choices. This approach differs in that it challenged preservice teachers to determine how their views and beliefs

changed over the course of the semester. It was found that many of the participants began their projects by focusing on their own behavior but shifted their focus to exploring how children constructed understandings of science concepts. Of note is how the participants directly cited editing video as the catalyst for this change. Shifts were also noted in how participants evaluated their pedagogical orientations and changed their planning and instruction. A profound shift was seen in the way participants conceived of the roles of teacher and learner in the science classroom (Yerrick, Ross, & Molebash, 2005).

# Chapter 3

# GUIDING FRAMEWORKS

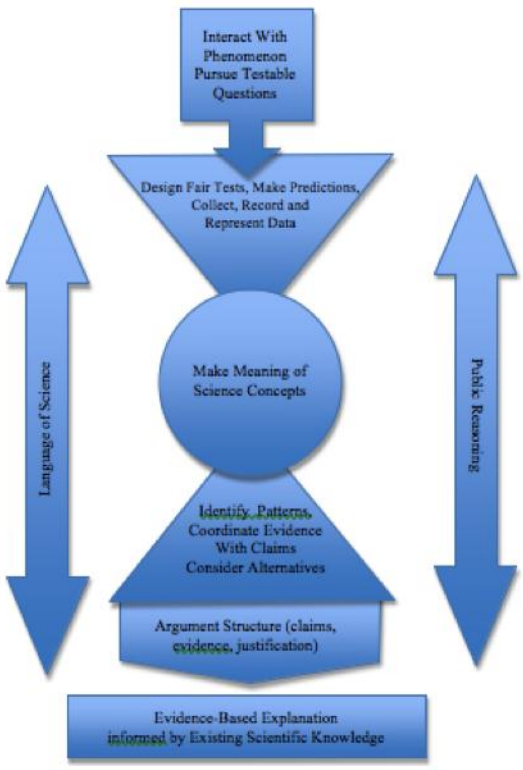
This section includes discussions of two different lenses used to inform this study. The conceptual framework addresses teaching science as argument with a review of the Teaching Science as Argument Framework (TSAF) by Carla Zembal-Saul (2009). The chapter then shifts to an overview of the theoretical framework which highlights the important constructs guiding this work, including how language is used in the construction of meaning, situated learning and legitimate peripheral participation.

## Conceptual Framework

In 2009 a paper set was published in the journal *Science Education* that addressed elementary school science teaching. Common themes emerged, including a need for a focus on problems of practice in elementary science teaching, the need to include dialogue about these problems of practice in preservice elementary science courses, and a commitment to developing tools to help support preservice teachers as they learn to reason about problems of practice. By organizing their research and instruction around problems of practice, the authors (E. A. Davis & Smithey, 2009; Schwarz, 2009; Zembal-Saul, 2009) used various frameworks, strategies, and tools to help their preservice students become "well-started beginners" (Hollon et al., 1991) who are ready to tackle similar problems in their own teaching. The scholars accomplished this by making a commitment to dialogue about problems of practice in ways preservice teachers can value and understand and by building on what preservice teachers regard as important (Mikeska, Anderson, & Schwarz, 2009).

**Teaching Science as Argument Framework (TSAF).** In contrast to TAP, the TSAF (Figure 3.1 reprinted with permission – see Appendix C) (Zembal-Saul, 2009) is informed by the sociocultural perspective on argumentation and science learning (J. S. Brown, Collins, & Duguid, 1989; Lave & Wenger, 1991; Lemke, 2001; Vygotskiĭ, 1978) and is grounded in the social practices and discourses of science. Students are situated in learning communities that are guided by norms of practice around the central aspects of scientific inquiry. In particular, this framework gives priority to evidence and explanation while communicating scientific findings. The framework is a teaching heuristic, a learning tool for enhancing preservice teachers' understanding of scientific practices associated with argument and an analytic tool for understanding practice. By giving priority to evidence and explanation, students learn to communicate using the language of science as they develop the skills of scientists (Zembal-Saul, 2009). The TSAF guides the current study.

**Figure 3.1:** Teaching Science as Argument Framework (TSAF) (Zembal-Saul, 2009) (reprinted with permission).




Situating learners in learning communities is essential as science is a social and cultural enterprise (NRC, 1996), which elementary school science should reflect. By actively engaging children in investigation-based science it is intended they will learn science

concepts while also learning about science in meaningful ways by developing testable questions, designing fair tests, making predictions, collecting data and making sense of evidence. Another central tenant of the framework is making thinking visible through the public reasoning. To provide a reasonable entry point for preservice teachers and students to participate in scientific discourse, the argument pattern used here is based on the work of Toulmin (1958), but the structure is simplified to focus on claims, evidence, and justification. Instead of analyzing argument patterns, this framework promotes the content of arguments and provides a guideline for how scientific explanations can be organized while making sense of evidence in the classroom. These supports extend beyond argument and include the modeling of reasoning strategies that support the development of scientific thinking by learners in the community. This is intended to call preservice teachers' attention to the importance of classroom discourse, using an argument structure during in-class science talks, reasoning publicly around natural phenomena, and utilizing the language of science. Utilizing the language of science is intended to help preservice teachers with limited background knowledge of science begin to understand the role of language in learning science, and how scientists must coordinate claims with evidence while weighing alternatives to contribute to the social negotiation of meaning. The TSAF is not intended to communicate all of the practices and discourses of science, but rather it is a learning heuristic aimed to promote preservice teachers' attention to scientific discourse and reasoning in the context of an investigation-based learning community (Zembal-Saul, 2009). The design of the framework was informed by a series of design-based research studies aimed at understanding how preservice teachers make sense of elementary school science as argument and to inform

iterations of an elementary science methods course (studies reviewed below) (Zembal-Saul, 2009).

Zembal-Saul's (2009) research is rooted in her elementary science methods course where she investigates ways in which preservice teachers make sense of elementary school science at the beginning of their teaching careers. Results are used to inform the design of the TSAF, as well as iterations of her elementary science methods course. Zembal-Saul is able to engage students in reasoning around core problems of practice, using the TSAF to inform the design of experiences in her elementary science methods course. Preservice teachers are led through model science lessons as learners; they then unpack those lessons as science teachers, in alignment with the framework. The framework allows preservice teachers to participate in science investigations while learning to construct evidence-based claims. It also highlights the role of classroom discourse as a way of negotiating meaning through the coordination of claims and evidence while making thinking visible through public reasoning. Preservice teachers also use the framework to inform the design of a series of lesson plans while they explore ways to organize instruction and use resources to inform planning. The framework assists preservice teachers in making thinking visible using science talks as a forum for public reasoning and as a way to assess students' sense-making processes. Social norms of science serve as an organizing frame of the methods classroom. Additionally preservice teachers are engaged in discussion mapping and video case studies to help understand the framework while making explicit connections to classroom practice. Responses to video cases serve as the primary source of data for Zembal-Saul's research. They bind together the study space by providing a common set of teaching episodes and analysis questions for the participants to address. Secondary data are collected during the

methods course and consist of teaching and planning artifacts created by participants, such as written reflections of the preservice teachers' initial science teaching experiences. Video-recorded lessons also serve as data, providing insights into the participants' actual teaching practices (Zembal-Saul, 2009).

Results from three iterations of study show that having a coherent conceptual framework to organize instruction can help preservice teachers make promising strides in their understanding of teaching elementary school science as argument. Initially participants held views of school science consistent with those described in the literature (E. A. Davis et al., 2006), but over time participants developed more sophisticated understandings as expressed through their responses to video cases. These improved understandings appeared to have been influenced by the TSAF. Results included a more focused interpretation of the role of evidence and argument in school science, with about half of the participants describing investigations as a means for students to collect data for constructing evidence-based claims. Participants also described investigations as a way for students to learn science concepts and processes, and came to see the role of teacher as one who questioned and monitored students to further their thinking and understanding of science concepts. Class discussions were described as being "necessary for students to make sense of what they were learning through investigations" (Zembal-Saul, 2009, p. 706). While participants placed greater emphasis on the role of classroom discourse and science talks as part of learning science, they tended to focused on discourse as a way to reach class consensus and did not consider possible alternative explanations nor did they encourage counter arguments. To address these limitations, researchers added a video case titled, *What happens when students disagree about evidence?* This was paired with a model science lesson where preservice

teachers had to weigh alternative arguments based on evidence. This particular case was associated with critical improvements in how participants came to view discussing claims and evidence with children, as well as how they problematized evidence (interpreted the same evidence in different ways and increased the validity of evidence to make stronger claims).

A crucial tipping point was observed when all participants used aspects of the argument framework to respond to video cases. This occurred mid-semester after they had responded to 3-4 cases in which reflections by experienced teachers were embedded in the case environment. Participants had also experienced several science lessons as science learners and were in the process of planning their own lessons. These experiences seemed to have come together at a crucial point in participants' developing thinking and practices and served to help them adopt aspects of the Teaching Science as Argument Framework. This pattern continued to be seen when participants' practices were analyzed, suggesting that the framework informed their science teaching as well.

Participants organized lessons around driving questions and had their students collect and analyze data associated with those questions. Participants prompted students using productive questions, and group discussions were used to help students identify patterns in data and to construct claims from evidence. Such practices are all notable for initial science teaching and draw on central aspects of the framework; including pursuing testable questions, using an argument structure, and making thinking visible through public reasoning.

## Theoretical Framework

People construct meaning in their lives through the use of shared symbol systems for representing people, objects, and their own and other's actions (Dyson & Genishi, 2005). Prominent among these symbols systems is language (Minick, 2005). Events are made meaningful by how they are represented or symbolized through language. Shared linguistic schemas allow people to name and narrate their experiences making language a medium for the construction of meaning in social action (Dyson & Genishi, 2005). When adopting a sociocultural perspective on education, talk is central to every activity. In this sense education is dialogue (Wells, 1999; Wells & Chang-Wells, 1992).

According to the sociocultural perspective that stems from the work of Vygotsky, learning occurs when people engage in social action mediated by semiotic tools; with language being considered the tool of greatest significance. This implies that learning is inherently social and language is the primary tool for learning, meaning construction, and cultural transmission (C. D. Lee & Smagorinsky, 2000). By participating in conversations, learners appropriate and make sense of a culture (Wells, 1999). What is noteworthy about this is that learning is constructed through joint activity – information is not passed from teacher to student (C. D. Lee & Smagorinsky, 2000). How a person makes sense of cultural experiences is dependent on the person's external activities (Arievitch, 2008).

**Language and the Construction of Meaning.** The discourse of science teaching and learning is considered an academic language, as well as a form of social language. "A social language is a way of using language to enact a particular socially situated identity and carry out a particular socially situated activity" (Gee, 2004). Science teachers speak and act

in specific ways. They pose questions, challenge students' claims, engage students' ability to debate and compare findings to form arguments, and search for patterns in their and others' results. Thus, to be a science teacher is to participate in the discourse of science teaching (Wells & Chang-Wells, 1992). As such, learning to teach science is intimately connected to appropriating the language and social acts of science teaching. It is also crucial to this process that the science teacher educator engage with the preservice teacher in ways that externalize in speech the internal mental processes involved in learning to teach (Wells & Chang-Wells, 1992).

A speaker's discourse choices serve to indicate which socially meaningful role the person is enacting (Gee, 2008, 2011). Discursive choices enable the speaker to enact a certain identity within a certain situation. They are how people use language, actions, tools, symbols, and ways of thinking/being to perform a certain socially recognizable identity. But discourse is more than just language choices; it involves language, as well the use of symbols, tools, and objects (Gee, 2005).

How these tools are used differs for each participant. For example, a learner makes meaning of cultural resources through joint problem solving with more knowledgeable others, as well as through collaborative tasks with peers (Wells & Chang-Wells, 1992). From a teacher's point of view those same interactions allow for increased appreciation of the learner's understanding (Wells & Chang-Wells, 1992). Teachers can use this knowledge to plan tasks that are a challenge to the learner, relevant to their current understanding, and fall with in the learners' zone of proximal development (Wells & Chang-Wells, 1992).

Discourse analysis draws attention to the use of language as a form of social practice (Gee, 2008; Group, 2000). When someone fully understands the discursive practices of a

discipline they are able to engage in social acts and practices distinctive of the discipline and fully interact with other members of the discipline in socially acceptable ways utilizing the social language characteristic of said discipline. In this manner discourse practices are matters of "enactment and recognition" (Gee, 2008). In education, it is through talk that students and teachers engage in the co-construction of meaning (Wells & Chang-Wells, 1992). In order for discourse annalists to understand the social practices and culture of education, they must examine how talk unfolds between teachers and learners.

By utilizing the constructs of discourse as language practices that allow communication within a community to be understood, discourse analysts can learn about much more than language alone. They can attend to and gain insight into the connection between knowledge production and the discourse practices used in particular social settings to construct knowledge (B. A. Brown, Reveles, & Kelly, 2005; Kittleson & Southerland, 2004). This is of particular importance because it is not enough for learners to be able to integrate the language of science into their classroom discussions, they must be able to use all of the discursive elements of science teaching and learning; posing productive inquiries, probing student knowledge and assisting students in the formulation of accurate scientific claims (Kittleson & Southerland, 2004; Lemke, 2001).

Kittleson and Sutherland (2004) used Gee's discourse analysis perspective (Gee, 2004) to understand the manner in which groups of students socially constructed scientific knowledge in an engineering design process. The overarching goal of this work was to investigate how implicit goals and agendas can shape the knowledge produced in the given context. The specific social activities the participants were engaged in were examined along with the participants' identity and relationship building. Results indicate that there was a

need for instructional congruence between conflicting ideological discourses. On a broader scale, it was noted that researchers who employ a discourse perspective should uncover the discourses of a given community as well as how these discourses structure and are structured by the community (Kittleson & Southerland, 2004). In later work, this team considered the interaction of group meaning making on the individual's understanding utilizing a microanalysis of student talk in conjunction with an analysis of individual student's conceptualization of a science topic. Findings indicated that the persuasiveness of a speaker held more sway over individual appropriation of the idea than the scientific accuracy of the idea itself. This finding prompted the researchers to consider how teachers can exploit this pattern to better promote scientific understanding (Southerland, Kittleson, Settlage, & Lanier, 2005).

The discourses of science teaching and learning are not unproblematic. Language is not neutral and all learners do not engage with it in the same ways. It is often assumed that science learners will appropriate the language of science by being immersed in the language practices of science classrooms (B. A. Brown & Spang, 2008; Gee, 2004), but this has been found not to be the case. In order to learn to teach science, preservice teachers must learn the language and social acts of science teaching. Before preservice teachers acquire the academic social language of science teaching, they must first see value in appropriating the language and understand that learning science in this way is not an "all-or-nothing affair". The understanding of science concepts develops over time when the learner is able to make new connections and better sense of the phenomena (Wells & Chang-Wells, 1992). When they first begin to use the language they will most likely find it awkward and not useful. They are not likely to recognize the value in appropriating the new language until they can

begin to see themselves as competent members of the teaching community with a personal understanding of and investment in the vernacular of the community (Gee, Kelly, Roth, & Yerrick, 2005). In order to do this they must move from peripheral to full participants in the culture of teaching science in the elementary school.

**Situated Learning and Legitimate Peripheral Participation.** Peripheral participation is how learning occurs. According to the situated perspective, learning to do something cannot be separated from the doing of the activity itself (J. S. Brown et al., 1989). It is not the passing on of a body of factual information, but rather a process of participation emphasizing the whole person where agent, activity, and the world are intertwined (Lave & Wenger, 1991). Learning is considered Legitimate Peripheral Participation in Communities of Practice. Learning is not simply situated *in* practice but rather learning *is* social practice; the two are not separable, "persons, actions, and the world are implicated in all thought, speech, knowing, and learning" (Lave & Wenger, 1991, p. 52). Peripheral participation suggests that there are multiple ways of being engaged in the social workings of a community and each individual travels along learning trajectories as his or her identities within the community develop and membership changes. Peripheral participation does not imply that there is a center or core to the community, but rather that peripheral participation can develop into full participation, which includes the diversity of roles and relationships involved in community membership. Being a peripheral participant is a way of gaining greater understanding through increased involvement in the community (Lave & Wenger, 1991).

Communities of practice are not neatly defined through common space or time. They are malleable, durable, and adaptable, based on how their members construct them.

Institutions do not define communities of practice; institutional boundaries may border one community of practice, many, or none at all. Communities overlap each other, adapt, and change as members leave and new members join – "the continuity of an emergent structure derives not from stability but from adaptability" (Wenger, 1998, p. 97). Communities cannot remain stable because members move in and out of the system, goals change, and innovations are introduced. Though communities are in a constant state of flux, this discontinuity mostly goes unnoticed because communities of practice accommodate advancement; they must be anonymously pliable to continue. If a community of practice is to survive beyond a single generation, there must be a way for new members to learn the ways of the community without unnecessary struggle. " ... 'legitimate peripheral participation' (characterizes) the process by which newcomers become included in a community of practice ... the required learning takes place not so much through the reification of a curriculum as through modified forms of participation that are structured to open the practice to nonmembers" (Wenger, 1998, p. 100). Newcomers must find their place within a community. They must determine where they fit in and how they best interact with other participants. This is not a passive process and cannot be achieved by simply reading a textbook (reification of a curriculum) or observing the action of others. It is only though participation that newcomers can truly learn the ways of a community of practice. Through this process the newcomers are taught how to negotiate the boundary objects (acronyms, forms, locations, procedures and language) of the community.

Studies in science classrooms have utilized the situated learning in communities of practice framework specifically with an emphasis on how learning involves the individual in a dialog driven environment and how talking, writing, and thinking are intertwined processes

(Varelas et al., 2005). There has been a push for teachers and researchers to pay attention to the social language of science (Gee, 2005) and science classroom discourses with a focus on the role language adoption plays in facilitating meaning making of the science ideas. Such research has provided promising evidence supporting the idea that the language used to express scientific reasoning and the act of scientific reasoning in and off itself are not able to be separated (Ash, 2008).

In this study, the guiding frameworks are used as tools to explain how the participants' discursive choices influenced their attempts to co-construct scientific explanations during their initial science teaching experiences. For example, by considering the sociocultural perspective, based on the work of Vygotsky, (Vygotskiĭ, 1978; Wells, 1999; Wells & Chang-Wells, 1992) the researcher will examine the participants' enacted views on the teachers' role in the construction of evidence based explanations. The work of Gee (Gee, 2004, 2005, 2008), informs the process of discourse analysis and helps the researcher understand the language choices the participants' made in relation to the Teaching Science as Argument Framework (Zembal-Saul, 2009). The work of Lave and Wenger on Situated Learning and Legitimate Peripheral Participation (Lave & Wenger, 1991) informs how the researcher understood the individual participant's stories in light of their development as beginning educators.

# Chapter 4

# METHODS

This study employed the qualitative case study tradition to understand how preservice teachers can use discourse to support science learning during their initial science teaching experience. The case under investigation is of three preservice elementary school teachers during their initial science teaching experiences. It is based on the premise that preservice teachers can successfully negotiate many of the complex dialogic practices associated with scientific argumentation in their early field experiences. Also that understanding how such success is developed can help inform future elementary science teacher education.

Classrooms are complex, busy places, so multiple data sources are needed (Creswell, 1997) to adequately understand the many factors influencing learning outcomes; a simple survey or interview would not suffice and so ethnographic data collection techniques were used. There was not a clean line between learning to use talk/discourse moves and their actual use by the preservice teachers in the methods course called "interns". Since this direct line did not exist, it became clear that both elements needed to be investigated in order to understand the entirety of the phenomenon. This implied that the context of how the interns learned to use talk/discourse moves was important and needed to be investigated. The specific research questions being studied are:

1) What is the nature of three preservice elementary teachers learning experiences in their science methods course?
2) In what ways do the preservice teachers attempt to support students in making sense of science ideas and practices in their initial science teaching experiences using productive discourse strategies? How else do they attempt to do this?
3) How do the preservice teachers make sense of their initial science teaching experiences through video based analysis of their practice?

## Study Design

This study is designed as a qualitative case study of three preservice teachers using ethnographic data collection methods. Data collection methods include participant observation, field notes, analytic memoing, and artifact collection. Ethnographic methods are used for this study because case studies seek to understand the holistic nature of a bounded system and ethnographic methods allow the researcher to become immersed in the real-life experiences of his or her participants within the study context. Ethnography is the study of people in everyday settings and seeks to understand how people make meaning of their cultural experiences (Anderson-Levitt, 2006). This study is presented in two parts, 1) an ethnographic description of a science methods course and, 2) a discourse analysis of teaching and self-analysis videos. Participant observation and field notes serve as the primary data for the ethnographic portion of this study, teaching and self-analysis videos created by the participants serve as the primary data for the discourse analysis. Analysis techniques include comparative analysis of field notes and discourse analysis of teaching videos. Each of these will be explained further in the following sections.

**Why Case Study?** Case Study is an appropriate tradition to guide this portion of the research because case studies are an investigation of bounded systems using in-depth data collection from multiple sources (Creswell, 1997) to investigate individual actions, social groups, organizations or events, and are used when the researcher aims to understand and/or explain complex social phenomenon bounded by time and place (Creswell, 1997; Yin, 2003). Case Studies focus on contemporary events, do not require control over outcomes, and ask "how" and "why" questions (Yin, 2003). Specifically case study research is interested in the

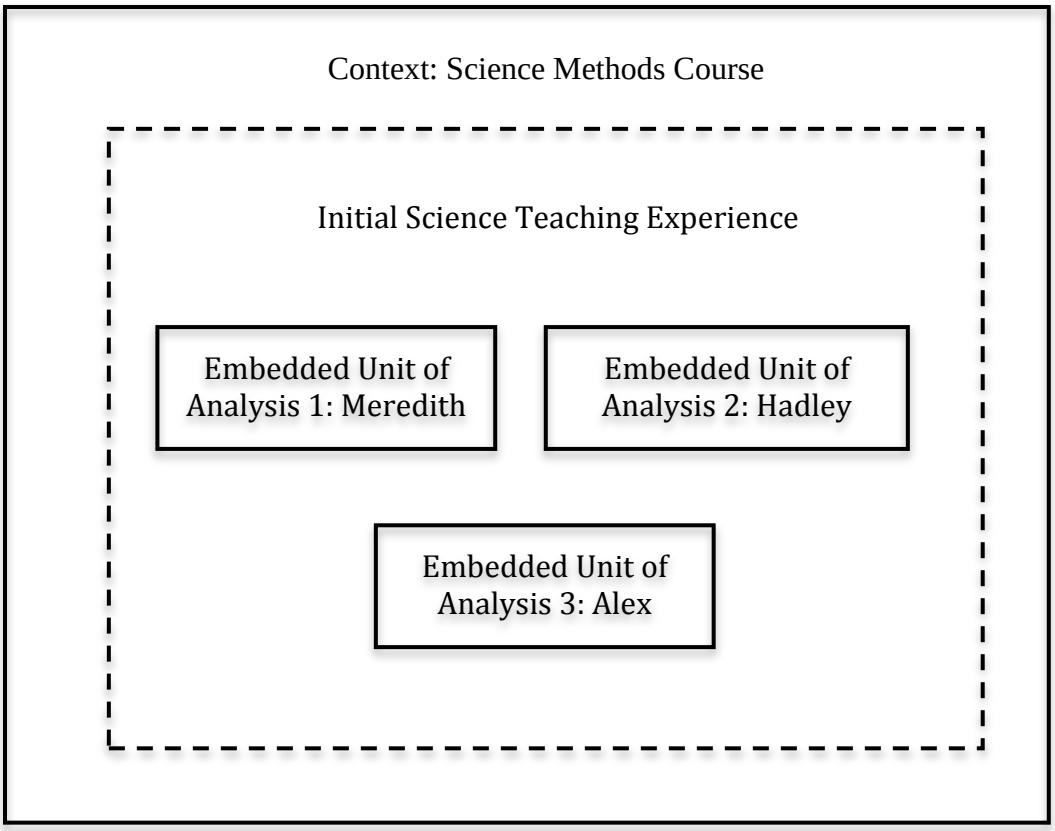
"*local particulars* of some abstract social event" (Dyson & Genishi, 2005, p. 3). Because they allow researchers to maintain the holistic and meaningful characteristics of events, case studies are only generalizable to theoretical propositions and not to wide-ranging populations (Yin, 2003). The intention of case study research is not generalization, but rather it is a study of the particular and its strength lies in its particularity and the situatedness of the case to its context (Stake, 1995). Qualitative case study researchers are interested in the meaning people make of given social situations in very particular contexts (Dyson & Genishi, 2005), where context involves the physical setting but also the social, historical, and/or economic setting of the case (Creswell, 1997; Dyson & Genishi, 2005).

According to Yin (2003) there are five components to a case study 1) study questions, 2) starting propositions, 3) unit of analysis/definition of "case", 4) the logic linking the data to the propositions, and 5) criteria for data analysis. Appropriate study questions for Case Study research take the form of "how" and "why" a certain phenomenon occurs (Yin, 2003). This study asked how participants use talk/discourse moves to achieve various educational ends. In order to fully appreciate the complete story of how the participants did this how they were prepared to teach using a discursive model of meaning making, as well as how they thought about and reflected on and made sense of their teaching needed to be understood. These starting points resulted in the three research questions stated above.

The study was also grounded by three starting propositions that directed the research in terms of what should be examined within the scope of the study (Yin, 2003). The first starting proposition for this study is that the science methods class influenced the participants' use of talk/discourse moves in their placement classroom, which led to the examination of the scope and nature of the science methods course the participants

experienced. The second proposition is that preservice teachers are capable of negotiating some of the complex dialogic practices associated with scientific argumentation in their early field experiences. This led to the need to investigate how the participants used discourse in their preservice placement classrooms and to attempt to trace their commitments to the constructs they experienced in the methods course. Thirdly, the study is grounded by the proposition that if the participants had a strong understanding of the affordances of structured discourse practices then they would use their discursive choices as evidence of how they co-constructed scientific claims and explanations with their students, which indicated the need to examine how the participants made sense of their practice in light of their demonstrated classroom commitments, as well as what they used as evidence to support their claims about their practice. Yin's (2003) third component of a case study is that the researcher must have a case of something and that the unit of analysis must be defined. This research is designed as a single-case of three preservice elementary teachers implementing their first multi-day science unit. Though there are three participants it is a single case because they all shared a common methods course and were prepared for their initial science teaching experience in the same way; thus this is a single-case with a common context and embedded units of analysis. Each participant was analyzed individually followed by a discussion of findings common to all participants. Figure 4.1 (used with permission – see Appendix D) represents the case design for this study. The case is embedded within its context but the boundaries between the case and its context are not always sharp (Dyson & Genishi, 2005; Yin, 2003) and are represented by the dotted line. The units of analysis are embedded within the single case.

**Figure 4.1:** Embedded Case Study Design




adapted from (Yin, 2003)(used with permission)

The fourth and fifth elements of case study design are the logic linking the data to the propositions and the criteria for interpreting the findings. These are also the least well developed in case study literature (Yin, 2003), and so potentially the hardest to explicate. The first part of the study was ethnographic in nature. The researcher collected extensive field notes as a participant observer in the science methods course. Considering the ethnographic nature of the data there was a need to employ an ethnographic method of analysis. Constant Comparative Analysis emerged as the logical choice; it is an ongoing, iterative process of coding field notes and making sense of the data. Since teaching and

learning are social processes organized through social interaction, (Gee, 2004, 2008) and the data for the second part of the study was discursive in nature, there was a need for a sociolinguistic analysis tool. Discourse Analysis (DA) emerged as an appropriate method for coding and analyzing the data (Gee, 2008, 2011). The DA for this study consisted of finding embedded sociolinguistic units in transcriptions of classroom talk (a complete discussion of the coding process and rationale is found in the Data Analysis section). The coding process resulted in analytic narratives of how the participants were prepared to teach, the nature of their actual teaching, and how they made sense of their teaching. When considered as a single case, each participant's analytic narrative results in findings addressing the stated research questions. Considering the study questions, starting propositions, definitions of the case, unit of analysis, the logic linking the data to the propositions, and the criteria for data analysis, case study is an appropriate research tradition for this study.

**Participants**

When choosing which participants to include in this study the researcher was primarily concerned with finding opportunities to learn (Stake, 1995) about preservice teachers *effectively* using discourse moves in their initial science teaching – what this looked like, and how such discourse moves were used during their initial science teaching experience. Research has already documented how classroom discussion can be a challenge for teachers (E. A. Davis, 2006), so this was not included in the scope of this study. Participants were not finalized until the end of the methods course and were chosen using purposeful sampling (Creswell, 1997) in consultation with methods instructors. The instructors were familiar with the research questions under investigation, had viewed the

participants' self-analysis videos, and understood the desire to learn how preservice teachers effectively used discourse moves in their initial science teaching experience. Based on these criteria, they suggested five interns as potential participants. After conducting an initial review of the data and drafting an analytical narrative of one participant, it was determined the research questions could be sufficiently addressed using three participants. The final three participants were chosen when the initial review reveled they were all at least attempting to use the Teaching Science as Argument Framework (Zembal-Saul, 2009) in their teaching.

The participants are all female, undergraduate elementary education majors at a large research university in the Northeastern United States. At the time of initial data collection they were in the first semester of their final year of a 4-year teacher education program, working toward the completion of a BS in Elementary Education. They had limited backgrounds in science. Prior to beginning the methods course they had completed one course each in earth, life, and physical science, as well as an accompanying lab experience. None had pictured themselves as science teachers and they were hesitant to label themselves as such. Their preservice teaching placements were in first, third, and fourth grade.

**Context**

The study took place in a K-6 Professional Development School (PDS) partnership between a large College of Education and the local school district. The PDS is an opportunity for undergraduate elementary education majors to experience an intensive, field-based learning alternative to the traditional campus-based program. Preservice teachers in the PDS are referred to as "interns". Interns abandon the university schedule and adopt the

calendar of the local school district. Interns teach and learn on-sight in a local elementary school and are placed in a mentor teacher's classroom for an entire year. During the first semester they work in the classrooms for four days a week, as well as take methods courses in Social Studies, Mathematics, Science, and Classroom Learning Environments. For the second semester they work full-time in the classroom and attend a weekly seminar with other interns that focus on engaging in teacher inquiry, a hallmark of this particular PDS (Burns, in press; Nolan, Badiali, Bauer, & McDonough, 2007). The program immerses the interns in the culture of the school, where they are able to develop an understanding of student learning and classroom dynamics, while positioning them with deeper insight into the teaching profession. An in-depth contextual narrative of the PDS science methods course is included in the next chapter.

**Data Sources and Collection**

Data was collected during the science methods course that was taught on-site in a third grade classroom after regular school hours using ethnographic methods. Ethnographic methods are appropriate for a case study because case study researchers aims to understand and/or explain the local particulars of complex social phenomenon bounded by time and place (Creswell, 1997; Dyson & Genishi, 2005; Yin, 2003). Ethnographic methods allow the researcher to become immersed in the real-life experiences of his or her participants within the study context (Yin, 2003). The researcher joined the methods class as a participant-observer in September during initial class meetings in the school-based classroom, and attended every subsequent meeting including lesson planning conferences and small group meetings. The group had met previously in a "Jump-Start" session where interns learned

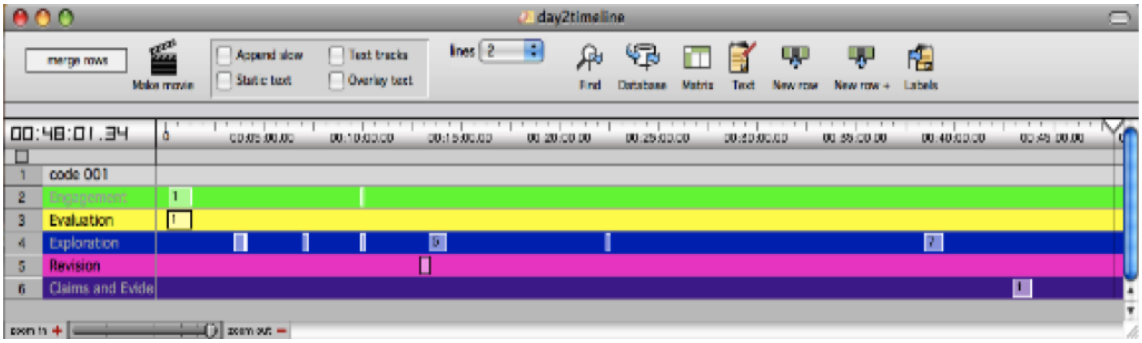
about the general structure of the course, expectations, and general requirements, as well as the use of embedded technology such as blogs and science notebooks. During class sessions extensive field notes were kept, creating a written record describing the lived experiences of the class members over the course of the semester (Emerson, Fretz, & Shaw, 1995). Field notes form the foundation to understanding the context of the case and provide an ethnographic sense of being in the science methods course (Dyson & Genishi, 2005) and to understand how the participants prepared for their initial science teaching experience. Following the class meetings, the written field-notes were transcribed and detail/clarification was added as needed.

As part of the course the interns planned and implemented a three-day science mini-unit. The implementation of the mini-unit took place in their field placement classrooms. Each of their lessons was video recorded and served as primary data for this study. The videos documented what took place in the classrooms during the participants' three-day teaching sequence, and provided the researcher with evidence of how the participants attempted to support their students in the co-construction of scientific claims and explanations using discursive and other means. Being a participant observer in the methods course provided background information and increased understanding of context when there was a need to interpret aspects of the interns' teaching videos. Additional primary data consisted of annotated videos the interns created as a self-analysis of their practice. The self-analysis videos provided evidence of how the participants made sense of their teaching experience and what connections to the methods course and the Teaching Science as Argument Framework (TSAF) they identified as relevant to their practice.

The interns used StudioCode™, a digital video analysis tool, to analyze the uncut video footage of their three-day teaching sequence and to create 12-14 minute analysis videos. The interns performed a very formal version of recognition work (Gee, 2005) when they analyzed their teaching videos. Their work highlighted how they made sense of their science teaching practices in their placement classrooms.

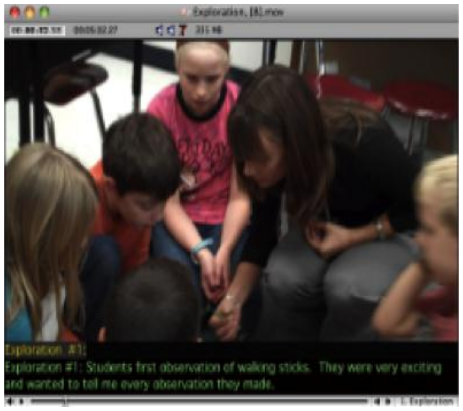
StudioCode™ is powerful for mining coded video using Boolean searches and provides simple analysis tools for codes and transcripts. Data can be mined across videos using an embedded database of codes, which allows users to create an ad hoc analysis framework while searching for patterns across cases (Rich & Hannafin, 2009). StudioCode™ allows users to create simple tags (codes), which appear as clickable buttons. Users then watch their video and can code the footage in real-time by striking keys on their keyboard. Each keystroke marks a clip's beginning and end with a label on a timeline. These labels appear as blocks (instances) on the timeline with each row specific to a code. For example in Figure 4.2, the green row contains two instances the interns coded as "engagement," the yellow row contains one instance coded as "evaluation," the blue row contains six instances coded as "exploration," pink contains one instance of "revision," and the purple row contains one instance coded as "claims and evidence."

**Figure 4.2** Intern's timeline showing five different codes




Once a video is coded, instances can then be played back as stand alone videos. Instances can also be accessed in multiple ways, arranged, ordered, and close-captioned. The interns' analysis of their practice was embedded on a stand alone video and appeared as text in boxes at the bottom of the video as seen in Figure 4.3. Annotated videos were then sequenced, grouped, and exported as a single video.

**Figure 4.3:** Intern's Self-Analysis




By cross referencing the TSAF with the discourse moves advanced in the methods course, the researcher performed a Discourse Analysis and identified pertinent instances of language being used to socially construct science concepts and meaning. Specific codes for the discourse analysis were developed utilizing elements of the framework and constructs from the methods course. Table 4.1 is a matrix cross-referencing the research questions with the data used to inform them.

**Table 4.1:** Data Matrix

| Research Question | Data Sources | | | |
|---|---|---|---|---|
| | Analysis Videos | Uncut Teaching Videos | Field Notes | Existing Archival Information |
| | 30: 6 per participant approx. 5 minutes each | 15: 3 per participant, lengths vary between 30 mins to an hour each | 131 typed pages representing approx. 40 hours of class time and 3 hours of conferences | Course Syllabus, assignment structures and expectations |
| What is the nature of three preservice elementary teachers learning experiences in science methods? | | | √ | √ |
| In what ways do the preservice teachers attempt to support students in making sense of science ideas and practices in their initial science teaching experiences using productive discourse strategies? How else do they do this? | √ | √ | √ | √ |
| How do the preservice teachers make sense of their initial science teaching experiences through video based analysis of their practice? | √ | | | √ |

## Methods of Analysis

Data analysis was divided into two parts – 1) Constant Comparative Analysis of field notes from the methods course, and 2) Discourse Analysis of the interns' teaching and self-analysis videos.

**Constant Comparative Analysis.** Comparative analysis was first introduced by Glaser and Strauss in 1967. It is appropriate for the first part of this study because it consists of ongoing sense making of what is being observed primarily through participant observation

and field notes. The researcher proceeds through a process of writing field notes, crafting analytic memos, and posing potential explanations (Anderson-Levitt, 2006; Glesne, 2006), as well as categorizing, synthesizing and searching for patterns in the data through systematic coding (Glesne, 2006). It is a process that is recursive and iterative, beginning on the first day in the field and continuing until the researcher formulated a "thick description" (Geertz, 1973) of the culture augmented with his or her "well-supported interpretation" (LeCompte & Schensul, 1999). This process can then lead the researcher to the development of theory based on his or her findings (Glaser & Strauss, 1967). Such theories are often called "Middle-Theory" (Becker, 1998) and allow the researcher to reach beyond the scope of his or her immediate data and propose an idea that is grounded in the current study but applicable to a larger field. Middle Theory is concerned with ideas that push fields of knowledge forward in a concrete way (Becker, 1998).

Primary data for this part of the study consisted of field notes gathered during four months as a participant observer in the science methods course. Analysis of the field notes consisted of searching for "sociocultural patterns characteristic of the group under study" (Merriam, 2002, p. 237), while also taking note of negative instances or instances that are unlike other patterns being found (LeCompte & Schensul, 1999). Beginning with open coding (Bogdan & Biklen, 2003) and proceeding through two additional rounds, finer grain categories of data were created. Open coding was grounded by the first of the four research questions guiding this study, specifically looking at the nature of the preservice teachers' learning experiences in their science methods course. Coding was also informed by the Teaching Science as Argument Framework (Zembal-Saul, 2009) and the a priori codes of Talk Moves and Productive Questioning as seen in Tables 4.3 and 4.4 (Chapin et al., 2009;

Elstgeest, 2001; Michaels, Shouse, & Schweingruber, 2008). The resulting coding scheme for the Comparative Analysis can be seen in Table 4.2.

Considering the nature of ethnographic participant observation and the resulting field notes, it was determined the best way to present the findings that emerged from the analysis process was through "thick description" (Geertz, 1973) or rather an in-depth narrative. This contexual narrative is presented in Chapter 5.

**Table 4.2: Coding Scheme, Definitions and Examples: Comparative Analysis**

| Categories | Constructs | Codes | Definition | Examples |
|---|---|---|---|---|
| Language and the co-construction of meaning | Public Sense Making of Teaching | vid | Video of Elementary Classrooms | "What did you see happening that made you think the class was a community of scientists?" |
| | | eled | Connections to Elementary Students and/or Classrooms | "I start with 'Can we find shadows in our classroom?' because many first graders often think you only have shadows outdoors …" |
| | | pln | Planning for Discussion | "I want you to think of three to four claims that you want your students to get out of your lessons." |
| | | sts act | Planning for Student Action | "What are you going to have your students do?" |
| | Public Sense Making of Science | collab | Working collaboratively /in small groups | "With your group, please go to two stations …." |
| | | KLEW | KLEW chart | "As students brainstorm ideas about magnets April adds their ideas to the first section of the chart labeled with the letter K" |
| | | miscon | Misconceptions | "Once they understand the concept of day and night …. Wait I really don't get it I guess." |
| | | thnk | Questions that prompt interns to think about the problem | "Why do you think ….?"<br>"What are you unsure of?"<br>"How do you know ….?" |
| | | intrn tlk | Several talk turns between interns not directly involving instructors during large group discussions | "So less transparent materials create better shadows?"<br>"Better?"<br>"More visible." |
| | | clms/evdn | Claims and Evidence | "And what evidence did you find to support that claim?" |
| | | invst | Investigations | "Can anyone think of a way to use a simple machine to lift the teacher?" |
| | | fr tsts | Designing and conducting fair tests | "What would we need to do to confirm that?" |
| Other Ways of Making Meaning | | ntbkng | Notebooking | "OK so I want you to write a claim in your notebook …." |
| | | sts wrk | Student Work | "This is a paper with drawings of battery and bulb connections that |

| | | | | |
|---|---|---|---|---|
| | | | | students have made. You need to look at it and decide ….” |
| | | diffr | Differentiation | “ … I was scaffolding different ways to differentiate.” |
| | | alter | Altering existing curriculum to fit an inquiry frame | “How can you take lessons and transform them to make them more inquiry based?” |

**Discourse Analysis (DA)** is appropriate for the second part of this study because it is the study of language in use. When using DA in the case study tradition researchers are particularly interested in social activities as organized by language use (Dyson & Genishi, 2005). Even though DA is tied to language structure it deals primarily with language in use in a social setting, as well as ideas and themes and how they are expressed in talk and writing in order to accomplish a task. DA deals with meaning in social, cultural, and political terms, and adheres to a broader approach to meaning than is common in other forms of linguistics (Gee, 2005, 2008, 2011). DA deals with language in use and so it is not enough to merely decode the grammar of a communication. More importantly, the discourse analyst must understand the many inferences that can be drawn from a communication and which ones are relevant. To do this the context of the utterance must also be examined to situate the communication and identify the shared cultural knowledge of the interlocutors (Gee, 2005, 2011).

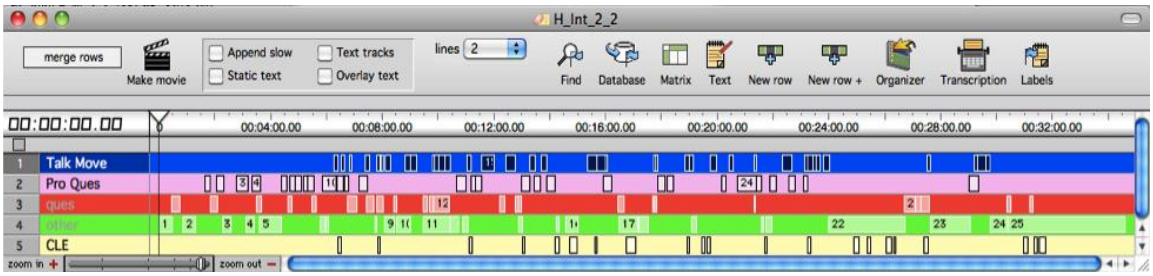
"Context" is a complex concept because it does not have a fixed meaning. Context could be the physical setting of a case or it could encompass people's actions constituted by social activities. It could also include speech events that refer to social activities structured by discourse (Dyson & Genishi, 2005). Context is also very important to case study research because contextual factors influence how people use language in a given social setting. These factors include the assumed purpose of the activity, the demographics of the participants (e.g., age, gender, role), the implicit and explicit rules governing the right to speak, and the social language being used (Dyson & Genishi, 2005). The context of a communication does more than situate the meaning of utterances; it also informs the discourse(s) being enacted by participants.

Speech events are social activities that are structured by ways of talking. They are organized by purpose, characterized by relationships among participants and are marked by expected topics and structures (Dyson & Genishi, 2005). Speech events have multiple meanings depending on the context in which they are used. They have an utterance-type meaning which is the general meaning of the word, and an utterance-token meaning which is the specific meaning of a word in a specific situation, as well as meaning potential, the entire range of possible meanings a word could have (Gee, 2005, 2011). Consider the phrase, "It's raining." The utterance-type meaning of "It's raining." is that liquid water is falling from the sky as precipitation. Examples of utterance-token meanings of, "It's raining." include "It's raining." (a child cannot go out to play); "It's raining!" (a farmers crops will be saved from a drought); "It's raining." (a resort owner loses profits because fewer people will be coming to visit); "It's raining." (the manager of a ski mountain is worried about the integrity of the winter snow pack); "It's raining!" (a family can go on a puddle walk). Without understanding the context of a communication the situated meaning of terms and phrases cannot be understood (Gee, 2005, 2011). Words take on much greater meaning in use than they do on the pages of a dictionary. Speech events are collaboratively constructed when participants understand the nature of the event and each other's roles and respective obligations (Dyson & Genishi, 2005).

The DA began by first watching the interns' uncut teaching video and using an open coding technique (Bogdan & Biklen, 2003) to identify potentially meaningful speech events. This was an inductive process, with each round of coding resulting in deeper layers of analysis (Creswell, 1997). Each lesson-specific speech event was coded as "potential." Those included all on-task speech events related to the lesson. Events such as asking to use

the restroom or being interrupted by another teacher entering the room were not included. Those events with "potential" were then reexamined and a finer grain coding was performed to group pieces of data into relevant categories of information that were pulled out and examined individually. These initial categories were Talk Moves, Productive Questions, Other Questions, Other ways of Meaning Making, and Classroom Learning Environments. Figure 4.4 is an example of a timeline from StudioCode™ with first round coding grouping speech events into related categories.

**Figure 4.4:** Example of a Timeline from the First Round of Coding



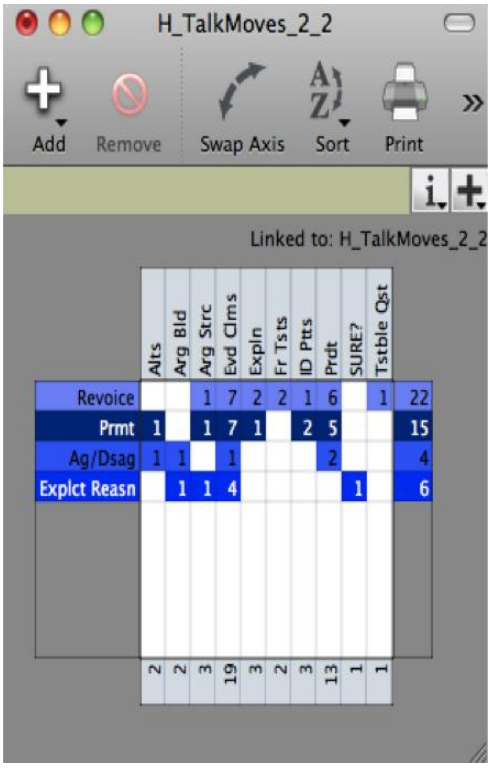

A second round of coding was then performed to refine the categories of Speech Events, a priori codes identifying productive questions and talk moves (see Table 4.3), as well as emergent codes, including other forms of questioning and other forms of meaning making, such as the use of demonstrations, KLEW charts, and diagramming. The second round of coding was open and grounded in the data with analytic codes emerging from both the Conceptual and Theoretical Frameworks. Figure 4.5 is an example of a second round

**Figure 4.5:** Example of a Timeline from the Second Round of Coding

timeline that refined the relevant speech event groups into individual codes. This timeline takes just the blue Talk Moves line from Figure 4.3 and refines them, using codes for the specific Talk Moves that were identified in the participants' teaching video.

The third round of coding involved comparing the previously coded instances with the TSAF and creating text labels to refine my understanding of why each discursive tool could have been used. This informed the researcher's understanding of what aspects of the methods course the participants tried during their initial science teaching experience and helped to inform the first proposition of the study that the science methods class influenced the participants' use of talk/discourse moves in their placement classroom. The outcome of the text labels were data matrixes that cross referenced my coding with the TSAF, an example Data Matrix can be seen in Figure 4.6, the vertical axis is the codes and the horizontal axis is the text labels from the TSAF See Tables 4.3 and 4.4 for a greater understanding of the coding and cross-labeling schemes.

**Figure 4.6:** Example Data Matrix cross-referencing Codes and Text Labels




Salient speech events were then broadly transcribed and compared across cases. Speech events are social activities that are structured by ways of talking (Dyson & Genishi, 2005). They were deemed "salient" during the final round of coding when they were organized by purpose through the cross referencing of codes

and text labels.  Analysis of salient speech events informed the case findings (Dyson & Genishi, 2005).

A similar coding and analysis process was performed on the interns' annotated teaching videos in order to understand what they identified as salient. This analysis provided insight into how the interns made sense of their own teaching, what they identified as important, and how they saw their teaching align with the concepts from the TSAF.

**Table 4.3:** Coding Scheme, Definitions and Examples: Discourse Analysis

| Categories | Constructs | Codes | Definition | Examples |
|---|---|---|---|---|
| Language and the co- construction of meaning | Talk Moves | ReVoice | Revoicing | “So you’re thinking that your shadow kind of moves as the sun moves?” |
| | | Sts Rest Resn | Asking students to restate someone else’s reasoning | * not seen |
| | | Ag/Dsag | Asking students to apply their own reasoning to someone else’s reasoning | “So you don’t quite agree with Hunter? Because Hunter said it (the shadow) was going to be beneath you.” |
| | | Prmt | Prompting students for further participation | “Katie would you like to add to that?” |
| | | Explct Resn | Asking students to explicate their reasoning | “So how would you describe that pattern?” |
| | | Wt Tm | Using Wait Time | 9 seconds elapse between the asking of a question and calling on a student |
| | Productive Questions | Att Fcs | Attention Focusing | “What did you see when you moved the flashlight counterclockwise?” |
| | | Msr Cnt | Measuring and Counting | "How many parts do you see on this insect? How many parts?" |
| | | Cmp | Comparison | “How is this different from the shadows you saw yesterday?” |
| | | Act | Action | “When is the shadow looking like a blob? Can you show me?” |
| | | Prb Pos | Problem Posing | “How could you make your pipecleaner person experience day and night?” |
| | | Resn | Reasoning | “How do you know that?” |
| | Other Questions | Recall | Recalling factual information | "How many dead bugs did we look at last time?" |
| | | Clr | Clarification | “What does it look like?” |

| | | | | |
|---|---|---|---|---|
| | | Non-Pro Resn | Non-Productive Reasoning | "When does it hiss? When does it do that? Do you know? |
| | | Non-Pro Act | Non-Productive Action | "Where do you touch him to make him move?" |
| | Other Language Tools | ire | I-R-E discussion sequence | “That’s a good one. I hope everyone noticed that one. The swaying is a really good feature.” |
| | | dclr | Declarative Statement | "If a bird is looking for dinner it helps them hide. Right." |
| | | rewrd | Asking students to reword or reform something they have already said | “So how could we make that a question?” |
| Other Ways of Making Meaning | | Lrg Grp Inv | Large Group Investigation | “We’re going to switch it up guys. Everyone come in a circle on the carpet.” |
| | | "sci" | Interest in science | “We are no longer in room 205. We are now scientists and we are going to be observing things.” |
| | | wrtng | Writing | “So could the reason our shadows looked different? That’s what I want you to write about.” |
| | | diagrm | Diagrams | “We’re not drawing smiley faces, we’re not coloring it, we’re drawing and we’re labeling.” |
| | | tools | Tools | “When we use our magnifying glasses, you’re all going to have magnifying glasses, we’re going to look and not touch.” |
| | | KLEW | KLEW Chart | “That’s a good Wondering, we don’t know that for sure right? Could we add that to our KLEW chart?” |
| | | pseudo-KLEW | Use of KLEW chart in way not aligned with its stated purposes | “This is what I wrote about what I Know about cockroaches. Does anyone else Know anything for sure about cockroaches?” |
| | | vocab | Terminology | “What are you supposed to do with these words? What’s that L word la, la, la” |
| | | ntbk | Notebooking | “Write that down, that’s an observation.” |
| | | demo | Demonstrations | “I need everyone to stay in their seats. I’ll come around, I’ll come around.” |
| Classroom Learning Environment | | Mng Expt | Manage Student Expectations | “So Hunter I’m going to ask you to help me out on the last one. |

| | | | |
|---|---|---|---|
| | Clssrm Mng | Classroom Management | "I need you to sit on your bottoms" |
| Participant Self-Analysis | fr tst | Designing Fair Tests | "Although this seems ridiculous to an adult, it was a testable wondering!" |
| | sts invst | Students performing small group investigations | "…two students discuss how their shadow has changed since the first time they were out." |
| | eval | Understanding how students make sense of the phenomenon | "If I were to grades these the first one would not have met expectations." |
| | evaltve | Evaluative – focused on the accuracy of claims and doing things "correctly" | "… and also ensures that the students are completing this activity correctly." |
| | sts lrn | Student Learning & Understanding | "Students were realizing a key concept of camouflage with some prompting and questioning." |
| | arg strc | Argument Structure | "She said that it makes a claim stronger because if only one cockroach likes it, we can't know for sure." |
| | phenom | Interacting with Scientific Phenomenon | "Students are very engaged in the observation aspect of the lesson." |
| | data | Gathering, recording and representing data | "I tell them that they are to use their recording sheets from the first day to show them what the shadow should look like in the morning." |
| | sts talk | Student Talk | "If you listen closely, you can hear a student as she tries to determine how she will describe the sun's position." |
| | sts act | Student Action | "This clip shows two boys trying to figure out how to make a longer shadow than what they seeing right now." |
| | sts think | Student Thinking | "... he realizes that he really doesn't know for sure and we need more evidence." |

**Table 4.4:** Text Labels of Previously Coded Instances

| Construct | Text Label | Definition | Example |
|---|---|---|---|
| Teaching Science as Argument Framework | Tstble Qst | Pursue Testable Questions | "But is it stopping the cockroach? Let's bring it back to our question." |
| | Phenom | Interact with Phenomenon | "Can you see up close on its face?" |
| | Fr Tsts | Design Fair Tests | "What could we do to stop them? To stop the pests?" |
| | Prdt | Make Predictions | "Who has a prediction about what you think will work?" |
| | Dta | Collect, Record and Represent Data | "What do you notice about the color of this one?" |
| | ID Ptts | Identify Patterns within the Data | "We have three shadows that changed throughout the day. What are the big differences we saw?" |
| | Evd Clms | Coordinate Evidence with Claims | "Did everyone experience that? Thumbs up? So we can make a claim about that? We can say that we were pretty sure?" |
| | Alts | Consider Alternative Explanations | "Does anyone have any other ideas about what having an exoskeleton means?" |
| | Arg Strc | Argument Structure | "Do you think that makes our claim stronger or weaker?" |
| | Arg Bld | Argument Building | "Can you elaborate on that? Yes we did try it but what did you see when you tried it?" |
| | Expln | Evidence Based Explanations | "You are going to explain how and why your shadows changed throughout the day." |

## Findings Overview

Four findings emerged from the data analysis process. The first finding is explicated in chapter four which is a contextual narrative that brings the reader into the science methods course the participants experienced as they prepared to teach their initial science unit. The remaining three findings emerged from the analytic narratives in chapter five. The narratives illustrate the nature of the lesson planning conferences between the participants and methods instructors, describe and explain what elements of the TSAF participants adopted and how

they attempted to use a discursive model of meaning making during their initial science teaching experience, as well as how they made sense of their experiences in self-analysis videos. The findings address the research questions, are grounded by the case's started propositions, and inform the theoretical meaning of the case. They serve as the basis for the formation of a Middle Theory that is discussed in detail in Chapter 7. The findings are:

1) Throughout the methods course, instructors modeled how the Teaching Science as Argument Framework can be used to negotiate scientific understanding by employing a Discursive Model of Meaning Making.
2) During lesson plan conferences the Discursive Model was emphasized as participants planned classroom discussion and explored possible student responses enabling them to anticipate how they could attempt to increase student understanding.
3) Participants displayed three distinct patterns of adoption of the Teaching Science as Argument Framework (TSAF), involving different discursive practices. They were,
    - Detached Discursive Approach: Use of some discursive strategies without an apparent connection to the TSAF.
    - Connected Approach with a Focus on Student Thinking: Intentional use of the Discursive Model informed by aspects of the TSAF.
    - TSAF Approach: Priority is given to the TSAF supported by substantial application of the Discursive Model.
4) The evidence participants chose to highlight in their self-analysis videos is reflective of their patterns of adoption of the Teaching Science as Argument Framework and their differing discursive practices.

# Chapter 5

## THE METHODS COURSE: CONTEXUAL NARRATIVE

The purpose of this study was to understand how novice preservice teachers learn to use productive discourse strategies to scaffold their students' ability to co-construct meaning of science concepts. Many studies have looked at the challenges faced by preservice teachers (E. A. Davis et al., 2006), but there is not a model of what it looks like when preservice teachers are prepared to teach science using a comprehensive, research based teaching framework that is supported and modeled using a comprehensive discursive model. In order to understand how the participants developed as elementary teachers of science, the researcher spent four months in their methods course as a participant observer. This provided access to how they were prepared, including all of the course meetings and lesson plan conferences between the participants and their methods instructors. The following chapter is an examination of how the participants were prepared to teach science through a detailed contextual narrative of their methods course. This chapter addresses the first research question: What is the nature of three preservice elementary teachers learning experiences in science methods? It also serves as the foundation for the Discursive Model of Meaning Making the instructors employed throughout the course and which emerged from the coding process of the field notes.

The chapter is broken into three major parts: 1) the course structure and overview, 2) an in-depth narrative of the course with embedded analytic descriptors, and 3) a description of the Discursive Model of Meaning Making. The narrative section is further broken down by session number.

**Course Structure and Overview**

The science methods course was taught as part of a Professional Development School partnership in a third grade classroom after regular school hours. Two veteran elementary school teachers served as instructors for the course. They provided unique insight into the workings of an elementary school classroom and bridged theory with practice. Each session was framed by a science topic as well as pedagogical theme. Each class was begun with a short discussion period where interns shared their successes and concerns from their week of teaching, this was a chance for feedback from both of the instructors as well as peers. The class then transitioned into a scientific investigation, enabling the interns to experience science as inquiry and argument. The investigation was then unpacked from a teaching perspective using a Teaching Science as Argument Framework (Zembal-Saul, 2009) and finally the class was wrapped up with either a video case study of actual classroom practice or opportunities to work in groups to plan, reflect on or revise their own teaching units.

The methods course was the first opportunity interns have to plan and implement their own science unit in their placement classrooms. Topics were chosen with assistance from mentor teachers and interns were allowed to work in collaborative planning groups of similar grade level and topic. Interns met with their methods instructors in Lesson Plan Conferences to finalize plans prior to teaching. The entire mini-unit implementation was then video recorded. Interns used this un-cut footage to create a 12-14 minute analysis video highlighting examples of what they considered their best practices and justifying their choices with subtitled annotations using external evidence from the Teaching Science as Argument Framework (Zembal-Saul, 2007, 2009). The interns' analysis consisted of their best examples of how they engaged students with the key concepts of the lesson; how they

assessed their students' prior knowledge as well as how their students collected data and made observations of the science phenomena. The interns also identified how they got their students to construct claims and support those claims with evidence. They final piece of the analysis was how they evaluated their students' understanding of the concepts and explained how they would change 1-2 aspects of their lessons if they were to teach it again.

**Situating the Case: Learning to Talk Science in the Methods Class**

**Session 1**: The interns enter the brightly lit classroom and other than their size it is hard to discern them from the regular group of third graders who call this room home. They looked around unsure of where to sit, "There are so many choices?" said one while another inspected a large wooden structure in the corner of the room draped in tapestries and covered in blinking lights to represent a time machine. Large stars with numbers on them hung over the tables and student work papered the walls. About a quarter of the students found seats and opened their laptop computers while the rest milled around talking. An instructor blinked the overhead lights and the rest of the class found seats and settled in. The group of senior level college students looked awkward wedged into seats designed to hold the average third grader but they also seemed eager to begin the semester. The group had already met for three sessions two weeks earlier at a pre-semester "Jump Start" program but this was the first day of regularly scheduled classes.

There were two instructors for the course one is a smartly dressed, middle-aged woman named Sarah with straight blond hair she tucked neatly behind her ears. The other, April, is taller with brown hair, wearing a long flowing skirt and plain top. Both April and Sarah worked as in-service elementary school teachers. April taught third grade in the

classroom the group was meeting in and Sarah taught first grade down the hall. They were both mid-career teachers, highly regarded and sought after in their districts.

April announced that the science topic for the day was magnets and that the theme was Building a Community of Scientists. She gestured to a large piece of chart paper taped to the board at the front of the room. The paper was divided into four sections K, L, E and W each letter representing a different tool for mapping argumentation and structuring class discussion and is subtitled with, "What do we think we Know …", "What have we Learned …", "What Evidence did we gather …" and "What are we still Wondering ...". This is the first time the group had used a KLEW chart to scaffold how they publicly made sense of science content. April told the class they will be performing an investigation to determine the properties of magnets and asked them what they knew about them. As students brainstormed ideas about magnets April added their ideas to the first section of the chart labeled with the letter K. Brainstorming, working together and other forms of public reasoning were major constructs of the methods course and set the foundation for the discursive model of meaning making.

"They are attracted to metal."

"Yes" answered Sarah, "but you know first graders would never use the word 'attracted' they'd say, 'stick to'."

Sarah is very grounded in her work with her first graders and will often use her experience to help the interns shift their thinking from that of a college senior to a professional working with young children. As the brainstorming continued Sarah placed bags on each work table and then asked the interns to sort the items in the bags into piles of what they thought would stick to magnets and what they thought would not and also to be

able to support their choices with reasoning. The interns were encouraged to work together and discuss their ideas openly. Items in the bag include a metallic spoon, fork, teaspoon, grapefruit scoop, twist tie, key ring, various coins, a yellow plastic amorphous shape and a small tin box. As Sarah walked around the room she noticed one group with a single pile of items on their table. She asked them why they have grouped all of the items together. “I don’t really know” answered an intern, “they’re not metally enough.”

“Not metally enough? What do you mean by that?” Sarah inquired. Questioning the interns and pushing them to think about their own reasoning forms the backbone of the discursive model of meaning making. Sarah and April used discourse to engage the interns in thinking about their own reasoning and to scaffold the interns’ abilities to make sense of the science content.

“Not thick enough I guess or sturdy enough.” The intern sounds hesitant and unsure of her reasoning.

April flashed the lights again and announced, “Before we test we are going to share our thoughts. What is one thing that your group thinks will definitely be attracted by magnets, one thing that definitely won’t and one thing you are unsure of? I’m giving you thirty seconds to get your thoughts together.”

Sarah asked the class, “Are we ready? What did you think definitely would not stick?”

“This tin container”

“Why do you think that?”

“I don't know”, mused the intern, “the texture? When I think of tin I just don't think of it as sticking.”

“OK so try to think like a kid. Why do you think they might think a magnet wouldn't stick to the box?” Sarah prompted.

“It's thin.”

“Oh” replies Sarah, “... we're going to put that under wonderings” as she wrote "Does thickness matter?" on the KLEW chart under W. “When you ask for wonderings you hardly ever get an answer so you revoice questions and say ‘Oh let's add that to our KLEW chart’. Let's do this group” Sarah pointed to a new table, “What are you unsure of?” The intern held up a metal padlock.

“Well some of us think it will and some of us think it won't.”

Sarah smiled and exclaimed, “Oh yes argumentation!”

“I just feel like I've had previous experience with it. I think the denser the metal the less likely it is to stick.”

“OK so for Derek we'll say, ‘Does density matter?’”

Another intern held up a greenish orb and said, “I think it will stick to this thing.”

“What makes you think it might be a metal?”

“It's shiny, it kind of looks like a rock but it has a sheen.”

“So we're going to add to our wonderings, ‘Does shininess mater?’” Sarah addressed the class, “First graders wonder very much about color. They would look at the color and pick a nickel over the penny because the nickel is the same color as other metals they are familiar with.”

April jumped in, “So this is how you build questions with kids - give them materials and allow them to interact with things then question them about their findings.” This is an

example of the interns experiencing science the way elementary students would then making sense of what they have done through the lens of teachers.

April then divided the class in half and asked one group to design tests to determine if magnets attract through objects and the other to determine if some magnets were stronger than others. Designing fair tests part of the TSAF and something the interns seem to lack experience with. The room became animated with noise and motion as interns discussed what tests they should perform. After about ten minutes, April flashed the lights and asked the group to share their findings.

"What did you do to test for strength?"

"We made paperclip chains."

"And what claim were you able to make?"

"Some magnets are stronger than others?" Sarah recorded this under the L section of the KLEW chart.

"And what evidence did you find to support that claim?" April prompted. Both April and Sarah prompted the interns to support their claims with evidence throughout the methods course.

"The large round magnet held five paperclips in a chain and the small round one held two." Sarah added this to the E section of the KLEW chart and drew a line connecting this evidence with the intern's claim.

After the discussion ended, April invited the interns to join her on the rug in the front of the room to watch a video but they hesitated and she had to ask each table individually to come up, pointing out that they were actually sitting behind a large wooden structure and would not be able to see the screen if they didn't move; they seem reluctant but move

anyway. She then asked them to record what kinds of things they saw the teacher doing in the video to help build a community of scientists as well as what kinds of questions she asked to facilitate this idea of a community of scientists. The video was of Sarah's first grade class discussing a magnet lesson they had recently completed. A student teacher led the discussion but Sarah was present and helped redirect when students drifted off topic. Watching video of science investigations in elementary school classrooms proved to be a critical part of the methods course. It provided the interns with insight into what is possible for real elementary students to accomplish and understand when their science inquires are scaffolded with a coherent research based framework and productive discourse.

After the video was over April asked the group, "What did you see happening that made you think the class was a community of scientists?" The interns responded in a very open discussion without raising hands.

“Asking many questions such as ‘Do you have something to share?’”

“Using the language of science like ‘evidence’, ‘wondering’, and ‘claim’”

“Gave students wait time.”

“Asked if any other students saw the same pattern.”

“Yes” chimed in April, “when building a community you want to get more opinions than just one"

“Sarah provided an 'on-the-spot' demonstration.”

“Oh yes” said April, “It's always good to have a bin with materials in it close at hand so you can easily demonstrate or have your students demonstrate their ideas without having to leave the circle.”

“The teacher asked the students to define 'evidence' when another student asked what evidence meant.”

“And did she do a good job?” referring to the first grade girl who provided the definition, “She was spot on wasn't she!”

**Session 2:** The topic of the next class was adaptations, the theme continued to be, “Building a Community of Scientists”. April borrowed a group of Madagascar Hissing cockroaches from the Entomology Department at the local university. They were living in a terrarium in the back of the classroom which the interns did not notice during their first meeting in the room. As she reached in to retrieve a cockroach one of the interns mumbled, “I'm itching and sweating because of this.” They were clearly uncomfortable with the idea of working with the cockroaches. April placed a cockroach inside a Petri dish so the interns could make observations without having to touch them. She then instructed the group on the importance of closely observing and making scientific drawings of their specimens. To test the intern’s skills of observation she gave them time to complete their drawings then collected the cockroaches and asked the class to join her on the carpet.

“Brings your notebooks and a pen and come gather in a circle.” April asked them to bring their notebooks so they will be able to share evidence they have collected at their workstations. The group sat around the cockroaches which were placed on the floor. “Is there a group who is pretty confident you can find your cockroach?” Hadley jumped into the center and reached for a dish. “Why are you pretty sure this is yours?”

“We got pretty close and you see he has a line down his back and well these guys do too but his is darker and” she was cut off by another member of her group, “one antennae is

longer and one is shorter. It's the Nemo of cockroaches!" She fluttered her arm in reference to the "Finding Nemo" movie where a fish has one fin smaller than the other.

"That's mine!" another intern reached for a dish.

"How do you know that one is yours?" asked April.

"Well she is really dark and caramelly colored."

"And her nub has a bump on it." chimed in another.

"The very bump on the end is flatter on that one"

"I see you're using 'her' so why are you using that?" April inquired.

"If he has horns on his head then it's a he so sorry to tell you but your she is a he" a third intern added.

April addressed the class, "I want you to think about this and write the answer in your notebook. One of the questions my students came up with is, 'Are the individuals different?' So think about that and write a claim in your notebook, 'Are the individuals different?'" Writing in science class gives meaning and purpose to writing while preparing students to share their ideas with the larger group (Zembal-Saul et al., 2013).

"When you say different do you mean species?"

"No, I mean individuals and that is actually really important because that is part of the state standards under ecology and environment." She waited while the interns wrote in their notebooks, "Callie what would you say?"

"I'd say yes."

"So can you turn that around and make a claim?" April pressed.

Callie paused then responded, "The individual are different because of size, shape , markings and color."

“What do you think is the standard that relates to this, ‘Individuals of a species have ... What do you think?” April and Sarah made sure to point out that teaching science as argument maps onto science standards.

“variations?” Callie questioned.

“Yes! Variations and what evidence do we have for this?”

“Our sketches and notes.”

“I always have my students jump right in and make sketches then label with the correct vocabulary later after they have had a chance to observe and have a context for the new terms.” April then led the group through a series of slides identifying the parts of the cockroach. While the interns labeled their drawings April pulled up a slide of a greatly magnified antennae.

“OK you are going to investigate the antennae and what they are used for and also the cerci and use a microscope to see if there are any differences in the male and female antennae. Go back to your group and figure out what you will need for your investigation then you can get your materials.” The interns got up and returned to their tables to begin their investigation.

“Let's do the second question first, ‘what are the differences in the antennae’?” An intern brought a box to the table and dumped their cockroaches directly into it from the petri dish. “OK what did they say about the cerci?” She was referring to the diagram from the slide.

April approached group, “So what are you noticing?”

“It uses its antennae to sense what’s around it.”

“How do you know that?” pushed April. In this way April encouraged the interns to reflect on their own understanding while also sharing their evidence with the larger group.

“It reacts with its antennae when I touch them and it doesn’t seem to like being touched on them.”

“So what differences are there in the antennae?” April puts the cockroach back in the petri dish and placed it under a microscope. An intern looked into the scope then said, “Oh so this is a male and so male’s are wavier and thicker.”

“That makes sense when you think about its reaction. If the male has thicker antennae it could react easier.”

April put another dish under the scope and asked each group member to look, “So what did you notice?”

“There is a lot more hair on the male.”

“And what would we need to do to confirm that?” asked April.

“Look at more?”

“So what are we predicting about the male? It’s going to be …” Making predictions and testing ideas are part of the TSAF.

“Hairier.”

“How many do you think you need to look at to feel pretty confident in this?”

“Maybe two?” While the interns had begun to understand key elements of science education such as pushing for evidence and prompting students to form claims based on evidence they had not yet formed an appreciation for how scientific investigations were conducted.

**Session 4:** April introduced an assignment the interns would complete in their placement classrooms. As part of the methods course the interns planned a three day teaching sequence they would implement in their placement classrooms. The interns had talked with their mentor teachers and negotiated a science topic they could focus their lessons on. A series of assignments were designed to lead the interns through the planning process, refining and revising their work as they went along. The first thing they did is survey their students to determine what they understood about the science topic the interns were going to teach. They then interviewed students to gain deeper insight into student thinking and finally planned and implemented their lessons.

"The first thing you need to do to prepare for your concept interview is a Quick, Draw, Write. As you can see on my KLEW chart I had my students draw what they thought insects looked like" gestures toward the board where a new KLEW chart is hanging. The 'What do we think we Know' section is filled with drawings the third graders made of insects. "We're going to have you do one in class on electricity, we're doing this because you will need to do one so you can choose students for your concept interview. It's going to give you a really good idea of what your students are thinking about your topic. Here's your Quick Draw Write. You have a baggy with a battery, a bulb and a wire and you are going to draw how you think they need to be arranged to get the bulb to light."

The interns looked confused, "We just draw it?" Though they were confused this was an important learning opportunity for the interns because through their experience they were able to anticipate how their students could react when presented with the same assignment.

"You can go ahead and label it too, that's why it's called a quick draw WRITE. As soon as you finish go ahead and hand it to Sarah or me." April and Sarah collected the

papers. “This is what you are going to do with your papers. When you get them you are going to sort them into piles, the people who are able to use the materials to figure out the problem, those who need more time exploring with the materials and those who don’t know what they are doing. Be ready in your mind for what you are going to do, err have your students do if they already know the answer. You also don't want to call on those kids right away because then others won't have a chance to answer but I have cued some students saying, ‘I'm going to call on you to explain this but you need to wait until the end, but I am going to call on you’ because you don't want that person to ruin it for others.” April drew several examples of the intern’s responses to the Quick, Draw, Write on the board.

“Now I'm going to give you a battery, bulb and wire. Work with your partner. Once you've figured out one way I want you to figure out another way that is especially for those of you who think you know what you're doing. Then draw it in your notebook and think about what needs to happen to get the bulb to light.”

“This is what I'm thinking.” an intern connected the battery, bulb and wire but it did not light, “Is there really a way to do this? Can it really light?”

“Well I feel dumb” said her partner, “let's try it this way.” Once again the bulb did not light. “Did you get yours to light?” she asked another group.

“Yeah we did!” she stuck out her tongue. The first group looked over and copied what they did.

April sat down at the table, “So did you find all four ways?”

“FOUR ways?!”

“OK so two, did you find two? Make sure you draw what configurations you tried.” She stood up and addressed the whole group.

“So how many people found four ways?” several interns raised their hands, “Good. So what has to happen for the bulb to light?”

“The lightbulb has to touch either the positive or negative side.”

“Did that surprise anyone?” asked April, “Because no one drew that it could light while being attached to the negative side. Do you think that's an important claim for kids to make?” several interns nodded. April and Sarah continued to model student responses and had the interns plan for potential classroom discussion in order to prepare them for what they could encounter while teaching and enabled them to anticipate how they could scaffold similar conversations. “So how could you word that?”

“The bulb will light on both.”

“And what is your evidence for that?”

“Our drawings. What we recorded in our notebooks.”

“Yup or you could say ...”

“We tried it and it worked?”

“We tried it and it worked!” April exclaimed, “What does it look like when the circuit is complete? And 'circuit' is not a word most elementary students would use. OK so I want you to write a claim in your notebook for, ‘What does it take for the circuit to be complete?’ What all needs to be connected for the circuit to be complete?” She gave the interns a chance to think and record their answers then asked, “So who has a pretty good idea?”

“For the circuit to be complete the metal of the wire needs to touch both ends of the battery and the metal of the bulb.”

“What parts of the bulb need to be connected for the circuit to be complete?” April pushed further.

“The metal and the nub. Does ‘the nub’ make sense? What else would we call it?” the intern asked.

“The ‘nub’ works for me” answered April. She then prompted the interns to observe their lightbulbs, “Some questions I want you to think about is why is it that both parts of the bulb need to be connected? Why is that? So here are some bulbs and here we have some that have been opened up a little bit. You're looking at the design of the bulb for what is important for the circuit to be complete?”

“It looks like there is wire all in there. This little bulb has wire coming out on the side and I think there is wire all wrapped around the inside of the base. This wire that connects to the filament part also connects to the side.”

“A lot of the bulbs have something on them that shows where it is connected. Can you find a clue that would indicate where the wire is connected?” April asked.

“The solder point?”

“The solder point! Everybody look at the bottom (of the lightbulb) and see if you can see a solder point. So why do you think it works? This is an important part of the circuit.”

“Does this disconnect when the bulb burns out?”

“Why would you think that?”

“The circuit would be broken.”

“Does it have something to do with the sound?” asked another.

“What sound?”

“When a bulb burns out you hear a ping sound like something snapping”

“And what do you think is happening?” April probed.

“Is the, the filament is breaking?”

“Yes, every bulb has a filament and when it breaks the circuit is broken.” Then April announced that she was going to give each group a flashlight and they are to take it apart to figure out how it works. After they had debriefed this part of the investigation April said, “Ok I'd like to talk about the 5Es.” The 5Es are a model for planning inquiry based science investigations. “What is the first step?” The interns had completed a reading on the 5Es prior to coming to class.

“Engage”

“OK so what was the engagement activity for this lesson?”

“The paper with the drawing?”

“Yes and you can do a very elaborate engagement but really kids get engaged when they can test their own predictions. What comes next?”

“Explore.”

“And what kind of materials did you have?”

“Battery, bulb and wire.”

Sarah jumped in, “And some people think you just throw the materials at the kids but we've always had a problem for the students to answer.”

“So what task were you given?” asked April.

“To make the bulb light.”

“Then (in your lessons) you'll ask your students to make a ...”

“Claim.”

“and back it up with ....”

“Evidence.”

“Then once you've explained through a claim you will extend learning or elaborate and how did we do that?”

“With the flashlights.”

“and what is the last part?”

“Evaluate.”

“So evaluate!” April prompted as Sarah handed out a sheet to the groups, “This is a paper with drawings of battery and bulb connections that students have made. You need to look at it and decide, ‘yes it will light’ or ‘no it wouldn't’.” The class reviewed the sheets and wrote their evaluations for the students. Sarah and April used examples of actual student work they had gathered from their classes. This enabled to interns to conceptualize what type of work elementary students are capable of.

**Session 5:** The interns had completed their Quick, Draw, Write assignments in their placement classrooms and had brought their results to class. April reminded the interns that they would use their results to choose two students to interview. These interviews were designed to be a one on one chance to sit down and talk with students on their ideas about the intern’s science topic in order to gain deeper insight into student thinking. An intern asked if they will be doing the interview in teams.

“What do you think would make sense?” responded April.

“Separate.”

“Right because you are doing your own class. Then after you interview write a quick profile of who you interviewed and what you asked them to do. From what you heard, the students’ ideas, I want you to think of three to four claims that you want your students to get out of your lessons. Here is another example of the instructors helping the interns plan for

classroom discussion and helping them understand what they need to do to enable their students to participate in the co-construction of meaning making. “Then write your implications like, 'This is a claim I want my students to make and this is how they will get there, by studying shadows or geckos ...' So if your implications are the same (as the rest of your group) that is fine but the rest is unique and based on your class.”

“So what about the student that knows it already?” wondered an intern.

“I'd maybe have him do some independent research and do a PowerPoint to present to the class. Or he could be you assistant? You could justify it by saying 'He's already taken a course in this' Does that make sense?”

“Yeah”

“But you'll also want his input but remember to cue him and say you will call on him last.”

“How long does this have to be?”

“You're going to hate this but it has to be long enough to explain it.” April smiled.

“Does the background profile information on the students have to do with science?”

“No, it should be on why you chose that student.”

“This is a formatting question but do you want it in sections or a more fluid paper?”

“Whatever works best for you, some people think better in chunks and some people think better in a more fluid way.” Though the interns seemed frustrated with that answer April and Sarah were actually working to empower the interns to make their own decisions while teaching. Another intern continued to ask questions about formatting, “How many questions should we ask?”

April continued to smile, “However many is useful but you don't want it too long so I'd say five to ten minutes. Does that help?”

“Yes” but her facial expression and tone of voice indicated she was not happy with the non-specific answers. April went on to explain the format of the next few classes, “Let me explain to you what is happening in science for the next two weeks. Next week we will not be having regular class. You will sign-up for meeting times with either Sarah or myself on either Monday or Thursday which is a planning time then the next week I want you to come in with at least preliminary lesson plans. We want you to include in the description how the 5E's will get in there, include them in the 'procedure' part. So we're going to send these sheets around and you'll sign up for a time with your entire group.”

“Do we need to have something planned for this?”

“Yes.”

“Ugh”

“At least a rough plan of what you are going to do.” added Sarah.

“Ok we have that. Like a general idea?

“Yeah that will work.”

April then reminded the group about due dates and expectations for the instructor meetings, “Your Concept Interview paper is due Monday. I want to review what you should bring to your planning meeting - computer, any books and resources you have because this is a brainstorming meeting.”

“So do we need to have what we want to do all hammered out?”

“No but you want to have ideas”

“OK it's not so scary anymore.”

As this was going on a piece of paper was being passed throughout the room and the groups are looking through planners to figure out a time when they can meet.

April motioned to Meredith who walked to the front of the room clutching a stack of half-sheets of papers. “So are you ready?” she asked. Meredith nodded. “Meredith is going to be performing her Quick, Draw, Write on you all.”

“For our Quick Draw we're doing shadows and the revolution of the earth and when you get this paper I want you to draw you, well it can just be a stick figure of you, and a picture of the sun directly over your head, then draw in where you think your shadow would be in this case. Where would your shadow be in this picture?” Meredith drew a stick figure and sun on board. The interns started drawing and discussing their ideas with each other.

“When you do Quick, Draw, Writes you don't talk to other students about your ideas” warns April, “ you just do it.” With that the class quickly quieted.

Meredith continued, “When I did this in my class I had three kids that knew you'd have very little or not much of a shadow then I had some, a lot, that had it out to the side and even some that had it disconnected from the body. I had very few that were totally accurate.”

“So we’re smarter than third graders!” quiped an intern.

Sarah introduced the day’s investigation, “I start with 'Can we find shadows in our classroom?' because many first graders often think you only have shadows outdoors, then I'd ask them what would happen if we took the shades down and some think it would be better and some think it would be worse, then I start turning off certain lights” she walks over to the light switch and begins turning different lights on and off, “and depending on where they are in the room they start to see that you need light to see shadows. These wonderings” she pointed to a KLEW chart taped on the back board, “are what my students have come up with,

well all of them but this one", she pointed to questions about what lenses do, "that's more of a sixth grade question. We've put a wondering at each table and also some tools. With your group please go to two stations, with the tools you have and could you design two to three investigations your students could do to collect evidence on your question. We have in the district light meters and anyone in the district can use them", goes to table and picked up a meter. "Light is measured in Lux and I don't expect my younger kids to understand what a Lux is but I say we measure weight in pounds and height in feet and the bigger the number the greater the measurement so the higher the number of Lux the more light. Now I'm going to shine a flashlight on it" the light meter, "to see what happens to the numbers and I say 'How could this meter help us determine how much light goes through things?'" she grabbed a sheet protector, "You could measure the light on its own then put the sheet protector over it and measure again and we could see in numbers how much the light changes and collect data on it. Think about the questions and think about how you could use the materials to set up investigations. So what we are going to do is six weeks worth of first grade science in about thirty minutes."

The interns picked up their science notebooks and distribute themselves around the room at the various stations. They became very involved with the investigation and seem committed to finding an answer to the questions posed by Sarah and April. Approximately thirty minutes later April got the group's attention by beating a Native American drum. She directed their attention to a piece of chart paper taped to the large wooden structure in the back of the room. The chart paper said, "Questions to Ask: Do you agree or disagree with my idea? Would someone like to add on? Are there any questions? Did anyone notice anything similar?" While doing this exercise the interns were practicing their productive

questioning skills. They were also experiencing classroom talk that is not the typical I-R-E sequence (Mehan, 1979). April and Sarah had set-up an experience that allowed them to step back from leading discussion and allowed the interns to guide their own sense-making.

"When you present your claim we'll add it to the KLEW chart then pick a question to ask the group" instructed April.

"OK our question is, 'Which materials make the best shadows and which objects reflect light?' Our claim is that darker materials cast more shadows because they absorb more light."

"When I'm just reading your claim it doesn't make sense what do you mean by 'more' shadows?" asked one intern.

"Like more visible of a shadow" answered the first.

"Did you see a darker shadow?"

"No, a more visible one. We had a black paper and a yellow paper and we could see the shadow better on the black paper."

"We found it helpful to turn off the overhead lights then that made the shadow more visible" added another group member, "We didn't have a white paper but we found that more light goes through the yellow paper." Six discussion turns had transpired between the interns before Sarah joined the conversation.

"So a shadow is light going through an object?" asked Sarah, "hmmm could you make a statement on how shadows are made." She then allowed seven more discussion turns to take place before she spoke again.

"Shadows are made when objects block more light."

"I'm having trouble with the idea of objects absorbing light." an intern pondered.

“If someone is wearing all black and someone else is wearing all white, the person wearing all black is going to cause more of a shadow?”

“No it has to do with transparency.”

“So less transparent materials create better shadows?”

“Better?"

“More visible.”

Sarah jumped in, “This is a common issue during science talks, what do you mean by the word ‘best’”

“This would be a good chance to ask your student to draw a picture about what she meant” added April. “OK based on this discussion, how might you change your claim now?”

“Less transparent materials cast more visible shadows.”

The discussion continued like this with each group presenting one question they answered and the other interns asked for clarification, more information or demonstrations. Sarah and April jumped in to add to the conversation but for the most part it was led by the interns. The discussion continued until the end of class when April said, “Sarah and I often have more stuff planned then we are able to get to during a science talk and then we all have so many ideas and talk so much, which is great but we run out of time and then we'll gather some books for the class and regroup in the morning but we don't have that chance but there's a good chapter in Wenham (the class text book) but if we had asked you to read that first would you have been very interested in it?”

“No”, many shook their heads in agreement.

“If we just told you that information it wouldn't have as lasting an impact then if you were figuring it out on your own” added Sarah.

"I remember doing experiments about this but I don't really remember the information."

"Because that was hands-on not minds-on!" jumped in another.

"So write down what you find in Wenham in your science notebooks and we'll see you at our meetings next week." The group picked up their things and many left but some stayed to ask questions about assignments and lesson planning.

Over the next two weeks the interns took part in small group meetings with April and Sarah to discuss their upcoming teaching sequences. These Lesson Planning Conferences are presented in the next chapter as part of the experiences specific to the participants.

**Session 7:** When the class met again the groups had had a chance to rework and refine their lesson plans; some had even begun teaching. April opened the class with, "Our major question for the day is teaching the Big Idea concept of Day and Night and Seasons there are a lot of misconceptions around the ideas of seasons so our major questions I'm going to ask you to write about is 'How do shadows change throughout the day?'", April addressed the Light and Shadows group, "What are you going to have your students do?" This question is the epitome of teaching science as argument. April is not asking what the interns are going to *teach* but rather how are the *students* going to be involved in their own learning.

"Go outside in pairs and chalk their shadows at three different times of the day then answer observing questions like where is the sun and what does your shadow look like?" answered Meredith.

April reached for a pile of papers on the front table, "I made a copy of pictures of students' shadows and I have them for you to look at." She began passing them out to the

class, “When we did the Quick, Draw, Write where did you predict the shadow would be at midday?

“Very little.” said one intern.

“Non-existent.” added another.

“So then that is your prediction and I want you to think about that when you look at these pictures.” replied April.

The interns examined the pictures, “So it goes like ‘big, big, big’”, she moved her arm as if it were the hands on a clock.

“Why isn’t he facing straight?” asked an intern in reference to the boy in the pictures.

“Do you think it matters?” Sarah replied.

“Well if he was facing us he’d have more of a shadow.” replied the intern, “No wait? I mean does it matter?”

“No it really wouldn’t change it at all.” said April.

“So I think you’d notice that when you hold a flashlight whichever side the flashlight is on the shadow would be on the opposite side.”

“The shadow isn’t on the same side as the sun so it would have to be in front of him but not over top of him because then he wouldn’t have a shadow.”

“So then look at the picture at noon why is that you see a shadow” April pushed.

“Maybe it’s closer to being on top?” mused an intern.

“Why is it like that at midday?” inquired April.

“Well I think it’s (the sun) not above but over here” the intern pointed behind her over her left shoulder.

“So is there a point during the day that the sun would be right above you?” April asked.

“There’s only,” began the intern, “well I’m thinking about a clock, does it matter what time of year it is because this is October so would that influence where the sun is like that?”

“So the seasons have an affect?” questioned another intern. Here the interns were talking through their ideas. They were sharing their questions and using each other as resources for their sense making.

“When I pictured it, I pictured the sun right over head but I guess depending on where you are on earth the sun wouldn’t be directly over head” responded the first.

Hearing an opening in the conversation April asked, “What evidence do you see that the sun isn’t directly overhead?”

“To me” began the intern, “looking at the 9, 12, and 4 o’cock pictures it kind of looked like a clock.”

“I related it to a sun dial and in ancient times but at noon it wasn’t right over head.”

“It looks like the shadow moves clockwise like a sundial.” stated the first.

“Do you think it’s true that the shadow always moves clockwise?” probed April.

“I think if you’re on the other half of the earth it wouldn’t.”

“I think everything is related to the equator and if you’re on the equator then the sun would be directly overhead.”

“Let’s check it out!” April exclaimed. She did not directly provide the interns with an answer rather she empowers them to determine if their ideas are correct. “So I want everybody to look at this with me. Sarah could you give everyone some pipe cleaners?”

Sarah handed out pipe cleaners to each group as April showed them how to make a small human-like figure. Each group was also given a globe and flashlight and asked to use the materials to replicate the apparent movement of the shadows in the pictures in order to determine which direction the Earth rotates. They easily recreated the shadows in the pictures but then spontaneously begin testing some of the group's wonderings such as if shadows moves the same way when you are south of the Equator.

April approached Meredith's group, "What claim could you make?"

"The earth rotates counter clockwise" Lexi answered.

"Because we were able to match up the pictures when we moved it counterclockwise" added Meredith.

"We made our person on the globe match the same shadow as the pictures so we were able to find out the direction of rotation" Lexi stated.

"And we can make another claim that the shadows move if the object moves" asserted Christina.

April nodded and added "So when you teach this lesson the idea of night and day is pretty obvious then the next lesson in the unit is talking about seasons but it's not an easy concept so I want you to listen to a brief video about how seasons occur and listen to the misconceptions that many, many people have." Learning about common misconceptions was helpful for the interns to begin to identify what ideas they hold that may or may not align with science.

The group then watched a segment from "A Private Universe" where recent graduates and faculty at Harvard University were being interviewed on what caused the seasons; most have the false idea that the Earth is closer to the sun in the summer than in the winter. They

then watch a “TeacherTube” video on the tilt of the earth and how it causes seasons to clarify these misconceptions. Once the videos were finished April asked, “So how would you teach this? Would you use the globes, would you use drawings? I want you to talk about it with your table.”

“I think I read about a dramatization with people and they mime spinning for day and night and the orbit” Lexi wondered.

Sarah approached the group, “Do you think you need to focus on the spinning?”

“Once they understand the concept of day and night, then do the seasons I guess so no you wouldn’t need to have it all in at once. Wait I really don’t get it I guess.”

“Think of it like this”, Christina grabbed a ball that was on the table and held a pen on an angle like it was the axis of the Earth then orbits them both around a water bottle representing the sun.

“Oh ok I can see it now.”

“That really makes sense!” Meredith exclaimed.

“How could we make the sun light-up?” wondered Lexi.

“Flashlights?”

“But that’s weird because you have to move the flashlight to light up the earth during all points of orbit” added Meredith.

“What about a bulb in the center, it shines out in all directions and can be kept in one place.”

“Yeah I like that!”

The class then talked about how they would teach the seasons and different ways to have students experience planetary motion on the small scale. Once the discussion began to

wind down April announced, “Next week we are going to start working with StudioCode™ and talking about our Lesson Analysis project and to begin I’m going to show you a project one of the Interns did last year.” This is the self-analysis project that serves as primary data for the second part of this study. “Part of the reason I really like what she did is she did an excellent job at making comments and commentary. You will have to put these on a DVD to turn in. There are 5 parts to the analysis. These are the different topics. If you go to TaskStream the rubric is in there. There is a section on engaging, on explaining, on exploring and evidence based claims and a really important part is your revisions and what you would change and this is an example of what I think is a really good job and pay attention to what she says in the annotations because you’re really going to be explaining why you chose each clip and you can go back and write and that’s where you do your analysis.” She then showed the ‘Explore’ section of a past intern’s video analysis project.

“What did you think?” April asked the class.

“It was loud” cringed an intern.

“Why was it loud?” questioned April.

“They were engaged.” answered another intern.

“What was she doing?” April continued.

“Asking them questions.”

“Did anyone notice what’s she said? Any important science words?”

“She said she was asking prompting questions.”

“What else?”

“She was using words like explanation and prediction.”

"So let's move on to the next thing, we did engage and explore and what would be the next parts?" asked April.

"Evidence."

"The evidence based claims they were making, so let's look at that part" April showed another clip from the video analysis.

"So you can see that part of the Lesson Analysis is looking at your lessons and picking out the best parts. What was different between this piece and the other one?"

"Quieter." stated an intern.

"Why?" probed April.

"It was a discussion."

"This is what I love about science class, the flow between exploration and discussion." mused April.

"And just because you have something in your lesson plan as an explore", stated Sarah, "she found a clip that nicely showed students forming explanations so you can chose pieces that best fit not just those that you said 'should' fit. This is important part of growing as a teacher. If you get to teach multiple times you could say 'I'd change' whatever it is you'd change. This is your analysis of your teaching. If something bombs you'd say how'd you'd change it and that is totally part of being a teacher."

**Session 8:** April asked who had already taught his or her science unit. Alex said that she had begun teaching about adaptations by having her fourth graders investigate Walking Sticks. She was concerned because she had a very unmotivated student in her class but was very pleased to announce that he was able to focus and loved working with the insects. Alex still had concerns about Wonderings; she wasn't sure what to do when her students would

jump in with answers to the questions she had been hoping the group would investigate. April helped by saying that was a common problem and that it was ok to preface a discussion by saying, "We're just writing these down and not answering them." Alex seemed very reassured because that is what she had told her class but was unsure if it was pedagogically acceptable. After more interns shared their teaching experiences April announced the question the group would be investigating that day was, "How can we lift the teacher?" She asked Derek and Callie to come to the carpet.

"Can anyone think of a way to use a simple machine to lift the teacher?"

"A lever?" posed an intern.

"Ok tell me more."

"Just put a long piece of something on the point of the what do we call that? The fulcrum?"

"Yup" said April, "the fulcrum, and what would we need to do it?"

"A long piece of ply wood or something?"

"Something like that?" April pointed to a two by four in the back of the room, "and something like this?" she reached into her bag and took out a brick. She placed the brick on the carpet and lay the board over it.

"It's like a teeter-totter!" said a happy sounding intern.

"Who should stand where?" April asked the group.

"Derek should stand on the short side." offered one intern.

"I don't think I agree." said another, "In my mind I think Derek should stand on the long end and Callie should stand on the short end and she'll lift him."

“OK so we have some disagreement” stated April, “We’re not going to test it right now because I want you to model it using these.” She held up a bag filled with Legos™ and Sarah handed them out to the interns. “You are going to construct a lever. Who in this” referring to Derek and Callie, “is the load?”

“Derek.”

“And so who would be the effort?”

“Callie.”

“Yes Derek is the load.” April affirmed, “So build yourself a lever and figure out if it is easier to lift if the fulcrum is closer to the load or if it is easier to lift if the fulcrum is closer to the effort.”

After the groups had used the Lego™ sets to model levers April asked, “What sort of claims can we make?”

“Less force is required to lift the load when the fulcrum is closer to it.”

“So where should Derek stand?” questioned April, “Come up here” she motioned to Alex, “and show me where they should stand and where should the fulcrum be?”

“Derek should stand on the short end because the fulcrum needs to be closer to the load.” Alex moved the fulcrum closer to the right side of the board and has Derek stand on that end. She had Callie stand on the end farther away from the fulcrum and Derek rose into the air. April asked both to get off the lever and she moved the fulcrum closer to Callie’s side, “What about now?” she asked the class. Callie is still able to lift Derek but it is clearly not as easy, “And now?” she moved it even closer, “No way!” says an intern as Callie jumped and down on the board and Derek stayed firmly planted on the ground.

“What are we increasing when we moved the fulcrum?” asked April.

"The distance away from the load."

"Try this with your Legos™, if the fulcrum is closer are we lifting the load very much?"

They move the fulcrum and noticed the load was not being lifted much. "Ok but how high are we lifting the load when the fulcrum is farther away?" The interns made the needed adjustments and saw the load was being lifted much higher than before.

"Distance is increased when the parts of the lever are moved" April instructed. "The next lesson we're going to do is a fulcrum activity." She held a long plastic Lego™ piece with ten holes in it and demonstrates how to set-up a lever using it, "Before you test it you need to predict how many pennies it will take to tip the lever over when the fulcrum is on the 4$^{th}$ hole, the 7$^{th}$ hole, and the 10$^{th}$ hole. What you're trying to do is to predict how many pennies it takes to tip the lever. Use evidence from the chart to support what you're doing." Derek and Meredith were working together. The entire text of their discussion is included because it demonstrates how the interns have developed in their sense making and how they are able to work collaboratively to solve a science problem.

Derek was unsure of what they are supposed to be doing, "The number of holes under the brick to the fulcrum?"

"We need to make predictions first about the 4$^{th}$, 7$^{th}$ and 10$^{th}$" said Meredith as Derek began the task, "You need to make a prediction first!" Derek asked April if they can use two levers side by side.

"As long as you're consistent throughout the investigation it shouldn't matter" April answered.

“How heavy is a penny?” posed Derek. The two held pennies in their hands and gauged their weight.

“How many do you think for the first one?” Meredith asked.

“I don’t know like twenty?” answered Derek.

“Well it should be easier when the fulcrum is close.”

“Oh yeah so let’s say four or five.”

“I was going to say five or six.” Meredith countered.

“So let’s go with five.” agreed Derek.

“We’re such good compromisers!” They tried five pennies and the lever did not move.

“Oh so more than five.”

“Ten?” wondered Meredith.

“Wait it needs to be on the fourth hole first” Derek made the needed adjustment.

“Oh right! Let’s say fifteen.”

“I have fifteen here.” Derek held out his hand, “I bet there’s some sort of exponential property to this.”

Meredith pushed on the fulcrum, which lifted the load and she meticulously estimated the weight of the pennies. “Add three I think?” Meredith put the fulcrum on the tenth hole and felt the force then counted out pennies in her hand to approximate the weight, “I have thirty one.”

“I have thirty two.” says Derek.

“Let’s go with thirty two.” agreed Meredith, “Now we need to predict for the other ones.” She counted out pennies adding three to each subsequent pile.

“Let’s start with the fourth hole.”

“The fulcrum’s on four right?” questioned Meredith.

“Yup.” Derek assured, “Good call!” Meredith’s prediction of adding three pennies for each fulcrum adjustment was working.

“I can’t help it if we’re geniuses!” Meredith gushed.

April told the class to make a claim about where the fulcrum should be to lift the lever using the least amount of energy. She then discussed how she would differentiate a lesson on simple machines by assigning groups of students different scenarios to solve using the Lego™ sets. She challenged the interns to solve the scenarios by building models then deciding which was least challenging and why. Meredith and Derek are given two scenarios to solve. One involves an old woman who dropped her glasses and is unable to pick them up. In order to solve the problem they needed to build a working model of something the woman could use to pick up her glasses. The other just says to build a working model of a dolly. Meredith and Derek do not have the third scenario but it involves a farmer needing to move vegetables by creating a wheelbarrow.

“So which one is easier?” Meredith asked.

“The one where you build the dolly is easier because you just do it” stated Derek.

“This one you have to think about.” said Meredith in reference to the scenario involving the old woman.

April joined them. “So what would you do?”

“I don’t know.” pondered Derek, “I have some ideas but it would take almost this whole box (of Legos™).”

“So think about it!” April challenged, “She needs something to reach down and grab.”

“It needs to grab?”

“Yup”

April moved on to another group and Meredith said, “It needs to be one of those reacher things with the fingers on the end.” as she mimed a trigger and a claw grasping. “This is third grade?” Derek wondered. He experimented with different set-ups using string and Legos™. The two finally figure out a working model where you pull a string to open the grasper claws and you pull a different string to close the claws. They have taken quite some time to put together the model and the rest of class had begun discussing their results.

“Let’s go ahead and share what we came up with.” April announced, “How about the wheelbarrow?”

“We used one wheel and put a bucket on it and it works.” The group demonstrated dumping out a load of toy vegetables.

“So where’s the fulcrum?” prompted April.

“Here right where the wheel is.”

“And the effort?”

“Way out by the end of the handles.”

“What about the tongs?” Groups showed different variants of tongs made out the building pieces. “OK but to be fair they did have some help.” April showed pictures the groups used to base their models on, pictures that Derek and Meredith did not have.

“Why didn’t we have those?” Derek asked incredulously.

"Because you were doing so well" answered April, "and I was scaffolding different ways to differentiate. So what did you do?"

"We built this." He showed their grasper and demonstrated how it worked, "but the tongs would have been so much easier. Why didn't we think of that?"

The class wrapped up with a discussion of how the interns had differentiated some of the science lessons they were teaching in their placement classrooms. Because the interns were so involved with building their models and discussing their findings they ran out of class time and are not able to complete their StudioCode™ training.

**Session 10:** The interns worked with and designed dichotomous keys and discussed why knowing how to use keys was an important skill for elementary students to learn. After the investigation they were taught how to use StudioCode™, the video analysis tool they would be using to compile edit and annotate their Lesson Analysis assignments. Up until this point the researcher had remained mainly an observer in the class. She had sat with the interns at their tables but had not actively taught them anything. Part of her job involved training preservice students on the use of relevant educational technology; this included StudioCode™. Though the interns were used to the researcher's presence, they were not used to seeing her as anything more than someone who wrote a lot in a notebook. The shift from observer to participant felt odd to her as well.

The workshop was entirely hands-on with the interns practicing the steps they were taught as they went. They seemed to take to the program easily, and were able to code a sample video by the end of the class. Their questions mostly revolved around more advanced uses of the program such as combining timelines, inserting still photos, and annotating more than one clip at a time. Because they had not truly begun working with the program yet most

of their confusion involves simply importing their video into StudioCode™, and converting between file formats. Their issues were discussed and they were left with instructions to practice coding video and to take note of where they ran into frustrations so they could troubleshoot the following week.

**Session 11:** As soon as the class began the interns started asking questions about StudioCode™.

"It's the technology, the actual coding isn't hard but I can't get certain clips to play – I tried contacting people in the class but I couldn't get a hold of them so now I am just stuck."

"The footage takes up a lot of space on my hard drive and I don't know how to save it to take up less space."

"It said it would take 15 hours to convert my files! Are they serious? I'm not even in the same place for 15 hours!"

Sarah jumped in and asked the interns to reserve their questions until the end of class. She then introduced their main question for the day which was, "How can you take lessons and transform them to make them more inquiry based?" April and Sarah passed out three lessons from a unit called 'Changes' on States of Matter. The class was told to look at the lessons and the lesson objectives and discuss what they would keep intact if they were teaching the lesson, what they would change and how. Some of their suggestions involved using more age appropriate science words while others went more in-depth and altered how the lesson were implemented. For example, one involved a teacher demonstration which one group wanted to turn into a student investigation, others changed the objectives of the lessons to make deeper connections to concepts their classes had already learned. Part of the lessons

they were examining had students sorting different materials into piles of solids and liquids. Sarah handed out recycled water bottles containing the various materials mentioned and asked the group to choose what they thought first graders would identify as solids and liquids. After the interns made their choices they watched a video of first graders performing the investigation in Sarah's class. Once the video wrapped up Sarah asked the interns what properties of the given materials the first graders identified?

"Taking the shape of the container."

"Solids are hard."

"Liquids were heavy."

"And they were totally surprised that most of the liquids weighed more than the solids weren't they?" Sarah continued, "That day we finally got to the definition of matter, they had enough experience with the objects so we made a Venn diagram and took away everything that didn't apply to all solids and liquids."

"What elements of teaching science as Inquiry did Sarah do?" April questioned.

"They had to explain their thinking" mentioned an intern.

"They had to come up with the definitions", said another, "Sarah didn't tell them."

"But it took a long time do you think it was worth it?" posed April.

"Yeah because they really knew it."

"Did you notice" Sarah inquired, "when I put up the K part of the KLEW chart? I didn't just say 'What do you know?' but I gave them a chance to sort (the materials) then once they had that experience we went back and added to the Know section." This is a lesson some of the interns do not internalize.

"This is why we do the Know section after they've had some experience so if you write 'What do you think you know?' they actually know something and I also say we're not deciding right and wrong right now."

"What if you have students that are right on?" wondered an intern.

"I would say 'Wow that's an interesting idea, let's write it down and see if we can see that'" April responded.

"When it comes time to write down learnings," asserted Sarah, "you want to make connections to the evidence so if students disagree you could retest in the big group or go to the web or do some research in a book."

April then had the interns create posters depicting their current notions of "Best Practices in Science Teaching." Their lists included: questioning, getting the students to think and discover, addressing misconceptions, using discussion to build ideas together, allowing students to explore instead of telling them content, explaining through evidence and making claims, using multiple representations, and being flexible.

The groups presented their visuals and hung them around the room, covering the work of the third graders. They then began to discuss StudioCode™. April clarified the Lesson Analysis Assignment and reiterated, "When you're justifying and doing an analysis you can't just say 'This shows my students making claims' it needs to say something like 'This shows my students making claims about how lizards are adapted to their environment based on the evidence they gathered.'" She tried to push the interns' thinking beyond the superficial, asking them to think about and reflect on why they made the choices they did, not simply on what their choices were.

**Session 12:** The group was very relaxed. April and Sarah brought in pizza and soda and they discussed the semester's highs and lows. Time is also reserved for debriefing the Lesson Analysis and use of StudioCode™. Some of the interns' comments included, "I've always thought of science as hands-on but it's the quality of the hands-on experience."

"It's ok to still have questions yourself."

"I've grown to have a better appreciation for science. I never really liked it in school but now my mentor wants me to take over teaching science when we come back because the kids are so engaged and want to learn."

"I always remember science being boring but one of my kids said, 'I learned stuff but I still had fun doing it!'"

April asked the group to think about why looking at their own teaching could be valuable and what they learned about themselves?

"Being able to see what all the students were doing. I had no idea!"

"I found it hard to stay away from management stuff. That stood out the most. When I watched the video I saw the management part but through the coding I saw the science part."

"I saw that I didn't give good feedback to my student's comments."

"I was really critical of myself before but I realized I wasn't really that bad."

"It was helpful to watch myself as I gave instructions", Meredith offered, "some kids weren't getting it and I was very frustrated in the moment but watching it I realized my instructions fell short."

"I realized a lot of it is I'm rewording their explanations so it feels like it's mine but it's based on what they are saying."

"I noticed I say, 'good' a lot like, 'good job' I need to compliment with a purpose not just say 'good'. Also I need to talk less and have them talk more there were whole clips of just me talking and I was like, 'Shut up!'"

The groups then split up and watched parts of each other's analysis videos. They shared their teaching topics and one video that captured the essence of their teaching. The class once again erupted in discussion and animated sharing. They all seemed very eager to share what they have accomplished, "You did such a good job!", "I would have never thought of that" and "Wow you handled that great!" filled the air. After a semester filled with a lot of hard work and strenuous thought it is clear the group has not only learned about teaching Elementary School science but also about each other and the need for a solid support system to help them through the their journey of becoming teachers.

**Discursive Model of Meaning Making**

The Discursive Model emerged from the coding of the field notes and illustrates the Teaching Science as Argument Framework (TSAF) in action. It is a way for teachers to situate the TSAF within elementary classrooms and begin to make sense of how they can employ the TSAF in their practice. This model consists of using the language of science in an on-going and consistent manner with an emphasis on the formation of scientific explanations based on evidence. As discussed in the Introduction, the language of science is abstract, conceptually dense, and not heard in everyday conversation (Kelly, 2008). Because the language of science is unfamiliar, all participants can be considered "non-native" science speakers. Thus, there is a need for teachers to make explicit interventions to emphasize the language of science in their classrooms. Without such scaffolding, students do not

spontaneously adopt the social norms or the epistemic aspects of argumentation for conducting productive classroom discourse (J. Osborne et al., 2001). It is often assumed that if teachers design interesting activities then children will talk more about science, but research has shown this not to be the case (Zhang et al., 2010). Teachers must make a point to unambiguously define and model expected classroom norms of discourse and discussion and give students the opportunity to practice talking science using prompts which bridge every day and scientific vernacular (Herrenkohl & Guerra, 1998; Varelas et al., 2005).

During investigations in the methods course, a combination of the language of science and productive questioning was used to scaffold the interns' thinking around what they were observing and to help guide the choices they were making. This was critical because preservice teachers tend not to hold strong commitments to the co-construction of science concepts, but rather want their lessons to be fun and hands-on (S. Abell et al., 1998). But students do not build a deep understanding of science through simple, fun activities. Rather their actions must be explicitly scaffolded using talk and questioning. Student thinking during investigations can be prompted with questions such as, "What are you going to do next?" "What outcome do you predict?" "What did you learn?" and "How do you know?" These forms of questioning-in-action prompt students to explain the reasoning behind their investigating. This helps facilitate the integration of newly learned and prior knowledge, especially when prompts are related to the negotiation of knew understandings or the meaning behind observations (Chi et al., 1994).

During the methods course the instructors also highlighted the importance of public sense making in their actions and discursive choices. Interns were pressed to form claims based on evidence and to make connections between what they were observing and the

scientific significance of the evidence through the use of talk moves, productive questioning, and other discursive tools. It is important for interns to experience public sense making because if left to their own devices, children tend to default into making causal inferences during their initial science explorations (Schauble, 1996) and are likely to selectively record data, as well as distort or reinterpret data to support their hypothesis (Kanari & Millar, 2004). Through the public negotiation of meaning, such issues are brought to the forefront and the group can collectively discuss the data and answer the driving question or decide if additional/different evidence is needed to make sense of their observations. During such discussions teachers can use talk moves, which extend classroom discourse beyond the traditional I-R-E pattern (Chapin et al., 2009; Lemke, 1990; Simon et al., 2006) and encourage students to expand their reasoning and arguments while fostering student-student interaction and debate.

The Discursive Model of Meaning Making demonstrates how the Teaching Science as Argument Framework (TSAF) (Zembal-Saul, 2009) is enacted and how the Framework can be used to co-construct explanations based on evidence. The next chapter describes three distinct images of the TSAF in action during the participants' initial science teaching. It addresses the differing discursive patterns used by the participants and proposes what can be learned from the examination of each.

# Chapter 6

## THE PARTICIPANTS: ANALYTIC NARRATIVE

The following case description addresses the nature of how the participants implemented their three day initial science teaching sequence, as well as how they analyzed their work it also gives additional insight into how they were prepared to do so through the description of lesson plan conferences they took part in prior to teaching. This chapter includes evidence that preservice teachers are capable of negotiating some of the complex dialogic practices associated with scientific argumentation in their early field experiences. This is noteworthy because preservice teachers often revert to simple authoritative talk patterns (Viiri & Saari, 2006) as represented by the I-R-E talk pattern (Mehan, 1979). Evidence in this case shows how preservice teachers are capable of moving beyond this simplistic version of classroom talk and illustrates how they can scaffold their students' abilities to co-construct scientific claims based on evidence using a discursive model of meaning making. Evidence is also presented that demonstrates the constructs of the methods course were being picked up and used by the participants during their field experiences as well as in how they analyzed their practice. This is significant because the Teaching Science as Argument Framework (TSAF) was not only intended to provide tools for teaching but also as a way for preservice teachers, with typically limited backgrounds in science, to begin to appreciate the relationship between the language of science and science learning including the importance of forming claims based on evidence (Zembal-Saul, 2009). By including elements of the framework in their self-analysis the participants are indicating they are making sense of their practice in relation to its affordances.

This case was constructed using a number of data sources, in addition to spending four months as a participant observer in the science methods course I also had access to video of the participants' initial science teaching experiences and their video based self-analysis of this experience. I have raw footage of the first time the participants implemented a multi-day science unit as well as annotated video the interns created as a self-analysis of their practice. The following chapter is an examination of how the participants lead a three-day science unit and attempted to co-construct the meaning of science concepts with their students. The chapter is divided into three parts, one for each participant. Each part is further broken into sections examining the Lesson Plan Conferences that took place between the participants and their Methods Instructions, the participants' implementation of their lesson plans during their Initial Science Teaching experience, and the interns' Self-Analysis of their practice followed by a breakdown of the themes from each participant.

The sections on Lesson Plan Conferences are based on field notes from observations of the meetings. As such it is appropriate to present transcripts because the field notes may not represent a verbatim record of what was said but rather a gestalt understanding of the interactions. Analysis of these sections contains narrative descriptions of the meetings with embedded analysis. Speech events are offset with right braces and their coding articulated horizontally, drawing the reader's attention to how the events are relevant to the case as seen to the right.

Example right brace

The analytic narratives discussing the participants' initial science teaching and self-analysis of their experiences includes transcripts of salient speech events, as identified through the coding of the video footage. For a thorough description of the coding process

please see chapter 3. The transcripts include how the instance was coded followed by its text label in brackets. An example transcript with embedded codes and labels follows:

*Meredith: It wasn't as skinny?[cmp:id ptts]*
*Noah: No it was-*
*Meredith: How would you describe it? [explct reasn: id ptts]*

In the first line Meredith asks a comparison question in order to scaffold her students' abilities to identify patterns in their data. She then asks Noah to explicate his reasoning on why he doesn't think the shadow was as skinny as the first one. For a complete set of definitions and examples of codes and text labels see tables 4.3 and 4.4 in chapter four.

This chapter addresses the final two research questions:

- In what ways do the preservice teachers use productive discourse strategies to attempt to support students in meaning making of science ideas and practices in their initial science teaching experiences? How else do they attempt to do this?
- How do the preservice teachers make sense of their initial science teaching experiences through video based analysis of their practice?

**Part 1: Narrative Analysis of Meredith**

Meredith is a very capable preservice teacher. She has benefitted from April being both her Science Methods instructor and her Mentor teacher so she is able to see what is discussed in class put into action on a daily basis. She is an example of what preservice teachers can accomplish when provided with high level, research based instruction and a supportive mentor who demonstrates argumentation and productive discourse in an elementary classroom. Meredith's unit plan is on light, shadow and the Earth's rotation. The overall learning goal of her lessons was for students to understand what causes day and night.

Lesson objectives included how shadows change throughout the day, and what direction the earth rotates.

**First Round Lesson Plan Conference.** Meredith is part of a Light and Shadows group meeting with April in her classroom. Along with Meredith the group consists of Christina and Evelyn. April addresses the three, "So I had a chance to look at your Concept Interview and now I want you to give me an impression of what will be important in your lessons." April is demonstrating that the simple mechanics of a lesson are not the most important things for the interns to be thinking about but rather they should focus on student ideas and science concepts. The interns pick up on her intention and begin to discuss their students' current conceptions of light and shadow.

Meredith jumps in, "None of my students thought the sun moved though it moved across the sky, it doesn't actually move and one girl thought the earth sat between the sun and the moon and that's why we have day and night and no one knew anything about tilt."

"I think I had a different impression because I have younger students, one thought the sun dropped, another boy, he knew the earth rotated and the sun sat still but he didn't know the implications and thought Alaska never faced the sun so he really didn't know the implications." Christina said.

"They knew the earth rotated" added Evelyn.

"They knew about shadows like if you stayed outside would your

Student Prior Knowledge

shadow move? And they would say if I moved my arm my shadow would move" said Meredith.

"So far you can't really make the claim that they understand rotation" April stated. "They really only know the word and not what it means. For third grade your first priority would be for them to understand day and night and as an extension would be to use your data to understand the rotation. So the collection sheet? There is just morning do you think that is enough?"

"So we'd need three?" asked Evelyn.

"Yup and the data sheet is divided so I think it is important to have a connection where they can visually connect what they are seeing and also take pictures. So how could we change it?" April has introduced the idea of data collection, reinforcing the need for students to collect evidence they can use to form claims and address the investigations guiding questions.

"Have specific prompts, maybe on the back?" answered Christina.

"I think it's important to have it on the front. And what do they need to collect?" asks April.

"Length, shadow direction and location of the sun" replies Meredith.

"How could we ask them to record sun location like up, left, down?" inquired Christina.

Data

"I think it is important to understand the idea of the horizon and a really good extension question is, 'You drew this, this is great but what time of year could this be?' And you should be able to do that from your data. 'Do we ever see the sun directly above?' 'Do you ever see smaller shadows at noon?' 'When would that be?' Use these to push your students' thinking" posed April. Here April suggests specific questions the interns can use during their teaching. She continues to do this throughout the rest of the conference. This is important because it sets the groundwork for the interns to use a more complex discursive model of meaning making rather than reverting to simplistic talk patterns such as the I-R-E sequence. This speech event is also significant because April highlights the role questioning plays in scaffolding student thinking.

Questioning

April then introduces the necessity for science talks and for listening to student contributions during these discussions, "So they are going to collect data one day but you're not going to be able to talk about it so you'll need another day to talk about it and maybe that could be on the back, 'What did you notice?', 'What's going on with the shadow?', 'Is it skinny, is it wide?' and I hear (from my students) all sorts of things they can add to the KLEW chart and listen because they still may say the shadow changed because the sun moved in the sky. So then the second day?"

"The second day or second activity?" asked Meredith.

"The, I mean I guess typically the second day they use the people and flashlights and how they could experiment with making and changing shadows."

"umm …."

When Meredith pauses and seems confused by April's question April refocuses their discussion on student learning and science concepts, "Let's first go to the end of the day and what you want them to get out of it."

"How changes with shadows happen." replied Evelyn.

Meredith indicates that she is thinking about the importance of questioning and classroom discussion when she contributes specific questioning prompts, "We could say something like, 'How could you make the longest, the shortest shadow?'

Christina jumps in, "So when does it take on the shape of the pipe cleaner and when is it amorphous?"

"What is a shape of a shadow because they think the shadow will always take on the shape of the object. And what else?" April has picked up on the interns' discussion of questions and adds another layer to the dialogue by bringing attention to the importance of students forming scientific claims based on the data they have collected. This is a specific construct of the TSAF.

"Angles" states Meredith.

"And what kind of claims would you like them to make about angles?"

"That the shadow is on the opposite side."

"They've had a chance to experiment and you bring them back and say, 'How did you change the shadows?', 'You moved the what?'"

"lightsource" states Meredith.

"And what happened outside?" asks April.

"They'll probably say the sun moved" replied Evelyn.

Student Learning

Questioning

Claims & Evidence

“So” says April, “you'll ask them, ‘How can you change the shadow by moving the surface?’ And that is your segue into talking about day and night and using the earth to make shadows?”

“Ok, well we don’t really have one yet” adds Christina.

“You need to be thinking about the mechanics and management and you want to set the tone about being scientists” replies April, “Do you foresee problems?” By asking the interns about potential problems during their teaching April is helping them problem solve and work through management issues before they arise setting the stage for a successful initial science teaching experience.

“I can think of a few.” says Meredith.

“Well you want to set the tone and identify what you might run into and the third day you want to come back to using the people and the globes and you want to practice with them yourself” April instructs.

“So do you tape them anywhere on the globe?”

“I'd tape them on Pennsylvania.”

Mechanics and Management

“And is this is partners?” Christina asks.

“Groups and you want to think about roles and your question is, ‘Can you make the shadow move the same way it did outside and can you determine the direction the earth moves?’"

“Counterclockwise?” muses Meredith.

April grins, “Prove it! What do you think about using the books?”

“I think at the end.”

"Why at the end?" pushes April.

"Because it's a good summary."

"And make sure you're reinforcing what they've seen. And what kind of claims could you add to your chart?" Even when discussing the mechanics of their lessons April returns to the importance of making claims based on the evidence the students are observing. She does not present the formation of claims as an afterthought to the lesson but rather as a central pillar of student learning.

"Day and night is caused by rotation and the evidence is from the globe activity." Meredith answered.

Claims & Evidence

"So how does that feel?" April asks.

"Better. I feel like we were just making it up last time but now it feels real."

"I love planning sessions!" adds Meredith.

Because of a change in scheduling I was unable to attend Meredith's second conference.

**Initial Science Teaching Experience:** To begin the unit, Meredith performed a short visualization with her class she told them it was midday, the sun was above them and they were to think about where their shadows would be as well as what it looked like. The students then drew a picture of how they imagined this scenario. This was called a Quick, Draw, Write and served as a preassessment to her planned unit on shadows and the Earth's rotation. The students' drawings could be grouped into three categories; the first group drew their shadows directly below them, almost like a puddle, the second group drew the shadow out to the side of them while the third group drew the shadow right below them but it looked

like a person. Meredith explained to her class the patterns she had seen in the Quick, Draw, Write and used this as a segue for introducing the day's guiding questions, "What do our shadows look like in the middle of the day?" and "How do our shadows change throughout the day?". Meredith had already added this question to the Wonderings section of a Know, Learn, Evidence, Wonderings (KLEW) chart. Meredith used this chart throughout her three day teaching sequence to map what claims her students made about the data they had collected and to scaffold testable questions for the group to investigate. Another pattern that Meredith establishes during her teaching is transitioning the class between active investigation, science talks and the formation of explanations, greater detail of this pattern can be seen in the paragraphs to follow.

After Meredith's introduction, the class went outside and traced their shadows on the paved basketball court in their school yard. They note the location of the sun, length of their shadow and time of day. They repeated this process two additional times and record the data in their science binders. After each trip outside, Meredith gathers the group on the carpet in the back of their classroom to discuss what they saw in order to identify patterns in their data. During this discussion she focuses her students' attention on the relevant data then revoices what her students contribute to the conversation. This not only ensures Meredith understands what her students' intended to say but it also highlights the importance of their contribution to the discussion and enables other students to clearly hear the original idea. She then pushes them to explicate their reasoning and continues to revoice their contributions. Connections to the TSAF inform the utterance-token meaning of these speech events. By asking her students to explain what they drew she is making sure her class is correctly representing the data they collected while identifying patterns in the data.

*Meredith: When you drew your shadow can you explain to me, what did you draw? What does it look like?[attn fcs: dta]*
*John: It's straight ahead but it's a little bit to the left.*
*Meredith: Straight ahead, a little to the left. [revoice: dta] Did it have your body shape? [explct reasn: id ptts]*
*John: Yeah I went like that (stands with arms at sides) but it had my body shape and was really tall.*
*Meredith: So it was taller than your body? [explct reasn: id ptts]*
*John: Yes.*
*Meredith: OK. Katia?*
*Katia: I feel like it looked like my body but it was tall and stretched out.*
*Meredith: From what you're saying if I were to draw my shadow it's kind of straight out, a little to the left, taller than my body but having the shape of a person. [revoice: id ptts]*
(ecb.md1.teachvid.11/09)

In response to John and Katia's descriptions Meredith draws a shadow on the board to represent the data and asks them if her drawing represents what they saw outside. She then asks the group to think about where the sun was in relation to their bodies. By questioning her students about the position of the sun Meredith is establishing a baseline for patterns they will identify later. Knowing where the sun was in the sky is essential for her students to understand the relationship between where the light source is located in comparison to where a shadow is. In the following example Meredith opens with a reasoning question followed by a question asking Hunter to recall where the sun was in relation to his body when they were outside collecting data. She then asks Henry to explicate his thinking about the location of the sun by adding more detail to the description in order to identify the baseline pattern that is the key to their ultimate conceptual understanding.

*Meredith: What did we figure out about the sun? [resn: dta] Where was it? [recall: dta] How could we describe that? [resn: dta] Hunter?*
*Hunter: Diagonal, diagonal to the right behind us.*
*Meredith: Was it way up high in the sky? [explct resn: dta] Was it down low near the ground? [explct resn: dta] Henry?*
*Henry: The middle of the sky.*
*John: Above the horizon but not super high.*
*Meredith: So you could say it was above the horizon but not straight above us?[revoice: dta]*
*John: Yeah.* (ecb.md1.teachvid.11/09)

In the above example, Meredith begins with a simple question, "What did we figure out about the sun?" but then becomes more complex in her strategies asking the students to describe what they saw using their own words. After Meredith records this information on the board she goes on to ask the class if they have any predictions about where the sun will be when they go outside after lunch and what their shadow will look like. She uses her questioning to encourage students to compare what evidence they already collected and to make inferences about what patterns they will see in the future. The following also contains an example of Meredith revoicing a student's idea using gestures instead of words

*Katia: I know the sun moves across the sky.*
*Meredith: So do you think it will be higher or lower than it was? [resn: prdt]*
*Katia: I think it will be lower.*
*Meredith: OK. Karen?*
*Karen: I think the shadow is going to be going to the right.*
*Meredith: So like this? (she moves her hands across the shadow drawing on the board like a windshield wiper moving to the right) [revoice: prdt] OK. Hunter?*
*Hunter: Usually at midday the sun is directly above our area.*
(ecb.md1.teachvid.11/09)

Meredith then uses a talk move to encourage Hunter to explicate his thinking about his prediction. She also continues to revoice student ideas.

*Meredith: So what does that mean for your shadow do you think?[explt resn: prdt]*
*Hunter: It's probably going to be like a puddle or maybe a little bit in front of us.*
*Cieran: I think the sun will go a little higher but not right above us. So I think our shadow will get shorter.*
*Meredith: So you think the sun will be higher in the sky and it's going to make our shadows shorter?[revoice: prdt]*
*Cieran: Yeah.* (ecb.md1.teachvid.11/09)

When Cieran's prediction is different than Hunter's Meredith recognizes an opportunity for her students to consider alternative ideas. She asks Cieran to apply his own reasoning to Hunter's prior prediction then revoices both boys' ideas.

*Meredith: So you don't quite agree with Hunter? [ag/dsag: alts] Because Hunter said it (the shadow) was going to be right underneath you. [revoice: alts]*
*Cieran: Well I'm not thinking the sun is going to be right above us. If it was then I'd think our shadows would look like puddles.*
*Meredith: But you don't think it'll be directly above us and you think the shadow's going to be shorter?[revoice: prdt]* (ecb.md1.teachvid.11/09)

This discussion leads Meredith to add another question to the Wonderings section of the KLEW chart, "How does the position of the sun change throughout the day?" This adds additional purpose to the class's investigation and connects their discussion to their data collection.

After lunch the class goes outside to draw their shadows again and John starts walking around like a robot, making high-pitched song-like noises with every step. When Meredith notices this she walks over to John and uses productive questioning to redirect him to the science task. Her questioning elicits John to make a prediction about what he thinks he will see when they come outside again, she also revoices his idea and uses his own thinking to redirect his behavior.

*Meredith: So John what do you think you'll see, when we come outside again?[resn: prdt]*
*John: I think it's going to be over here more (waves his hand to the right).*
*Meredith: And what about the size? [explct resn: prdt]*
*John: I think it's gonna be like this size (walks on the shadow he just drew).*
*Meredith: You think it's going to be the same size?[revoice: prdt]*
*John: It's not too long till recess.*
*Meredith: (nods) Very true.* (ecb.md1.teachvid.11/09)

Meredith then gives John a job to complete by asking him to draw the shadow in his science binder. This keeps him on task for the rest of the class's time outdoors. When the

class returns inside, Meredith leads a discussion identifying the patterns they saw. The class agree that their shadows had moved further to the right, were shorter in length than previously and skinnier than their bodies also that the sun was behind them, diagonal to the left and higher in the sky than previously but not directly over their heads. Because of this they are able to make the claim that at midday their shadows have a body shape, extended to the right of their bodies and were taller than the students were. For evidence to support that claim they stated that they tried it outside and that was what their shadows looked like. The group then predicted their shadows would keep on moving to the right and the sun to the left but that the sun would continue to move higher in the sky. A complete set of student data can be seen in figure 6.1.

**Figure 6.1**: Complete Set of Shadow Drawings

While the class is recording their third round of shadow drawings Meredith uses attention-focusing questions to help students identify patterns in their data. She also clarifies their reasoning by revoicing ideas.

*Meredith: So what did you notice about the shadow Hunter? Shadow number three?[att fcs: dta]*
*Hunter: Um it's like the second one in shape except it's taller.*
*Meredith: So it's longer than the second shadow? [revoice:dta]*
*Hunter: Yeah.* (ecb.md1.teachvid.11/09)

When the class returns to the classroom they gather in front of the KLEW chart and Meredith leads a discussion on their newly collected data. She employs several varieties of talk moves, in order to help the class identify the patterns they have observed throughout the day. To begin she prompts students for participation, and revoices their contributions.

*Meredith: Katia, can you please describe for me how I should draw the third shadow?[prmt: dta]*
*Katia: Taller than the second one but not as tall as the first one.*
*Meredith: And to which direction?[explct rsn: dta]*
*Katia: (approaches the board) not all the way to the right but further to the right than before (she points to where the shadow should be drawn).*
*Meredith: OK so not as tall as the first guy, taller than the second guy and slanted more to the right. [revoice: dta] Jordan?* (ecb.md1.teachvid.11/09)

Jordan then describes his drawing and Eddie disagrees about the shape of the last shadow. Meredith then facilitates a basic form of argumentation by listening to the students' claims, acknowledging the different viewpoints and asking the class for agreement before adding the drawing to the board. By asking for student agreement Meredith is prompting them to think about their own ideas and to apply their own reasoning to another students' reasoning. She finished by revoicing Timmy's idea, indicating she is in agreement with him without ever making a declarative statement that he is "correct".

*Jordan: I thought the latest shadow was chubbier than the twelve o'clock one.*
*Meredith: Do you all agree with that? Thumbs up if you agree. [ag/dsag: id ptts] (Waits for the class to raise thumbs or not) So this was the widest shadow?*
*Eddie: That's not what I was seeing.*
*Meredith: You don't agree Eddie?[ag/dsag: id ptts]*
*Eddie: I'd say it's as tall as the twelve o'clock but not as skinny.*
*Meredith: Timmy?*
*Timmy: I think it was like the same, it was as chubby as the twelve o'clock.*
*Meredith: So it was around the same width?[revoice: id ptts] (several students nod)*
(ecb.md1.teachvid.11/09)

The class then identifies where the sun was on their last trip outside and makes comparisons between all of their data sets. This speech-event serves to identify patterns and make sense of their data. Meredith asks them to reason about their data and state claims to answer their original question, "How do our shadows change throughout the day? A reasoning question is appropriate at this juncture because the class has gathered three different sets of data on the scientific phenomena. Notice how Meredith starts with a broad

reasoning question then when Teah has a hard time answering, as indicated by the eight second pause, she narrows the scope of the question by asking Teah to recall if the shadows changed location this helps to focus her thinking on the location of the shadow. She also revoices Grayson's ideas about the size and shape of his shadow.

*Meredith: How do shadows change throughout the day? [resn: evd clms] What were the big differences we saw? [resn: id ptts] Teah do you have any ideas? (waits for eight seconds) Did they change location? [recall: id ptts]*
*Teah: They were moving.*
*Meredith: How did they change? [resn: id ptts] What way were they moving? [recall*
*Teah: To the right, like a clock.*
*Meredith: So our shadows were moving clockwise. [revoice:id ptts] Grayson how did they change in size?[resn: id ptts]*
*Grayson: Well the morning one was tall and skinny and they got flatter and chubbier at twelve o'clock then the next one was taller than twelve but skinny again.*
*Meredith: So our twelve o'clock was the widest one you're saying? [revoice: id ptts]*
*Grayson: Yeah.*
*Meredith: And these two (morning and afternoon) were longer and thinner? [revoice: id ptts]*
*Grayson: Yeah.*
*Meredith: OK. Ruthie?*

(ecb.md1.teachvid.11/09)

At this point Meredith recognizes Ruthie has brought up an important concept the class needs to understand in order to make sense of why the shadows move in the pattern they have identified. Meredith revoices Ruthie's idea and prompts her to speak louder to emphasize the importance of the idea to the class.

*Ruthie: I think those two (morning and afternoon) were the same size but in different spots because it had to do with where the sun was.*
*Meredith: That's interesting you bring that up. Ruthie said the different locations of our shadow were because the sun looked like it was in different places in the sky. [revoice: expln]*
*Teah: Wherever the sun goes your shadows are in the opposite direction.*
*Meredith: Can you say that louder please?*
*Teah: Wherever the sun is the shadow is in the opposite direction.*

(ecb.md1.teachvid.11/09)

Meredith then performs an on-the-spot role-play where she pretends she is outside again and that the clock on the wall is the sun. She asks the class to decide where her shadow would be. The students point to the floor in front of Meredith and away from the clock. Meredith pushes her students to explicate their reasoning by asking them how they know where the shadow would be. This talk move improves students' abilities to build scientific arguments and reason logically by encouraging them to consider what evidence they have seen to support their claims. She also has them apply their own reasoning to their classmate's reasoning by asking them if they agree with what Teah has said.

*Meredith: How do you know that?[explt resn: evd clms] Look at your evidence of where you wrote where the sun was and look at where you drew your shadows for those times. Does that back-up what Teah's saying? [ag/dsag:evd clms] Was the sun in the opposite direction of the shadow? [recall: id ptts] (several students nod and answer yes) Does anyone agree with that?[ag/dsag: id ptts]*
*Ruthie: When I look at the data I see that at nine o'clock we have a long shadow and the sun isn't very high in the sky but when the sun is higher the shadows get shorter.*
*Meredith: Do you agree with that, the higher the sun was the shorter our shadows were (most of the class nods)? [ag/dsag, revoice: evd clms]*

(ecb.md1.teachvid.11/09)

Meredith does not use an evaluative statement such as, "correct" to indicate her students have shared an accurate idea rather she adds claims to the KLEW chart and revoices their ideas to visually emphasize and highlight the concept. In order to prompt her students to share their current understandings she uses productive questioning. She further indicates her students have shared an accurate conception by prompting them to share evidence in support of their claim. This sequence serves as the backbone to how Meredith helps her students make meaning of the science concept.

*Meredith: (Meredith's tone of voice then changes from an inquisitive tone to a more authoritative one.) So let's look at our KLEW chart. The other wondering I had was, 'How do our shadows change throughout the day?' and what was it we learned about how our shadows were changing? [klew, tstble qst] Eddie?*

*Eddie: Um they um move clockwise. They move clockwise and as the sun elevates higher they get shorter.*
*Meredith: (As she is writing on the KLEW chart) Shadows move clockwise and ah what was that that you said?[klew, revoice: evd clms]*
*Eddie: When the sun elevates higher they (the shadows) get shorter.*
*Meredith: (Continues to write on KLEW chart) The higher the sun the shorter the shadow. [klew, revoice: evd clms] And Teah can you remind us what you said about where the sun is how that affects where the shadow is?[prmt: evd clms]*
*Teah: The shadow's the opposite direction from the sun. (Meredith adds that to the KLEW chart)*
*Meredith: So I need some evidence, some concrete evidence to back-up what we just said. So (points to KLEW chart) shadows move clockwise. What can we say? Why do we know that?[explt resn: evd clms]* (ecb.md1.teachvid.11/09)

As seen in the examples above, Meredith consistently prompts her students to use their notes, consider the data and to provide evidence to support what they are saying which establishes a commitment to dialogically making sense of science concepts.

Meredith ends the days' lesson by having her students write an explanation for how and why their shadows changed throughout the day using writing scaffolds. As mentioned in chapter 2, a scaffold is a temporary support teachers can use to help students accomplish a task they may not be able to do on their own (Bransford et al., 2000). The question the students are addressing in their written explanations is, "How and why do our shadows change?" Meredith writes it on the board and adds a list of words the students should include in their explanation; these are shadow, sun, direction and location. The students are then dismissed to their seats and given time to write.

The next day Meredith reminds the class of their prior investigation and introduces the new lesson. Each group of students is provided with a flashlight and a pipe cleaner. Their task is to use the pipe cleaners to represent themselves in the schoolyard by forming pipe cleaner people, they are then charged with recreating how their shadows changed throughout the day using the flashlight to represent the sun. The goal of this lesson is to

investigate where the light must be in order to create the shadows they saw outside and to determine the apparent motion of the sun across the sky.

While the students are collecting data Meredith employs productive questioning techniques to help focus their attention and scaffold their abilities to identify patterns between the model and what they saw the day before. By posing comparison and reasoning questions Meredith is helping her students identify patterns in their data and make sense of the claims they crafted the day before in relation to the evidence they are seeing using the models. Notice how Meredith does not tell Ava she is wrong but rather pushes her to examine the data and compare the data with the patterns she is currently seeing.

*Meredith: So was this the way our shadows looked like yesterday at midday? [cmp: id ptts]*
*Ava: No.*
*Meredith: Why not? [resn: id ptts]*
*Ava: Because our shadows were bigger.*
*Meredith: Why were they bigger? [resn: id ptts] Was there something different about where the light was?[cmp: id ptts]*
*Ava: Yeah the flashlight was up high.*
*Meredith: So what was the sun like for us yesterday? [recall: id ptts] Was it directly overhead like in this?[cmp: id ptts]*
*Ava: Yeah.*
*Meredith: Look at your notes. Was it? [cmp: id ptts]*
*Ava: (looks at science binder and shakes head) No.*
*Meredith: So could that be why our shadows looked different? [resn: evd clms] That is what I want you to be writing about. [wrtng: evd clms] OK?*

(ecb.md2.teachvid.11/09)

Meredith also uses attention focusing questions and comparison questions to help her students take note of what they are doing and what patterns they are seeing.

*Meredith: Which is your drawing for midday? [attn fcs: dta] (student points to drawing in science binder) How did you hold the flashlight?[recall: dta]*
*Cieran: Overhead (lifts flashlight directly above pipe cleaner person).*
*Meredith: Right overhead? What did you see?[attn fcs: dta]*
*Cieran: The shadow is right beneath it.*
*Meredith: Is that like anything we saw yesterday?[cmp: id ptts]*
*Cieran: Nope, cause the sun was never right above us.*

(ecb.md2.teachvid.11/09)

She also uses action questions to encourage her students to investigate the relationship between where the sun was in the sky and how their shadows looked as well as comparison questions to push her students to represent the data accurately. The following example is one of the only times Meredith used a declarative statement to indicate her student had accurately represented the data but notice how she quickly returned to productive questioning to scaffold their ability to represent the data.

*Meredith: Can you use the flashlight to make this pipe cleaner person's shadow move in front and to the right like ours did yesterday? [act, cmp: dta] (She waits as Karen aligns the flashlight behind and to the left of the pipe cleaner but very high in the air. Meredith points to the shadow on the floor). Is that how short the shadow was? [cmp:dta]*
*Karen: Yeah.*
*Meredith: Really? Can you make the shadow longer? [act:dta] (Karen stands and walks away from the pipe cleaner person but continues to hold it high).*
*Jordan: No go down. Go down, go down. (Karen moves closer to the model and holds the flashlight lower. Jordan takes the flashlight from Karen and moves it even closer to the ground).*
*Meredith: Aa-ha! I think that is what our shadow looked like at midday. [dclr: dta]*
*Jordan: Yeah!*
*Meredith: So how are you holding the flashlight? [attn fcs: dta] Where is it in relation to the pipe cleaner? [attn fcs: dta] That is what you need to draw.*

(ecb.md2.teachvid.11/09)

When the class finished gathering data they regrouped on the carpet for another science talk and Meredith makes a notable shift in her use of discourse strategies. Up until this point she has relied mostly on productive questioning to push individual student thinking and prompt them for further action. Now she shifts her strategy to include a greater number of talk moves designed to encourage discursive participation during larger group discussions. While the students are situating themselves Meredith prompts Cieran, letting him know she is going to call on him for participation later in the discussion this allows him to prepare his explanation and not be surprised by it while also enforces to Cieran that his ideas are worthy

of being highlighted. She also prepares the entire group for what to expect in this talk helping them to focus their thoughts and be ready to share their findings.

*Meredith: So Cieran I'm going to ask you to help me out on the last one ok? 'Cause we're going to talk about why that was happening. [prmt: expln]*

(ecb.md2.teachvid.11/09)

Meredith then reviewed the data collection sheet and prompts a variety of students to share their findings. During this time she revoiced student contributions to clarify their ideas and enforce the importance of the contributions to the rest of the class. She also continues to ask her students if they agree with statements other students have made which encourages them to think about what the other students have said and to apply their own reasoning. Meredith also asks an action question which allows Ruthie to answer the question and demonstrate her understanding of the concept using gesture rather than speech.

*Meredith: OK what about at nine thirty in the morning? How did you do that? [act: dta] Ruthie?*
*Ruthie: Well to make the shadow we moved the flashlight a little lower.*
*Meredith: Do you want to show me? [act: dta] (Ruthie comes to the front of the group and takes the flashlight from Meredith)*
*Ruthie: So you have it here (she holds the flashlight closer to the floor and to the right of the model)* (ecb.md2.teachvid.11/09)

Meredith then reinforces Ruthie's findings and signals her work was important while also highlighting the significance of the concept to the class by revoicing Ruthie's actions.

*Meredith: So it's in a different direction and it's down much lower cause at midday we had our flashlight like that (takes the flashlight and moves it higher and to the left) up here, in the morning we were down low and over here (moves flashlight back to the right, close to the floor). [revoice: dta]*

(ecb.md2.teachvid.11/09)

The science talk was concluded with Cieran demonstrating how to move the flashlight in an arch to represent the sun's apparent movement across the sky. Meredith then has the students draw diagrams and write an explanation describing the sun's apparent

movement. Specifically they are asked to write an explanation for how the flashlight was moving to make the three different shadows they had seen. She gives people the opportunity to use the model to clarify their thinking and scaffolds their writing by asking them to include what direction the flashlight was moving in, and what level they held the flashlight. The day's investigation is concluded with a return to the KLEW chart. They make claims on how to make short and long shadows in relation to where the flashlight is held as well as what shape the flashlight must be moved in to recreate the apparent movement of the sun. Meredith sets-up the next investigation by introducing a question on whether the sun actually moves or not.

The third and final investigation is a challenge for the students to determine which direction the Earth rotates by creating models of themselves using pipe cleaner people and attaching them to a globe on their home state of PA. A group member holds a flashlight still to represent the sun and the rest of the group rotated a globe to recreate how their shadows moved throughout the day. They needed to synthesize and rely on their previous two days' worth of data collection to complete this task. Meredith follows the same pattern of discourse strategies previously described; productive questioning while the students collected data and a mixture of productive questioning and talk moves while they are having a science talk. She prompted her students to rely on the data they had collected previously to inform their investigation by asking them to compare what they were seeing with what they had previously observed. This helped the students identify patterns between their past and current observations. When students tell Meredith they have completed the task she poses action question to have them show her what they know instead of simply telling her. And as previously she moves the students between small groups actively collecting data and whole

group science talks where they make claims about the scientific phenomena and support those claims with evidence from their investigation.

Meredith continued to not rely on declarative statements to indicate her students had explicated an accurate understanding but rather asked if they agreed with what was shared, revoiced their contributions, and added their ideas to the KLEW chart.

*Meredith: What did you find? [resn: dta] Which way did you turn the Earth? [recall: dta]*
*Ruthie: We turned it counterclockwise.*
*Meredith: What's another way to say that, we turned it to the …*
*Several Students at once: Right.*
*Meredith: To the right or counterclockwise. [revoice: dta] Did everyone experience that? Thumbs up if you agree. [ag/dsag: dta] So can we make a claim about that? [resn: evd clms]*
*Several Students: Yep.*
*Meredith: So we're pretty sure? [explt resn: evd clms] Do you agree? [ag/dsag: evd clms] (watches for nodding heads then writes on the KLEW chart and voices the claim) The Earth rotates counterclockwise (as she is doing this several students are saying the claim along with her). What can we use as our evidence for this? [explt resn: evd clms] What did you see happen so we know this is right? [explt resn: evd clms] Katia?*
*Katia: We taped a little person on where we live on a globe then we tuned it to the right and that was the way the shadow was going when we tried it outside.*
*Meredith: So when we turned the globe to the right the shadows moved to the right? [revoice: evd clms] Is that right?*
*Katia: Yeah.* (ecb.md3.teachvid.11/09)

To build on her students' understanding of the Earth's rotation, light and shadow Meredith shows them a video of the Earth from space. This confirms the patterns they have already seen and reinforces the claims they have made. A video at this point in an investigation is appropriate because her students have already interacted with the science phenomena, conducted investigations, collected data, identified patterns and made claims about what they have observed. They are not using the video to build their understanding but are rather confirming what they have already found.

As a final investigation the class used the globes and flashlights to move the pipe cleaner person through an entire 24-hour rotation of the Earth. Meredith prompted the

students to take notice of who is experiencing night time when it is daytime in Pennsylvania and used attention focusing and reasoning questions to help her students notice what occurs when the Earth rotates.

*Meredith: So what continents are you seeing? Ava are you watching this?[attn fcs: phenom]*
*Trinity: Mostly Canada and all the, well most of North and South America is having sunlight.*
*Meredith: And when you keep turning- (Trinity moves the flashlight) Is it the sun that moves? [recall: phenom] (Trinity moves back to where she was and Ava rotates the globe) What is happening to Pennsylvania when the Earth keeps turning?[attn fcs: phenom]*
(ecb.md3.teachvid.11/09)

When the group reconvened for their final science talk, Meredith asked them what they observed and gets input from several groups. She continues to revoice the patterns they described and finally asked the class to make a claim about they have learned.

*Meredith: What can we say, let's make a definitive clear statement hear, what causes day and night? [resn: expln] (few students raise their hands and Meredith waits six seconds) [wt tm: expln]] You all just did it so I should see all of your hands up. You all know it because you just did it on the globes. [prmt:expln] (Waits four more seconds)[wt tm: expln] Grayson.*
*Grayson: The turning of the Earth.*
*Meredith: Thank you! [dclr: expln] So I'm going to call that the rotation. If we were astronauts we would talk about the rotation but yeah the turning, spinning, rotation of the Earth. (she writes on the KLEW chart and revoices Grayson's claim) day and night is caused by Earth's rotation. [revoice: evd clms] And do we have evidence for that claim? [explt resn: evd clms]*
*Eddie: We tried it.* (ecb.md3.teachvid.11/09)

Meredith then urged Eddie to form a stronger claim by adding additional evidence to the KLEW chart other than, "We tried it". This is a shift from what Meredith accepted as appropriate evidence earlier in the teaching sequence which provides evidence that her initial science teaching experience has added to her understanding of the TSAF.

*Meredith: Yes we did try it but can you elaborate on that. [explt resn: evd clms] What did we see when we tried it? [recall: evd clms]*
*Eddie: Um we held the flashlight, then we turned the globe*
*Meredith: And so what happened to our pipe cleaner person? [explt resn: dta]*
*Eddie: It went from day to night when the Earth turned into the shadow.*

*Meredith: So our pipe cleaner experienced day and night. It experienced light and dark when we turned the globe (adds this to the KLEW chart). [revoice, dclr: evd clms]*

(ecb.md3.teachvid.11/09)

Meredith finished her teaching sequence by reading sections of a book on the rotation of the Earth. She paused to make connections between what the book said and what the class had experienced. As a final evaluation the students drew a picture of day and night from a global perspective and wrote an explanation for what causes day and night. Meredith scaffolded her students' written explanations by providing a word bank containing words they should include in their written explanations these were Sun, Earth, day, night, shadow, rotation, and axis. As she reads the word axis she realizes they have not discussed the term and so provides an on-the-spot demonstration using a globe from the student tables. The students are released to their tables to write their final explanations.

**Learning From Practice: Meredith's Self-Analysis.** Meredith's self-analysis is focused primarily on her students' ability to make accurate claims from evidence as well as how they crafted explanations for scientific phenomena. This is consistent with the TSAF which gives priority to evidence and explanation when communicating scientific findings. Other aspects of the framework included in Meredith's self-analysis are pursuing testable questions, interacting with the scientific phenomenon, making predictions, gathering data and forming evidence-based explanations.

Meredith uses science itself to engage her students in the lessons, she does not provide a "hook" but rather uses her students' interest in testing their predictions as a way to engage the class in her lessons. This example also points to her recognition of the importance of a guiding question to lead an investigation.

*At the start of the first lesson, I remind the students of the quickdraw activity I had them do a few weeks earlier. I use this as a jumping off point to discuss the big questions [ques] that we are going to be exploring as we work with [phenom] our shadows. The students are engaged because they are interested in seeing if their drawing predictions were accurate.*

(ecb.msavid.eng1.12/09)

April and Sarah consistently pushed for the interns to make connections between what they were seeing/doing and the scientific phenomena; there is evidence that Meredith recognized this pattern, applied it in her teaching and reflected on it in her self-analysis. She makes connections between student thinking and the investigations they have performed that lead them to be able to craft their claims.

*In this instance, two students are able to make claims [arg strc] about the change in shadows due to the change in the light's position. The second student explains [sts think] in detail how he saw long shadows when the light was low, and short shadows when the light was high, explaining that how the light hits your body effects (sic) the kind of shadow that will be made.*

(ecb.msavid.expn2.12/09)

Meredith not only references data collection but also discusses data as a way to encourage her students to think about their own reasoning.

*To test their understanding [sts lrn], I gave them a hypothetical situation that the wall clock was the sun, and asked them to point to where my shadow would be. They determined that it would fall to my diagonal left. To further ensure their understanding [sts lrn], I asked the rest of the class to look at the data [data] they had collected to determine if that statement was correct, and they agreed [ag/disag] that that was (cut off).*

(ecb.msavid.eval1.12/09)

Meredith also discusses how her students are able to form explanations based on evidence.

*A student provides evidence for the fact that the earth's rotation is the reason we experience day and night. He explains [arg strc] how when he rotated the globe to the right (the way we had determined the earth spins earlier in the lesson), the shadows of the pipe cleaner person changed, until (cut off) person was in a giant shadow of darkness, or night.*

(ecb.msavid.expn8.12/09)

And also discusses how those explanations help to lead into further discussion.

> *Her comments explaining [arg strc] how the earth's rotation is what causes those differences provides a great way into a conversation and activity on day and night.*
> (ecb.msavid.expn7.12/09)

In addition to providing evidence that she was able to make sense of her teaching practices using aspects of the Teaching Science as Argument framework Meredith also attends to student discourse and discussion, especially as a way to evaluate her students' understandings. In this example she points to discussion as a form of evaluation and how she used the discussion to learn about student thinking.

> *The evaluation [eval] for the first lesson was in the form of a science talk [sts talk]. I was listening to learn about the connections [sts think] the students had made about the sun's location in the sky, and the shadow that it makes. In this instance, a student made a claim [arg strc] that the sun is in the opposite direction of the shadow (making a kind of diagonal line).*
> (ecb.msavid.eval1.12/09)

> *Rounding out the science talk for the second lesson, a student is able to recall (with a little help from a classmate) that for the shadows to move in the direction, and size they do, the light source moves in an arc to the left. At the close of this science talk, I feel comfortable in moving on to the final lesson [eval], because my students have been able to talk about what they observed and make accurate claims [arg strc] about their experience.*
> (ecb.msavid.eval6.12/09)

Throughout her analysis Meredith is very attentive to her students' actions and discourse but has a tendency not to include her own actions in the discussion. Where I have identified her as using 58 separate talk moves, and 52 uses of productive questioning Meredith mentions her use of only two talk moves and never mentions her questioning throughout her entire analysis.

> *Here, a student makes a claim that the higher the sun, the shorter the shadow. I asked if that was something the class agreed upon [Talk Move], and they all did, unanimously.*
>
> (ecb.msavid.eval2.12/09)

This may be due to how the assignment was framed. The interns were charged to use StudioCode to create 5 separate stand-alone videos that showed their best examples of 1) how they engaged students with the key concepts of the lesson and how they assessed prior knowledge, 2) how they engaged students with collecting data, 3) how they got students to construct claims and support them with evidence 4) how they evaluated their students' understanding as well as 5) something that was unexpected, how they dealt with the incident and what they would revise if teaching this lesson again. The assignment does not specifically ask the interns to pay attention to student discourse nor their own use of discourse to co-construct science understanding. I had hypothesized that if the interns had a strong understanding of the affordances of structured discourse practices then they would have at least used their discursive choices as evidence of how they got students to construct claims and support them with evidence, but there is no evidence that Meredith did this. She uses talk moves and productive questioning strategies consistently and effectively to help students co-construct science understanding but does not include them in her best examples of how she scaffolded her students' abilities to form claims based on evidence. Rather she describes her students' actions and discourse choices when forming claims.

> *This clip shows a student explaining [arg strc] and demonstrating for the class. He is showing [sts act] how the light moves during the day to make the shadows change. He explains [arg strc] how he made the long morning shadow, how he changed the position, and direction of the flashlight to make a shorter noon shadow, and how he changed the position of the light again to make a longer afternoon shadow as he continued to move the flashlight to the left.*
>
> (ecb.msavid.expn4.12/09)

She also does not provide evidence that she made the connection between her discourse choices and her students' learning but rather focused on the physical act of data collection as the catalyst for their growing understandings.

> *Here, a student provides clear, and correct [sts lrn] evidence to prove that the earth rotates counterclockwise. She explains the activity that they completed, and comments on how when she turned the globe to the right, the shadows moved to the right, which matched the pattern they had observed [data] on the very first day of these lessons.*
>
> (ecb.msavid.expn6.12/09)

**What can be learned from Meredith?** Meredith is an example of a highly capable pre-service teacher. She seems extremely comfortable guiding her students' in the co-construction of meaning of scientific phenomenon using discursive tools and shows the beginnings of a deep understanding of why it is appropriate to push students to be a part of the sense making process.

Each science lesson was opened with a Wondering or Driving Question. This question served as a constant theme and provided authentic reasons for her students to perform an investigation. Meredith used these questions to guide data collection and representation as well as class discussions while making sense of their data. At the close of a lesson her students crafted written explanations addressing the day's Wondering. Meredith established a pattern of segueing her class from active data collection to discussion and sense making. When students were off task Meredith employed productive questioning; using a student's own thinking to redirect behavior. After students collect data and interact with the phenomenon, Meredith lead class discussions highlighting important aspects of the data in order to identify patterns used to make sense of the science concepts. During these discussions she focused her students' attention on the relevant data and revoiced her

students' contribution to the conversation. This not only ensured Meredith understood what her students intended to say but it also highlighted the importance of their contribution to the discussion and enabled other students to clearly hear the original idea. She encouraged students to compare evidence and to make predictions about what patterns they would see in the future. Meredith also pushed her students to think about their own reasoning in light of what other students contributed to the class discussions.

Instead of evaluating her students' responses Meredith added claims to the class KLEW chart and revoiced their ideas; visually emphasizing and highlighting the science concepts (Cazden & Beck, 2003). She used productive questioning to prompt her students to share current understandings and indicated that conceptions were accurate by asking them to explicate their reasonings by providing evidence to support their claims.

At the end of a lesson Meredith had her students craft written explanations answering specific questions in relation to the scientific phenomenon under investigation. She scaffolded their abilities to do so by providing word banks containing important terms as well as opportunities to redo parts of the investigation if needed.

In Meredith's self-analysis she provided evidence she was aware of and concerned about her students' thinking and sense-making in relation to the science concepts. She focused on student discussions, demonstrations and data collection as evidence of student learning. She also included discussion of several aspects of the Teaching Science as Argument Framework including pursuing testable questions, interacting with the scientific phenomenon, making predictions, gathering data, crafting claims based on evidence and forming evidence-based explanations. While Meredith's self-analysis did not include

evidence she reflected on her discourse choices or their role in student sense making this may be due to how the assignment was framed rather than a reflection of Meredith's thinking.

Meredith is an example of what pre-service elementary teachers are capable of achieving. She counters the predominant deficit model of elementary teacher preparation (S. K. Abell, 2006; V. Akerson et al., 2006; E. A. Davis et al., 2006; Smith & Anderson, 1999) and sheds light on what is possible when pre-service elementary teachers experience alignment in their methods and placement classrooms and are prepared to teach science in a comprehensive manner using a researched based framework.

**Part 2: Narrative Analysis of Hadley**

Hadley interned in a first grade classroom in a small semi-rural elementary school. Her mentor was an experienced teacher who taught science frequently though not regularly. Hadley struggles with some of the typical challenges faced by preservice elementary teachers (E. A. Davis et al., 2006); she is very concerned with classroom management and exerts great effort on it. She is also an example of someone who is very committed to using the constructs of the TSAF. She discusses her concerns and commitments during her lesson plan conferences and also in her self-analysis. She is purposefully working to make sense of the framework and its application in her classroom; at times her work looks seamless while at others her sense making is evident in her classroom discussions. Hadley is very mindful of the constructs of the framework and is an example of what it looks like when a preservice teacher is working very hard to make sense of the framework and integrate it into her teaching. Her lesson objectives are for students to understand what all insects have in common and how to safely investigate live insects.

**First Round Lesson Planning Conference.** Hadley and Sarah are meeting in Sarah's first grade classroom where the tables and chairs are even smaller than the ones in April's room but Sarah sits with the confidence of an experienced first grade teacher. Sarah is not Hadley's mentor teacher though Hadley is working with first graders. Hadley has chosen not to work in a planning group, and mentions that she, "just wants to get the work done." She does not waste any time starting the conference; referring to comments Sarah made on her subject matter knowledge paper Hadley begins, "So I feel like from your comments that I should just get rid of the whole section on the value of pests right?" she sounds defeated.

"I would throw it out because it's more of a values, social studies topic and not an inquiry based science topic, you wouldn't study cockroaches with that question either you would study something like bees." Sarah shifts her tone, "You want to think about the hands-on, minds-on stuff, the body part one is good observational data but you really want to think about where your kids can gather data. We want to make it as easy as possible for you to have a good inquiry based experience." Right away Sarah directs the conversation to what data the students will be collecting and what evidence they will be able to gather. She highlights the importance of the students experiencing science rather than being told about science while also supporting Hadley in her emerging practice.

Data & Evidence

Hadley still sounds uncertain as she asks, "So should I totally axe that section of my paper?"

"Um hmm"

Hadley gets to the heart of what is bothering her when she says "but then I would

have to write-up an entirely new section and do additional research?"

"No, you have good ideas to work with." Sarah reassures her while also focusing Hadley's attention on the importance of the science concepts, "The idea that all insects have similar parts is a Big Idea and you've got that in your paper."

Science Concepts

"You also said I had to do the investigation?"

"Yes," Sarah answers, "You don't ever want to do anything with your students you haven't done yourself so I want you to physically do the investigation on your own and write it up."

Hadley writes this in her science notebook then transitions to her lesson plans, "So the first lesson we will be looking at insect parts, like diagrams?"

Sarah recognizes that the use of insect diagrams will not allow the students to collect actual data and so suggests the use of live insects instead. "Well I think you can make it more inquiry based by looking at some live insects and asking what they have in common. How many students?" Sarah inquires.

"20" Hadley looks up as if counting an invisible class, "um yeah 20."

Sarah again highlights the importance of the students collecting, recording and representing data while also providing tips on the mechanics of the lesson. "So have five different insects and groups of four and have them observe, draw pictures and see what they all have in common and pass them around, use dead ones if you don't have access to live ones but you can get crickets and grasshoppers at Petco."

Data

Hadley looks very concerned, "How do I deal with kids who I know will freak out?"

Classroom management is a common concern for Hadley, one she will refer to often.

Sarah changes the character of the discussion from potential problems to thinking about the tone of the classroom and how to pre-manage behavioral issues. “Be proactive and talk about being a scientist and that scientists don't scream and scientists don't say eeew and you want to talk about that ahead of time.”

“I also thought I could pair them (the kids who freak) with people who don't have a problem.”

Sarah then changes the focus of the conversation to what Hadley should be doing during the investigations including emphasizing the need to listen to student discourse, “You want to make sure you are walking around when they are working because that's when you're going to be able to intervene if people are having problems and when you'll hear good wonderings and be able to say things like, "oh that's a good question, make sure to write that down.”

Mechanics & Management

Hadley demonstrates additional frustration when she says, “I've been struggling with how do you get questions and wonderings from your kids. My mentor admits to not being good at it and it's like pulling teeth in my class.”

“That's something I've struggled with too” comforts Sarah, “so you have to be able to integrate it into the conversation and question them along the way, it's not easy.” By saying this Sarah underscores the importance of questioning and discourse while also affirming to Hadley that the discursive

Listening to Students and Leading Discussion

processes of science are hard work.

"When we did the initial KWL chart, they were coming up with awesome things so I was thinking it would be easy but-"

Sarah interjects, "The problem with that chart is that you never get a chance to address their wonderings so you always have the same wonderings."

Data & Evidence

"Yeah like in the plant unit everyday they will say, 'I wonder if it will grow' and I say 'Well it is growing, what else do you wonder' and we never seem to get anywhere. When I teach my unit should I actually allot time to test their wonderings?"

Like April, Sarah stresses the importance of scaffolding student thinking during the investigation process, "If you have the opportunity and they are testable questions I think that would be great because we want to value what your students think and not just randomly collect ideas and not do anything with them. And I want you to turn in an actual KLEW chart you draft with your lesson plans because that will help you know the learning you want them to have and the evidence you want them to see and it will help you to remember to ask certain questions." By asking Hadley to turn in a draft KLEW chart Sarah is helping to scaffold Hadley's abilities to focus on the important science concepts during her teaching. Hadley is quickly writing this all down. Sarah then explicitly addresses what sort of evidence the students will be able to collect, "So for evidence," Sarah continues "you could put that they will see an insect has six legs and that they are always attached to the thorax. For the third lesson you want to think about how you could stop a cockroach and that could be your connection to pests, you could say, 'Look at

Student Thinking

these! These could come into your house! How do you think you could stop them?' and then you've got your wonderings. And you want to see if you can include their ideas in the tests."

"What if they say you could stop them by spraying insecticide?" queries Hadley.

"Well then you'd talk about how we're not allowed to spray in our school and you have to try to think about school friendly ways to stop them."

Hadley is looking over her notes, "So start with what insects have in common …"

"And while they're looking at what the insects have in common you might want to then ask what are the differences." Hadley had begun to ask a mechanics questions but Sarah transitions the focus to discourse and discusses specific questions Hadley could use.

"as far as the cockroach you could say ...?"

"'What kind of animal is this? How do you know? What else do you notice?' Messing around with, getting to know the cockroaches you could ask 'What do you think it eats?', 'Why do you think that?' I want you to think about some questions and what they will say and how could you turn that into them looking closer and it's all about getting them to learn more about the cockroach and think about what we did (in class) that day, maybe the cockroach isn't moving and you'll ask, 'Why did you think it isn't moving?' and they might say, 'I think it doesn't like the light' and you'll say, 'Well here's a box, how could you figure it out?' What were some of the things you were wondering during the cockroach investigation we did?"

Questioning

Hadley flips through her science notebook then replies, "I noticed the hard back and

wondered if they could flip themselves over."

"So you'll say, 'Let's flip them over, how do you think we could figure this out?'

The following talk sequence demonstrates Hadley's emerging commitment to students experience the practices of science like Sarah and April displayed in the methods course, "And I feel like if they don't have an activity or actual worksheet then it isn't a lesson but you seem to be saying that observations are fine?"

"So some people are not comfortable with that and you could say have them observe for five minutes and then gather them together and ask them what they noticed about the cockroaches legs and say, 'look at those legs, what do you think they can do with those legs?' and then go figure it out by saying, 'Come up with two to three things you think the cockroach can do with their legs' and I want you to come up with things you think your students will be interested in that would nicely lead into "How do you think we can stop them? You know they can climb so how to you think we could stop them?'"

Situated Learning

Hadley continues to write as a group of interns enters the room for their conference with Sarah.

**Second Round Lesson Planning Conference**. Hadley arrives late for the conference and seems flustered. "My first lesson is Discovering Insects" She tries to jump right into discussion about her lesson but Sarah has not yet had a chance to review her updated plans so Hadley retracts and says, "Well I'll let you scroll through it" She waits while Sarah briefly looks over the lesson plans.

When she is finished Sarah immediately focuses the conversation on science concepts and student thinking, “You want them to name two similarities and two differences, name the body parts, has a head, abdomen and thorax and where they are located and that they have six legs.”

Science Concepts

“We did an art project on Halloween and I had them make insects and made sure they put six legs but that was art not science.”

“Well you were setting the stage for them” Sarah says reassuringly.

For a previous assignment Hadley designed a podcast to teach her students about a wetlands ecosystem and pretended to be a caricature of a scientist to get her students interested in the subject “The hook is similar to what I did during the podcast but I don't know if they'll go nuts.” Again Hadley brings up her concerns of classroom management and Sarah uses this as a chance to discuss tone and being proactive rather than reactive when managing student behavior.

Mechanics & Management

“Well you have to be serious about it” Sarah affirms. “The first thing is going to be the whole group and you're going to show them the body parts first.”

“Yes, I was going to be explicit unless you want-”

Sarah jumps in “I would have them look first and then talk about it. The more you can get coming from them the better.” Sarah is again underscoring the importance of listening to students and using their ideas as starting catalysts for discussion. “At some point someone at the stations should start talking about the body parts and you can go from there. The heads should be easy but the thorax and abdomen are harder. After they've done two rotations you can have them talk about it then go back to the last one.” She then shifts the conversation to student data collection and

Listening to Students

representation, “Are you going to have recording sheets?”

“This is the first time they'll had experience with data unless they've had a very sciency kindergarten teacher.”

“So you don't need very advanced data collection, it can be drawings and compare the drawings from the first two stations with the ones with the last two to see what they've gotten from your discussion and that can be part of your evaluation. I always spend time talking about the differences between pictures and diagrams, either through modeling and or discussion or even you draw a picture that has the sun, and flowers, and then talk about what a scientific diagram is. Depending on how much time you have at each station you could give them signals like five minutes on just observing without picking up a pencil. Will you have an adult at each station?” Sarah usually has a number of parent volunteers and other helpers in her room.

“Maybe if there are parent volunteers” Hadley seems dubious.

“I think it's important to help them just focus on looking and observing and sharing and using magnifying glasses” Sarah asserts. “Now I know you have been worrying about the Wonderings, you might need to, to listen closely to what they are saying when they are looking at the insects.” Sarah brings up the need to listen to students again in order to assuage Hadley’s fears but also reinforce the need to use discourse to help students co-construct the meaning of what they are observing.

“I'm so focused on them saying, “‘I'm wondering ...’”

Sarah shakes her head “No they won't say that they'll say something like ‘I

Mechanics & Management

Listening to Students and Leading Discussion

see antenna' and you'll have to say 'Do you think all insects have antennae?' and the kids might say yes and another might say no and you can say 'Let's add that to our chart.'"

"So it doesn't have to come from them directly?" Hadley wonders.

"It's still coming from them but you are being the one to guide the discussion." Sarah then reminds Hadley of the science ideas the students should be learning and the evidence they will collect, "So what they learned would be the three parts of the insect bodies and your evidence is they saw it on this, they saw it on this, they saw it on this ..." Sarah points to invisible insects sitting on her hand.

Listening to Students and Leading Discussion

"This when we're focusing on the cockroaches and they are doing things similar to the first lesson but I want them to really think about the live animals and they can't let something silly get in the way."

"So you might want to say something like 'Students will practice handling live insects and use their self-control when working' in your lesson objectives and they've learned the body parts so you want them to identify-"

Mechanics & Management

"I want them to identify two to three behaviors like they hiss when you touch the cerci and climbing" Hadley interjects.

"I'd be specific about the two to three you want them to see" by having Hadley articulate what specific behaviors she wants her students to observe Sarah is helping Hadley to guide discussions around pertinent science concepts.

Student Learning

Hadley picks up her lesson plans and starts reading then points to the page, “This thing with the ice cubes and flashlight I have to do it because it says they like moist places but when I sprayed them with water they freaked out.”

“Was that for pest control?” Sarah asks.

“Yup”

“You may want to have a wet paper towel and dry towel and see which one they choose.”

“oh ok” Hadley makes notes in the margins of her plans.

“And you know your hook is the whole thing.” Sarah pretends she is holding a cockroach and showing it to a class of students. “’I've found this really interesting cockroach that you can't even find in Pennsylvania!’ like say, ‘My Professor friend from Madagascar sent them because he heard you were so interested in insects.’ Make them know it's a privilege to do this and …” She quickly scans Hadley’s lesson plans, “what kind of recording sheet will you use?”

“I want to make it simple with check-offs, yes or no.”

“So you want to have some specific experiments you want them to do like do they go to the wet paper towel or dry and you want to do it in two sessions. How could we use these materials to learn about the cockroaches and the recording sheet could be, ‘Which did your cockroach like the best?’” At this point Sarah is discussing issues of lesson mechanics but she is also encouraging Hadley to think about age appropriate ways to allow her students to accurately collect and record data. She is also having Hadley plan specific

Data and Mechanics & Management

pieces of evidence for her students to observe.

"and circle it?" Hadley asks as she draws circles in the air.

"and think about how much time they have in the environment and how long they should wait before recording and you have wet and dry …"

"hot and cold, light and dark"

"and you can have rough versus smooth and hot versus cold and well maybe it doesn't matter they could like both? Yup it looks like our time is running short."

Data and Mechanics & Management

The next group of interns enters the room. Sarah and Hadley agree they have more to discuss but since Hadley arrived late they have to schedule another time to meet. Their next meeting is set for during the week when I was unable to attend.

**Initial Science Teaching Experience.** Hadley introduces her lessons by putting on a set of dark glasses complete with a fake nose and mustache attached, she is wearing a large white shirt which she has written, "Professor Orvieto" on the left breast pocket. "Good Morning Class!" She announces in a high nasally voice. "We are scientists today boys and girls and my name is NOT Ms. Orvieto it is Professor Orvieto. And you all are going to be my assistant scientists today!" Her first graders think this is very funny and they all begin laughing. She asks her assistants for help setting up their KLEW chart but as she begins she takes off the glasses and the students question if she is still a scientist, she confirms that she is because she is still wearing her lab coat. She begins their discussion with an overview of what a KLEW chart is and how they are going to be using it. The first column is labeled, "What we Know about insects" the lack of the word "think" is an immediate difference in how Hadley uses the KLEW chart as compared to Meredith and Alex. A characteristic of

Hadley's teaching is that she pushes her students for information on how they know what they know, asking them to explicate their understanding but does not always provide them with the opportunity to interact with and observe the scientific phenomenon before doing so. She opens the class with a discussion of what the students know about insects, she urges them to think about their own reasoning in comparison to their classmates' reasoning and revoices their contributions while also using declarative statements and the I-R-E seqeunce to evaluate their input. Similar to Alex, Hadley seems to have a very specific response she is seeking from her students and is not open to discussing alternative ideas even when, as seen below, the children's alternative ideas are accurate conceptions as is the case here when Hadley is trying to get Caleb to say that mosquitoes bite people and he is saying that bees bite people.

*Hadley: Does anyone else know anything about insects? Oh I love all these hands. [clssrm mng:prdt]  Daniel what do you know about insects?[prmt:prdt]*
*Daniel: They have six legs.*
*Hadley: They have six legs. [revoice:prdt] How do you know that Daniel? [non-pro resn:prdt]*
*Daniel: um because … (nine seconds) [wt tm:prdt] I don't know.*
*Hadley: Ok would you like help from a friend? (Daniel nods) Ok does anyone know how, does anyone agree with Daniel? Who agrees with Daniel? [ag dsag:prdt] (several students raise their hands) That they have six legs? [revoice:prdt] (Hadley waits six seconds) [wt tm:prdct] Miah how do we know they have six legs? How do we know? [non-pro resn:prdt]*
*Miah: Because um some other bugs, other bugs sometimes have six legs but not spiders.*
*Hadley: Oh that's a good thought but I am going to hold onto what you said because I want to see if you can see the six legs on our insects today but that was a great thought. [ire:prdt] Does anyone else know anything about insects? Anyone else? Caleb? [prmt:prdt]*
*Caleb: Some bite.*
*Hadley: Some bite [revoice:prdt] oh that's a good one. [dclr:prdt] (writes on Know section of KLEW chart) Some bite, [revoice:prdt] what kind of insects bite us? [recall:prdt]*
*Caleb: Spiders-*
*Landon: Spiders aren't insects!*
*Hadley: Why aren't they insects? [non-pro resn:prdt]*
*Landon: They have eight legs.*
*Mia: and bees!*
*Hadley: Ah I'm going to go back to, what insects bite us? [recall:prdt]*
*Caleb: Beetles.*

*Hadley: Beetles bite us? What buzz in the summer? [recall:prdt]*
*Caleb: Bees.*
*Hadley: It begins with an M. Ma, Ma, Ma, [vocab:prdt]*
*Grayson: Mosquito!*
*Hadley: Mosquito! [revoice:prdt] Your friends helped you out there.*

(ecb.hd1.teachvid.11/09)

During this initial interaction Hadley expected her students to be able to give evidence supporting their ideas about insects. They struggled to do so, as seen when Daniel didn't know how he knew that insects had six legs. At this point they had not had any opportunities to observe insects or collect any sort of data yet Hadley was still pushing them to explicate their thinking. At such an early stage of a lesson it can be detrimental to students' willingness to participate if they are asked to explicate their thinking about a topic they have no way of knowing the answer to. When Hadley says, "What kind of insects bite us?" She is asking an open-ended question that can be interpreted as an invitation to brainstorm possible responses but she is looking for students to say, "mosquito" a very specific answer. By setting up a guessing game type scenario she is potentially shutting off her students willingness to continue to engage in conversation (Elstgeest, 2001).

Hadley then introduces a guiding question for the investigation. She is connecting to the teaching framework and setting the stage for subsequent class discussions as well as the formation of claims. Hadley takes the next five and a half minutes to tell her students how to use a magnifying glass as well as describing the differences between a drawing and a scientific diagram. She stresses that scientists look with their eyes but do not touch what they are looking at. During her lesson plan conferences with Sarah, Hadley expressed concern over her students "freaking out" and "going nuts" she continues to be very concerned with classroom management and seems to be trying to ensure everything will go

smoothly. After about 2 minutes of her oral instructions several students begin to have trouble sitting still, and start rocking back and forth, pulling at the carpet and wiggling their legs Hadley stops talking several times to tell students to sit, "on their bottoms". She is ten and half minutes into her lesson before she dismisses the students to their work stations.

Once the students have dispersed to their work stations Hadley begins circulating throughout the room, moving from group to group asking her students attention-focusing questions and trying to see if they know they names of the parts of the insects. She revoices and evaluates her students' responses as well as prompts them for participation.

*Hadley: So did everyone notice that the wings are on top? Right?[attn fcs:phenom]*
*Addie: uh huh.*
*Hadley: What else is up here? [attn fcs: phenom] (She points to the insect's head)*
*Addie: It's eyes and-*
*Hadley: What is this part?[attn fcs: phenom]*
*Brandon: Don't touch, don't touch!*
*Hadley: I'm not touching.*
*Addie: The antenna.*
*Hadley: Great science word, the antenna! [dclr,vocab:phenom] Brandon is there anything else you noticed?*
*Brandon: His, his these (points to insect's back) are closed.*
*Hadley: His wings are closed (uses arms to mime a flying motion). [revoice:phenom] Good, good. [dclr:phenom]*

(ecb.hd1.teachvid.11/09)

Hadley works to help her students recognize how many legs their specimens have. She uses attention-focusing and measuring/counting questions while revoicing student ideas demonstrating that she is now open to discussing her students' observations and engaging in the investigation with them.

*Hadley: How are we doing guys?*
*Tasha: That's the question, I can't see how many legs he has.*
*Hadley: You can't see how many legs they have? Ok well you know what I'm going to turn one over, I'm going to hold one for you. (She gently picks up the insect) How many legs do you see?[msr cnt: phenom]*
*Tasha: (without looking at the insect) Six?*
*Hadley: Do you see this? [attn fcs: phenom]*

*Tasha: (leaning in to closely look) Four?*
*Hadley: You see four? [clr, revoice:phenom]*
*Dylan: See right there? (He points to the specimen)*
*Hadley: Oh there IS two right there! Do you see how Dylan noticed that? There is two little short ones right there and then there is four long ones right here.*

(ecb.hd1.teachvid.11/09)

Even though Hadley has expressed concerns over student Wonderings she is able to productively negotiate this challenge during her initial lesson. She uses attention-focusing, actions and comparison questions to push her students' thinking on the observations and claims they are making. Todd shares what he has noticed and Hadley asks him to explicate his thinking she then follows his line of reasoning while revoicing his contributions and pushes him to think about his thinking as well as to make connections to evidence in support of his reasoning. She also urges her students to think about their own reasoning in comparison to their classmates' by drawing comparisons between evidence the two boys have shared.

**Figure 6.2**: First grade student's diagrams of insects


*Hadley: (She joins a group observing a specimen of a bee) What are we seeing here? (Several students start sharing their observations at once and it is difficult to discern what they are saying) Oh one at a time let's have Todd go first. [clsrm mng:phenom]*
*Todd: See right there (he points to the bee) that's where the sucker's coming out (he mimes a large tongue coming out of his mouth).*
*Hadley: Really? How do you know that? [non-pro resn:evd clms]*
*Sean: Magic School Bus told me that.*
*Hadley: You saw that on Magic School bus [revoice:evd clms] but you (points to Todd) saw a bee do it?[ag dsag:evd clms]*
*Todd: Yeah uh huh to a flower.*
*Hadley: To a flower? [revoice:evd clms] That's where it sucks the pollen out? Thank you for sharing that. [ire:evd clms]*
*Sean: I see the antenna.*
*Hadley: You do? Can you point to them? [act:phenom] (Sean uses his pencil to identify the antenna) What do you think they do with their antenna? [resn:prdct]*

*Todd: They feel with them like this (uses fingers to mime wiggly antenna coming off of his head).*
*Hadley: Do we know that? That they definitely feel with their antenna? [non-pro resn:evd clms]*
*Sean: Yeah.*
*Hadley: Are you sure? [explt resn:evd clms]*
*Sean: Yeah!*
*Hadley: Do we have any evidence to back it up? [explt resn:evd clms]*
*Sean: Yes.*
*Hadley: What is it?[explt resn:evd clms]*
*Sean: Magic School Bus.*
*Hadley: You saw it on the Magic School Bus. [revoice:evd clms] How about with your eyes? Have we seen it with our eyes?[explt resn:evd clms]*
*Sean: (nods head yes) I saw a bee and he was like feeling the grass.*
*Hadley: It was feeling the grass? [revoice:evd clms] How did you know the bee was feeling? What if it was smelling? [explt resn:evd clms]*
*Sean: Well they smell with their antenna too.*
*Hadley: They smell and feel? What a great Wondering. Isn't that a good Wondering, 'What do they do with their antenna?' [klew:tstble qst]*
*Sean: I know they feel with their antenna but I'm not sure about smelling.*
*Hadley: So you're not sure. Let's put that on our Wonderings chart. [klew:tstble qst]*
(ecb.hd1.teachvid.11/09)

Once the students have made their initial observations and have drawn detailed diagrams of the insect specimens Hadley gathers them on the carpet to discuss their data. She begins by asking the students to share one thing they noticed during the station exploration as the students are sharing she makes connections to Wonderings she has heard while visiting the groups. She revoices a question Grayson had while at the stations and asks a reasoning question to determine how they know if a butterfly is a male or female. She then asks Grayson to explicate his thinking by providing evidence to support his reasoning and pushes him think about alternative forms of evidence other than the observations they have made and finishes with a declarative statement evaluating his response.

*Hadley: I want to share another Wondering we had. Who had the Wondering, 'How do we know if it's a boy or a girl?' [revoice:tstble qst] This came up at the butterfly station. How do we know if it's a boy or a girl Grayson?[prmt:expln]*
*Grayson: A boy has two dots by the bottom of the wings on the flat part.*
*Hadley: uhm hmm what about a girl?[prmt:expln]*

*Grayson: It would have (5 second pause) [wt tm:expln] one?*
*Hadley: It would have one? [revoice:expln] You didn't sound too sure there, do you think we need some more evidence to make that claim? How do you think we could get that? [act:evd clms]*
*Grayson: On the computer?*
*Hadley: What a great suggestion! [dclr:evd clms] The computer is a great resource to help us find out more about our insects. Good suggestion. [ire:evd clms]*
(ecb.hd1.teachvid.11/09)

Hadley then transitions the discussion so they are focused on what they learned during the observation. A student shares that he saw an insect's head and legs. Hadley recognizes that during their earlier discussion the idea that insects had six legs had come up and that the students did not have any evidence to back up their ideas. She takes what the student shared and uses it as a segue into a discussion about how many legs all insects have. Hadley revoices ideas her students shared about insect body parts and makes connections between their observations and learning from evidence by pushing the students to explicate their thinking.

*Hadley: You said two important words, head and legs. What do we know about, about insect legs after looking at the two insects that you looked at? [attn fcs:dta] What do we definitely know about these legs Sam?[klew:evd clms]*
*Samantha: They have six.*
*Hadley: They have six! [revoice:evd clms] How do we know that? How did you find out they have six legs?[explt resn:evd clms]*
*Samantha: I counted them.*
*Hadley: You counted them, [revoice:evd clms] you looked at them right. You looked with your own two eyes (She adds, "insects have six legs" to the learning section of the KLEW chart).* (ecb.hd1.teachvid.11/09)

During the lesson plan conferences Sarah had told Hadley to listen for what her students say and to use their ideas to guide the discussion. One of the learning goals Hadley had for the first day's lesson was for her students to know that insects have six legs and that they have three body parts. During the observation time one of her students brought up the head, thorax and abdomen; Hadley uses this as an opening to discuss the parts of an insect

and asks the student to explain what the head, thorax and abdomen are. She also uses attention-focusing questions to encourage the other students to think about their own observations. She interrupts her own thought process to ask a student to sit down. Throughout Hadley's teaching she often intersperses her discussion with explicit statements to manage her students' behavior. Classroom management is a concern for Hadley as seen when she worried about her students "freaking out" over live insects.

*Hadley: I want to come back to something that Sean said during the centers. Sean you said-Hannah can I have you sitting crisscross and looking up here. Thank you. [clssrm mng] Sean what did you say about the head (she points to her head)? [prmt:dta]*
*Sean: The head (points to his head), thorax and abdomen.*
*Hadley: What do those big words mean?[vocab:expln]*
*Sean: Head is their head (points to his head). Thorax is kind of their neck (points to upper chest). Abdomen is their belly (points to his stomach).*
*Hadley: Wow what a great explanation! [dclr:expl] Did anyone else notice that the insects have three parts? (several students raise their hands) [ag dsag:dta]*

(ecb.hd1.teachvid.11/09)

She teaches them a song with hand motions highlighting the words head, thorax and abdomen as a way to remember the vocabulary. She will use this song the next day to help her students remember the body parts during their observations of live cockroaches. After the students perform the song they are dismissed back to the centers and are allowed to observe the remaining specimens. During this time Hadley continues to use attention-focusing questions but she also includes several measuring and counting questions to help her students pay attention to how many legs and body parts each specimen has.

The next day Hadley begins the second lesson by asking her students to remind her what they did the day before in science. The students tell her they looked at "dead bugs". She then asks them what bugs they looked at and reminds them that she is "Professor Orvieto" and that they are her assistant scientists. She has filled in part of the Know section of the KLEW chart and tells the class she knows that cockroaches can sometimes get in their

house. She then opens up the discussion by asking if anyone else knows anything about cockroaches. This discussion follows the same format as the previous lesson where Hadley asks the students what they know about cockroaches then presses them on how they know before providing them with the opportunity to gather any evidence. She only adds information to the KLEW chart after students can confirm they are sure about the information they have shared, this is not in line with the scaffolding provided by the KLEW chart as way to document prior knowledge map students' changing thinking during an investigation (Zembal-Saul et al., 2013). But this is evidence that she is trying to make sense of and use the scaffolds provided by the KLEW chart. During this discussion she stops several times to tell students to sit on their bottoms, put their pencils down and to raise their hands. She does not do this during the actual investigations; it seems like she feels more comfortable interacting with small groups for a focused purpose rather than leading a whole class discussion where she may not be able to predict the outcome.

The focus of this lesson is observing live cockroaches. Students express fear at the idea of live cockroaches and Hadley picks one up to show them, "How not scared Professor Orvieto is" of the cockroaches and to get the students' used to being around live specimens. She remains very calm, quiet and focused during this time, patting the insect's back as she tells the class where she obtained the cockroaches and why it is special for them to be able to observe them. She shows the students how to properly touch a live cockroach as well as her expectation for them to draw diagrams of the cockroaches instead of drawings. She also scaffolds their ability to label their diagrams by giving them a list of terms to use as labels; the terms are legs, head, abdomen, thorax and antenna. These are the same features the

students observed on the various insect specimens during the first lesson and they are now applying what they previously learned to the cockroaches.

When the students begin their investigation of the cockroaches Hadley moves around the room asking the students attention-focusing questions then typically following-up with reasoning and action questions as well as asking the students to explicate their reasoning about what they think a feature is for and why they think this way while revoicing their ideas. Every so often her interaction with the students is interrupted by abrupt bursts of loud squealing when one of the cockroaches attempts to escape its container but she remains calm and in control the entire time.

*Hadley: What are we seeing over here? [attn fcs:phenom]*
*Lisa: I did my drawing.*
*Hadley: You did? So what do you think these are? (She points to the cerci) [attn fcs:phenom]*
*Lisa: I don't know I just saw them and drew them.*
*Hadley: What happens when I touch them? (She touches the cerci) [act:phenom]*
*Lisa: Whoa get away from me!*
*Mia: Ah Aaah! (jumps away from the table when the cockroach hisses)*
*Hadley: It's ok, it's ok. What happens when I touch those?[attn fcs:phenom]*
*Sean: He doesn't like it!*
*Hadley: What happens? What does he do?[attn fcs:[phenom]*
*Lisa: He doesn't like it and he hisses.*
*Hadley: So what do think they're for? (points at the cerci again) [resn:phenom]*
(ecb.hd2.teachvid.11/09)

When the group gathers on the carpet to discuss their observations and fill in more of their KLEW chart Hadley uses what the students have said to introduce and expand upon science concepts. She revoices ideas her students have shared, pushes them to explicate their reasoning and focuses their attention on their observations while getting her students to apply their own reasoning to someone else's reasoning.

*Hadley: Kaden came up with a great Wondering, what are the spikes on their legs for?[revoice:tstbl qst] Who else noticed the spikes on the legs? [attn fcs:dta] (the entire class raises their hands) What do you think they could be for? [resn:dta] Andy?*

*Andy: Well if another animal tries to eat it, it could use them to try to hurt it.*
*Hadley: To try to hurt it, [revoice:evd clms] that's what Kaden thought too. Kaden thought, what did you think buddy that they could be used to killed its prey? [revoice:evd clms]*
*Kaden: uh huh.*
*Hadley: What did you notice about them in the box?[attn fcs:phenom]*
*Isaac: They were really active.*
*Hadley: They were really active. [revoice:dta] When you say active what do you mean? [explt resn:dta]*
*Isaac: Fast!*

(ecb.hd2.teachvid.11/09)

Hadley then demonstrates that she wants the class to think about how the cockroaches climbed out of the box and she scaffolds their prediction about what the spikes on a cockroach's legs could be for. She makes a connection to the teaching framework by urging her students to test their ideas about why the cockroach could have spikes on its legs.

The class then makes predictions on why they think the cockroaches hiss and come up with the claim that cockroaches use their hissing to scare other animals, the evidence the students used is that the hisses scared them. Hadley adds this information to the KLEW chart. She has recorded several Wonderings on the chart and addresses one next. She revoices an idea shared by one of her students and focuses the students' attention on the cockroaches' abdomen while using a student diagram to demonstrate where the class should be looking. She also prompts students for participation asks her students to explicate their thinking to come to a testable question the students can pursue at their work stations.

*Hadley: What about this Wondering (points to KLEW chart) What do the ends of the abdomen do? I'm going to show you this, right here (points to cerci) Tasha noticed this. Look at her diagram, [ntbk:dta] do you see these little ends on its bottom, err on its abdomen? [attn fcs:dta] (several students nod and/or say yes) What do you think they're there for?[resn:prdct]*
*Todd: They're to sting!*
*Hadley: To sting. [revoice:evd clms] Does anyone else have any other ideas? [prmt:prdct] Estelle?*
*Estelle: (unintelligible) hurt it.*
*Hadley: Hurt it, they could try to hurt it. [revoice:prdct] Natalie what do you think? [prmt:prdct]*

*Natalie: Maybe like if they wanted to eat they could pick it up with that and eat it off the ground.*
*Hadley: Ok I'm going to touch it and I want you guys to see what it's going to do. (holds cockroach in palm of left hand and touches the cerci with her right hand) What did it do? [attn fcs:phenom] (several students say "hiss") What else did it do? [attn fcs:phenom] (several students in unison say "move") If you think, if you touch that do you think it's going to move all the time? [resn:prdct] (at the same time some students say "no" while others say "yes"). How 'bout we test that. [prb pos:tstble qst]*

(ecb.hd2.teachvid.11/09)

The next part of the lesson involves the students testing different factors to see if the cockroaches like them or not in order to figure out what kind of environment that cockroaches prefer. The variables are warm versus cold, and wet versus dry. Hadley asks the class to predict which variable the cockroaches will prefer and they discuss what it would look like if a cockroach liked something and what it would look like if a cockroach did not like something. The class is then dismissed to their centers and the room becomes very loud. Soon it becomes clear to Hadley that the students do not know how to perform a comparison investigation on their own and there is a need for her to guide what they are doing. She announces to the class that they are "switching things up" and for them to return to the carpet with all of their materials.

Hadley and the students sit in a circle on the carpet. Hadley has gathered the materials she needs for the whole class investigation and they are arrayed in front of her. She asks the class once again to predict if the cockroach would like sitting on a hot pad or a sheet of ice in a Ziploc bag. Their predictions are mixed. She carefully places a cockroach on the Ziploc bag and it immediately scurries onto the carpet. Hadley scoops it up and asks the class what happened and if they think that means the cockroach liked the cold. They conclude it didn't like the cold but go on to test whether it likes sitting on the heating pad. When placed on the warm pad the cockroach does not move. The students think this means

that cockroaches like warm and not cold but Hadley wants them to do the tests again using another cockroach to see if they get the same results. They retest and see the same pattern. She asks her students to think about what they saw and to reason about why she had them test more than one cockroach as well as what they could do to make a definite claim.

*Hadley: Now that we did two experiments with two different cockroaches do you think that makes our claim stronger or weaker? [resn:arg strc] That it likes warm? (several say stronger) Why does it make it stronger? [resn:arg strc] Natalie?*
*Natalie: If only one cockroach likes it we can't know for sure. Cause if one cockroach likes warm, and others like warm and cold, they might not all like the same thing.*
*Hadley: Good, good. [dclr:arg strc] So if we had time to do all of these cockroaches and they all liked warm we could definitely say that cockroaches like warm better than cold right? [resn:arg strc]*

(ecb.hd2.teachvid.11/09)

**Figure 6.3**: Investigation to determine a cockroach's preferred environment.

Hadley brings out a paper towel half soaked with water. She asks the students what they think they are going to test next based on what they see. The students think they are going to test whether the cockroaches like it wet or not wet. Hadley asks the students who has a prediction for what the cockroach will prefer; their predictions are split between wet and dry with some saying both. The first cockroach they test scurries off of both the wet and the dry paper towels and the students think this is very funny and think it means it likes Hadley's hand. She brings out another cockroach and places it on the wet part of the paper towel and it doesn't move. She then places it on the dry paper towel and it doesn't move again. The students say it likes both wet and dry. The third cockroach also seems to equally like the wet and dry paper towels. Hadley asks her students to make a claim about what they have seen but they are not familiar with the term so she asks for input from class members who seem equally perplexed as evidenced by the long

stretches of wait time between her questions prompting students for participation. She revoices student ideas and urges them to think about the parts of the KLEW chart making connections between what questions she asks them and what they have recorded on the chart. Throughout this discussion she is demonstrating a commitment to the Teaching Science as Argument framework; having her students make sense of the science concepts by forming claims supported by evidence.

*Hadley: Who can make a claim about whether a cockroach likes wet or dry? Who can make a claim with their hands raised? [prmpt, clssrm mng: evd clms] Tasha?*
*Tasha: What's a claim?*
*Hadley: Oh that's a good question! [dclr] What is a claim? Daniel do you know what a claim means? [recall:evd clms]*
*Daniel: Um … what you think?*
*Hadley: What you think. [revoice:evd clms] Based on what? [explt resn:evd clms] (six second pause) [wt tm:evd clms] Every times you guys make a statement what's the next question I ask? [recall:ebd clms]*
*Sean: Are you sure.*
*Hadley: Are you sure [revoice:evd clms] or how do you know. So we can make a statement but then what do we have to do? [resn:evd clms] (five second pause) [wt tm:evd clms] What do we have to do? [resn:evd clms] (five second pause) [wt tm: evd clms] Do we have to say how we know? [recall:evd clms] (seven second pause). [wt tm:evd clms] OK when we say (points to KLEW chart) right here, what we learned about something what is the arrow pointing to? [recall:evd clms]*
*Isaac: It's pointing to the right. It's pointing to words (inaudible)*
*Hadley: But what's the difference? How do we know? [non-pro resn:evd clms] What's this? Evidence right. We need to have evidence to support our claim. [declr:evd clms] So what did we see between the wet and the dry? [recall:dta] Can we make a claim, can we make a claim based on what we saw Owen?[prmt:evd clms]*
*Owen: Two of them liked both of them.*
*Hadley: Two of them liked both of them, [revoice:evd clms] so what's our claim, that cockroaches …. [prmt:evd clms]*
*Owen: Like wet and dry.*
*Hadley: Like wet and dry [revoice:evd clms] good [dclr:evd clms]and how do we know that? How do we know that they liked wet and dry? [explt resn:evd clms] Brandon?*
*Brandon: We tested it.*
*Hadley: We tested it! [revoice,dclr:evd clms]*

(ecb.hd2.teachvid.11/09)

Hadley finishes the lesson by reviewing what they observed and walking the students through recording their claims in their science notebooks.

Hadley begins her final day of teaching by comparing cockroaches to raccoons. Earlier in the day the class had talked about how raccoons can be pests when they get into trash cans or houses and she makes the bridge that cockroaches can also be pests if they enter a home. The group reviews what they learned the previous day making connections to cockroaches preferred environments based on evidence from their previous investigations. This is a very fruitful discussion; the students have had two days to interact with and observe insects and when Hadley asks them if they are sure about something or when she pushes them on how they know something the students are able to provide evidence from their previous investigations. The students have also developed a comfort level with the cockroaches that they did not have at the beginning of the previous day. Hadley holds a roach on her hand and walks around allowing the students to touch the cockroach and most of them do. This is a very calm time no one screams or seems agitated. As the students touch the cockroach Hadley asks them to describe what the cockroach feels like. She uses their descriptive words to discuss the idea of a hard exoskeleton.

Hadley then returns to the notion of cockroaches being pests and challenges the students to think about the cockroach's physical characteristics to determine an effective method of stopping them from entering a home. She displays different materials for the students to test while they investigate different methods of stopping cockroaches from moving. They begin in a large group so Hadley can scaffold their abilities to perform the investigation. The group will test salt, water, tape, hand sanitizer, canned cat food and wooden blocks. Prior to performing any investigations Hadley asks the class for their

predictions, revoices their ideas and asks them to explicate their reasoning behind their predictions she also makes connections to evidence they collected the previous day. Hadley reminds the class that touching the cerci will usually make a cockroach move. She asks for a volunteer to use the eraser end of a pencil to touch the cerci and make the cockroach walk across a piece of double sided tape. Unfortunately the cockroach they are testing doesn't mind if its cerci are touched and it will not walk forward so Hadley picks it up and places in on the tape. The cockroach's feet stick to the tape but it is able to pick up its feet and move off the tape. Since this evidence is not definitive Hadley engages the class in a discussion about the need to gather additional evidence. She chooses two students who disagree about whether they need to gather more evidence and asks them to explicate their reasoning. She revoices the students' ideas and engages them in a basic form of argumentation then makes a connection to the teaching framework by suggesting they perform additional tests.

*Hadley: Can we say for sure that the cockroach was stopped by the tape? [resn:evd clms] (a chorus of no and yes in heard from the class) Some say yes and some say no. Who's saying yes raise your hand. [ag dsag:evd clms] Audrey why do you say yes? [explt resn:evd clms]*
*Audrey: Because he was having a harder time getting off.*
*Hadley: He was he was having a harder time getting off. [revoice:dta] Who says no that it doesn't stop? Cole why?[explt resn:ebd clms]*
*Cole: Because he was able to get through it.*
*Hadley: He was able to get through. [revoice:dta] So boys and girls do you think we could test another cockroach and see if we wanted to. [resn:arg strc]*

(ecb.hd3.teachvid.11/09)

The class discusses testing a smaller cockroach as well as the idea that the large cockroach did not like staying on the tape. They conclude that tape might work depending on the size of the cockroach. Spraying water on a cockroach does not stop it from moving, as evidence to support why this might be Hadley draws the connection between what they found the previous day when determining a cockroach's preferred environment and how some cockroaches like it wet. When a cockroach is placed on a small pile of salt it initially sits still

seemingly tasting the salt but then scoots onto the carpet. The students are not sure to make of this and make an initial claim that salt may be able to stop a cockroach. Hadley pushes them test another and it immediately runs off of the salt. This leads to a discussion of what it means to "stop" a cockroach. There are differing opinions but it is finally concluded that neither the tape, water or salt actually stopped the cockroaches from moving.

Using their new understanding of "stopping" Hadley challenges the students to investigate whether hand sanitizer, canned cat food or wooden blocks are able to stop a cockroach from moving. She divides the class into three groups; each assigned one variable to test. The following example comes from the groups testing whether cat food is an effecting way to stop a cockroach. Hadley asks the students for predictions, revoices their ideas and asks them to explicate their reasoning, she then asks for alternative predictions and continues to push for her students to share their reasoning around what they observe while focusing their attention on the investigation.

*Hadley: Tasha would like to go first with the cat food. What do you think will happen?[prmt:prdt]*
*Tasha: He won't like it.*
*Hadley: He won't like it, [revoice:prdt] why do you think that Tasha? [explt resn:prdt]*
*Tasha: Because it's wet.*
*Hadley: Because it's wet [revoice:prdt] and some cockroaches like … [prmt:evd clms]*
*Tasha: wet and dry.*
*Hadley: like dry. [revoice:evd clms] Does anyone else have a different prediction besides Tasha?[prmt:prdt]*
*Cole: I have no idea!*
*Hadley: You have no idea, [revoice:prdt] so you just want to test it and see what happens. Are you ready Tasha? (Tasha reaches out her hand and Hadley places a large cockroach on her palm)*
*Mia: He's stuck.*
*Tasha: I was wrong. I feel like I'm wrong (the cockroach is not moving).*
*Hadley: Is he stuck? [attn fcs:phenom] (reaches in to move the cockroach)*
*Tasha: No, I don't (inaudible).*
*Hadley: Can he move? [attn fcs:phenom]*
*Tasha: No.*
*Audrey: Not really.*

*Kaden: It's like being trapped in a mud pile.*
*Audrey: Yeah.*
*Hadley: It's like it's getting trapped in a mud pile hmmm. [revoice:expln]*
*Tasha: It's like your being trapped in a mouse trap but you're not slamming it.*
*Kaden: Oh you mean a mouse trap like-*
*Hadley: What are you guys seeing here? What's happening?[attn fcs:phenom]*
*Tasha: I think he likes it.*
*Cole: No he's stuck!*
*Hadley: Can he move? What's getting on his legs? [attn fcs:phenom]*
*Kaden: Cat food!*
*Hadley: Is that stopping him from moving? (a few students say yes) [resn:phenom] You think? What do you think we could put for did it stop the cockroach? [resn:evd clms] I need eyes up here. I need you to sit. [clssrm mng] Did it stop the cockroach? (almost entire group says yes) [attn fcs:evd clms] How did it stop the cockroach? Kaden how did it stop the cockroach?[explt resn:evd clms]*
*Kaden: It got cat food on it.*
*Hadley: Cause he got cat food on him and it stuck to his legs. [revoice:evd clms]*
(ecb.hd3.teachvid.11/09)

By the end of the day the class is able to claim that only the cat food really stopped the cockroach. The hand sanitizer made it not move very fast but still able to advance and the wooden block trap the students made proved to not be even a slight impediment.

**Learning from Practice: Hadley's Self-Analysis.** Hadley's self-analysis provides evidence that she is concerned with and thinks about her student's thinking and sense-making. She discusses many aspects of the teaching framework including pursuing testable questions, forming claims based on evidence, collecting data and reasoning publically. She also explicitly discusses classroom management and keeping her students "on track". This is consistent with a challenge often faced by preservice teachers (Eick, 2002) but unique in the work of my three participants. Hadley's self-analysis is also unique in that she uses student quotations as evidence for her reflections on her practice.

Hadley begins her analysis with a discussion of her "hook" and how she wanted her students to be "interested" and make sure her lesson was "fun and exciting". The desire for fun science lessons is common of preservice elementary teachers (S. Abell et al., 1998).

> *I selected this clip for engagement because I grabbed their attention with an interesting hook. I dressed up like a professor and really tried to set the tone for science. I thought this was necessary, especially because we did we did not have a lot of science instruction before this lesson and I wanted to make them aware that they had a fun and exciting [sts int] science lesson ahead of them.*
>
> (ecb.hsavid.eng1.12/09)

Her concern over classroom management is seen in her talk with Sarah during their lesson plan conferences as well as how she often interrupts her own discussions while teaching to tell a student to raise their hand or sit on their "bottom". She explicitly addresses this concern in her analysis of her practice when she used "on-task behavior" as evidence of an engaging lesson.

> *I selected this clip for engagement because I was very impressed with how focused and on-task the students [cls mngt] were on my first day of science, especially because this lesson dealt with dead insects, not live ones. The students are all intently observing, diagramming and labeling to the best of their abilities, I consider on-task behavior as evidence of an engaging lesson.*
>
> (ecb.hsavid.eng2.12/09)

Hadley discusses classroom management and student behavior four additional times in her self-analysis.

Though attending to student thinking and areas of potential difficulty is often overlooked by preservice teachers (Zembal-Saul et al., 2000) Hadley demonstrates she is concerned with what her students are thinking and how they are making sense of the science concepts. Here she is demonstrating that she is attending to student talk and student thinking as she makes sense of her own practice.

> *I found this part of the lesson to be engaging for students because they are sustaining a science talk on their own [sts talk]. They are coming up with questions and wonderings on their own, without any prompting. For first grade this is impressing and it takes the students' true engagement for this to occur. In the particular instance, the boys are conversing abut (sic) the cricket bones. They try to explain their thinking to the young lady but she is questioning their thinking [sts think]. That's so encouraging for a teacher to see children questioning others thinking and not just taking it at face value.*
>
> (ecb.hsavid.eng4.12/09)

Hadley is the only participant to use quotations from student talk as evidence for the claims she is making about her own teaching. This serves as additional evidence that she is attending to student talk and aware of its importance in sense-making.

> *For this instance, students are freely exploring the phenomenon [phenom] that insects have bones, sometimes on the outside of their body. "The bones will come out if you do that!" one student exclaimed [sts talk]. This generated interest and one student wondered if they had bones. The male student is explaining the hard shell on the outside was it's (sic) bones.*
>
> (ecb.hsavid.expl3.12/09)

Important aspects of the Teaching Science as Argument framework Hadley includes in her self-analysis are interacting with the scientific phenomenon (as seen above), designing fair test, collecting data, making predictions, and coordinating claims with evidence.

She discusses collecting data at two different times in her analysis; as evidence her students were actively exploring the science phenomenon, and as an evaluation tool of her students' understanding. In the following example she uses data collection as evidence that her students are exploring the science phenomenon, she also discusses why she made this pedagogical choice.

> *I chose this clip as explore because they are collecting data [data] (how many legs the caddis fly has), inquiring more and observing closely to try and find out the answers to their inquiries. I am providing them a closer opportunity to the caddis fly in order for them to discover that it does have six legs, not four.*
>
> (ecb.hsavid.expl1.12/09)

In the following examples, Hadley describes data collected by her students and discusses how she used this data as an evaluation tool. She was also making connections between prior knowledge and what the students have learned in their investigations.

> *These were two students (sic) diagrams of the insects they were observing (I believe it was the caddis fly). Students were using their prior knowledge and the information they learned in this lesson to label their diagram accurately. It also showed me that these students were on task and interested in the assignment. They were very particular about where their labels were placed. It was rewarding to see students apply their science knowledge into a measurable piece of data [data].*
>
> (ecb.hsavid.eval1.12/09)

> *This is a great comparison between two diagrams. I made sure to share my expectation for diagrams before we began. They were not cartoons; they were serious scientific drawings that were detailed and had labels [data]. The first one here is not labeled and has minimal detail. The second one is much more detailed with several labels. If I were to grade these [eval], the first one would not have met expectations. I may have to restate them to the class if I saw more diagrams like this.*
>
> (ecb.hsavid.eval2.12/09)

Here Hadley describes when her students are collecting data in order to make claims about what types of habitats cockroaches live in. This example also serves as evidence of Hadley valuing discussion as a form of meaning making in her science lessons as well as how she scaffolded her students' abilities to make claims based on evidence.

> *In this whole group experiment, students are observing and collecting data [data] to try and make a claim [arg strc] about what kinds of habitats a cockroach lives in or likes. We are testing [fr tst] different ideas (wet vs. dry, cold vs. warm). As students are observing, some disagree [ag/dsag] with each other which sparks conversation among the group. Discussion [sts talk] was a great and influential factor in these science lessons for some, especially because they don't happen too often in our first grade classroom. They enjoyed sharing their ideas and coming up with claims through these experiments.*
>
> (ecb.hsavid.expl4.12/09)

She also reflects on why designing fair tests is an important aspect of the framework and discusses how she negotiated this understanding with her students.

> *I chose this clip because my one student had a great explanation as to why testing more cockroaches for different habitats (we were testing warm vs. cold) was important [fr tst]. She said that it makes a claim [arg strc] stronger because if only one cockroach likes it, we can't know for sure, "because if one cockroach likes warm, and others like warm and cold, they might not all like the same thing …" Since we tested more than one cockroach and some liked hott (sic) and some like cold, we concluded that they could live in all types of weather and places.*
>
> (ecb.hsavid.expn7.12/09)

Hadley's self-analysis is particularly noteworthy because she specifically references her discourse moves and her role in using discourse to scaffold her students' co-construction of science concepts. She uses her questioning as evidence of how she scaffolded student learning and pays attention to how she thinks her students are making sense of the science concept.

> *The student in the Steelers jersey noticed the antennas. "What do they do with their anteenas (sic)?" They (sic) boy in the red was convinced that they feel with their antennas. He was using outside resources (TV, Magic School Bus, Field Trips) as his evidence as to how he knew these things. As I asked more probing questions [pro ques], "Are you sure?" or "How do you know?" or "What if they are smelling?" he realizes [sts think] that he really doesn't know for sure and we need more evidence. I realized the less I talk and the more the student does, the stronger his understanding [sts lrn] became.*
>
> (ecb.hsavid.expn2.12/09)

**What can be learned from Hadley?** Hadley is an example of a very eager preservice teacher who shows desire and willingness to try on several aspects of the TSAF during her initial science teaching experience. She struggled with classroom management but that is a very typical challenge for beginning teachers as seen in the research literature (E. A. Davis et al., 2006). She is aware of what challenges her as well as her strengths as

evidenced in her discussions in class, during lesson planning conferences and in her self-analysis. She purposefully works to make sense of the framework and its application in her classroom. At times she does this in a seamless manner integrating discourse moves and using argument to co-construct meaning with her first grade students. At other times her work to make sense of the affordances of the framework is evident when she rewords and restates questions followed by long wait times and unsure student responses. Hadley is very mindful of the constructs of the framework and is an example of what it looks like when a preservice teacher is working to make sense of the framework and integrate it into her teaching.

Her focus on the framework is also seen in her self-analysis of her practice. Hadley explicitly discusses how her students pursued testable questions, how she led them in the formation of claims based on evidence, how they collected data and reasoned publicly. It is notable that Hadley extensively uses direct evidence from her teaching in support of the claims she makes in her self-analysis. She references student discussion and sense-making as evidence of their learning. She also writes about places of concern using off task student discourse to substantiate her claims. Hadley consistently demonstrates she is aware of and concerned with how her students are making sense of the science concepts and expresses desire and willingness to continue to learn from her practice.

Hadley is an example of a preservice teacher who is not only willing to try to use the constructs provided by the TSAF but of someone who actively investigates its usefulness and purposefully works to integrate meaningful aspects of it into her work. Though her implementation is not always picture perfect she is noteworthy because of her mindful

intention to use the scaffolds provided by the Framework and modeled in her methods course.

**Part 3: Narrative Analysis of Alex**

Alex interned in a fourth grade classroom in a large elementary school with a diverse population. Her mentor is an early career teacher who does not teach a lot of science in her classroom. Alex is an example of a preservice teacher who is trying on aspects of the TSAF but who is still making sense of it and its usefulness in the classroom. Alex demonstrates a commitment to using Talk Moves and Productive questioning to co-construct the meaning of scientific phenomenon with her students but at times she defaults to the I-R-E discussion model typical in schools (Mehan, 1979). Alex's unit plan is on adaptations focused on Australian Walking Sticks. Daily lesson objectives are for her students to understand insect body parts, specific adaptations of the Walking Sticks and why adaptations are important.

**First Round Lesson Planning Conference.** Alex and Rose meet with April for their lesson plan conference. April begins the discussion, "From your Concept Interviews what do you think is going to be important to get your kids to form some claims?" She asking about what Alex and Rose have learned their students know about adaptations and what they still need to learn in order to form claims.

"Observe insects, see how they move and figure out adaptations" starts Alex.

"So you want really great observations and a day with observations is ok." April assures.

Rose is paging through her Science Notebook, looking at the results of her

Student Prior Knowledge

Quick, Draw, Write, “A lot of my kids drew insects with hundreds of legs during the Quick Draw.”

“I think if you can integrate a discussion about the parts-”

“and as a class label it?” Alex jumps in.

“Yes as a class!” exclaims April, “Draw as much detail as they can and if they've had to think about labels they will focus more and then add the labels as a group.” As in Meredith’s conference April encourages Alex to think about student thinking and discussion as a means to scaffold thinking.

“Many of my kids knew the abdomen but not the thorax so a class diagram would be important.”

“and how they move?” April prompts.

“Walking Sticks are so cool,” declares Alex, “they sway in the breeze!” Alex is very interested in this adaptation and she will return to it frequently in her teaching.

Data and Questioning

“In terms of getting to the adaptations part,” April shifts, “if you are going to take a day to really observe and label it seems like it would make sense to take another day to make an adaptations chart.”

“So the first one is a more general observation then have a more focused observation on adaptations how do they move, what do they do?” confirms Alex.

April nods, “So if they did some sort of chart where they had space to write about adaptations-”

“- like ‘How does it move ..?’” mutters Alex as she writes.

“So the first day would be more, ‘What do you notice?’” continues April as she

Leading Discussion

inserts specific productive question types into the conversation.

"For the detailed drawing, what they saw, what they noticed about color and movement." Alex and April are talking in an almost overlapping pattern and their thoughts appear to be in sync. Alex has picked up on the questioning thread and enthusiastically adds her own to the mix.

"And the second one would be more focused like they sway and its function is to make it look like it's in the wind."

"- and the last day would be more fun to go outside and find the pipe cleaners" finishes Alex. She is referring to a role play where her students will act like birds who are trying to eat the Walking Sticks. The goal of this investigation is for students to collect data that will enable them to make sense of why Walking Sticks are adapted to blend in to their environment.

Mechanics & Management and Questioning

"I think you should do it a little more focused than you described" April picks up their lesson plans and begins discussing issues related to the mechanics of the lessons, "So you could do it in teams of three and have twenty bugs for each group" She gets up to find a set of pipe cleaners and shows them how to make a simple model of a Walking Stick. "So they're making the Walking Sticks and have twenty of each color and one person is the hider and one person is the predator, what would be a predator?"

Questioning and Student Learning

"A bird." adds Rose.

April continues to help the interns work out the mechanics of the lesson but she shifts the focus to making sense of the data and using science talks to scaffold the students' abilities to identify patterns in the data "One person would be a bird and one person would record

how many they found of each color and you could come back and talk about, ‘what did you notice?’ and ‘what did you see?’ then you rotate so you do three trials so each gets each job and the bird would have to bring it back to the recorder like going back to their nest and I think you'll get good results to talk about what environments would allow each color to survive, just to get them to think about it over time, ‘Why do you see a certain color in a certain environment?’”

Questioning

“Over time they adapt to their surroundings.” Rose answers.

“Over generations” confirms April, “It will be hard for them to really get that but also really interesting to talk about.” The idea that adaptations take place over generations is a Big Idea for the students to understand and an important science concept April wants the interns to talk about in their teaching. She gets up once again and returns with a large book titled, "The Natural World of Bugs and Insects". She is looking for pictures of different colored Walking Sticks.

“They're so much cooler than cockroaches!” exclaims Alex.

April brings the focus back to their lesson plans and asks the group about what their students will learn over the course of the teaching sequence, “So at the end of these three lessons what do they know about the parts of insects and how they're adapted and how they change over generations?”

Student Learning

“They'll know that an adaptation helps them survive over time” states Rose.

“Are you thinking of doing a KLEW chart?” questions April as she segues into the importance of using student ideas to co-construct the science ideas, “You could use the

things they already know for the Know part and you can listen to what they say and say ‘Bring that to the group’ or I could say ‘I'm noticing not everyone has the same amount of legs’ to start the discussion.”

“So would you say ‘What do you know about Australian Walking Sticks?’” asks Alex.

“Well I'd phrase it about all insects and you're using Australian Walking Sticks to illustrate that and put their Quick Draw Writes up as what they already Know.” April is broadening how the interns’ think about their topic and making sure they use student prior knowledge in their discussions. She then inquires if the interns have identified any potential problems with using a discursive model of meaning making during their teaching. “When you're thinking about doing the talks do you have any concerns?”

Listening to Students

“My class will be ok with talking but some of them have a fear of being wrong but some of them are ok with trying.” Rose responds.

“Mine are pretty OK with trying and not afraid of being wrong” Alex reports.

“What about listening to other people?” April asks.

“Like management?”

“Like building off of other's ideas.”

“Oh” Alex seems a little deflated.

“I'd have some questions ready like ‘Did anyone else see that?’ prompts April.

Listening to Students and Leading Discussions

Alex and Rose think for a few seconds before Alex says, “I think they'd be ok with

that."

"Do you have a chart or some sort of poster you could add the parts to?" April inquires.

"I could make this bigger on the copy machine," Rose holds up a blank diagram of a Walking Stick, "then white out the parts they don't need to know."

"You also want to think about what concepts you want them to know."

"like standards?" asks Alex, "Because there are a lot of standards."

April ends the conference with "What concepts, what ideas you want them understand."

Science Concepts

**Second Round Lesson Planning Conference.** The next week Alex, Rose and April meet again to finalize their lesson plans.

"So the Walking Sticks are a go?" Alex wants to make sure April has been able to borrow the insects from the Entomology Department at the university. April confirms that she can. "This is so exciting!" exclaims Alex.

"So what kind of mouth parts do Walking Sticks have?" April is testing the pairs' subject matter knowledge on Walking Sticks.

"Oh my god what do they have? I think they have chewing or overlapping? No chewing ..."

"What do they eat?" prompts April.

"Leaves! Ok so they have chewing." Alex looks relieved.

"I'd like you to think about what claims and evidence your students can make. Do you have any questions about the procedure because I'm very

Claims & Evidence

interested in the end, the claims." April is setting the tone for this meeting by indicating the interns should have worked out several of the issues they had previously discussed about the mechanics of the lessons and it was now time to focus on what the students can learn from the lessons and how they will construct this understanding.

"We're going to use a KLEW chart" answers Rose.

"And you as teachers are also listening because they may not form it as a question" Aprils adds in reference to the Wonderings section.

Leading Discussion

"We're going to have them do a detailed drawing of the head then abdomen and add below what they are seeing and hearing and the closure is to come back to the KLEW chart to see what they learned from their observations." Alex discusses the overall flow of the first day's lesson. "The second day we're going to do more observations but focus more on mimicry, imitation and camouflage, is mimicry the same as imitation?" she asks Rose and April but doesn't pause for them to answer. "Our hook is to review what we saw the day before then as a class we will complete the adaptations worksheet and we can complete the definitions of mimicry and camouflage."

April listens intently then brings up a concern about transitioning between data collection and class discussion, "Would it be possible to go over one example then send them off to do some on their own or in small groups then come back to the science talk?"

Mechanics & Management

Alex and Rose both nod and add to their notes. "After we've completed the worksheet

I want to come back to our wonderings and see if they can answer some of them."

In order to prepare the two for their science talk April pushes them to brainstorm what the students might say during the lesson, "Let's think about some things they could say, claims they could make." Planning for specific claims the students could make frees the interns to focus on the science ideas specific to the lesson and not feel obligated to discuss everything the students bring up.

"Adaptations help them survive" Rose begins.

"Um hmm and you have some specific evidence for that" April points to their lesson plans. "And think about the vocabulary because they can make claims about that."

Questioning and Student Learning

"Like camouflage helps animals hide from predators?" asks Alex.

"Yes" April affirms. "So let's go back to the first day."

"They could determine if the Walking stick is an insect" Rose begins.

"And they have clear evidence on that" April points out the section of their lesson plan where the students are making observations of the Walking Sticks.

"And they could make claims about their adaptations" Alex adds. "The second day the closure would be a wrap up of the day's activities and a preview of the next day's activity."

"So that is your segue and you'll want to introduce it earlier that day" suggests April. "Let's think about that third day and how that's going to work and also some teacher questions you can ask. What questions do you have for the predator prey game?"

"What color Walking Sticks survived?" Rose asks hesitantly.

Claims & Evidence

April pushes the interns to focus on the science ideas behind the data and what students will learn from playing the predator prey game by saying, “You want to start it with this and ask them to write down why they think that color survived.”

“What do we do if they find all of them?”

“You only have 30 seconds and they only bring one back at a time.”

“Should we explain this in the classroom and then go out?”

April nods, “um hum” then asks, “What will they be able to claim from the game?” redirecting the discussion from logistics to meaning making.

“Creatures survive due to adaptations.”

“Like ...” pushes April.

“camouflage and mimicry”

“and your evidence is ...”

“they only collected the bright colored ones” Rose responds.

“which were ...”

“not camouflaged” concludes Alex.

Claims & Evidence

April nods then goes on, “I was thinking if you had the whole class data-“

“oh you'd have to combine the data?” Rose interjects.

“on a chart” April mimes a large rectangle in the air.

“To have more evidence?” Alex questions. “So we'll collect all the data then they can go back to their desks and work on their conclusions. How much time should we allot?”

“I'm not sure because I haven't done this before” responds April.

Data & Evidence

“10 minutes outside?”

April pauses in thought then answers, “I'd give them 15 and you'll need time to collect data and make conclusions on the KLEW chart.”

“So what do we do with the KLEW charts?” Rose wonders, “Just write up what they know?”

“You could put up their drawings and see if they all have three body parts and if they don't then add that to the chart.”

“Do I put up things even if they are wrong?”

“Underline ‘What do we think we know’” April draws in the air “and emphasize the THINK.”

Student Thinking

“So if they said spiders are insects I could say, ‘Do all insects have eight legs?’”

“Change it around to a testable question like, ‘How many legs do insects have?’”

“And if they don’t know?” asks Alex.

“I don't think you'll get great questions if you just ask it like that.” April assures, “Do you have some kids with great knowledge, a go to guy?”

“Yeah Jeffery knows everything about insects” Alex grins.

“No not really” grumbles Rose.

In response to Rose April asks her about what her students do know.

“They don't know much not even head, thorax and abdomen.”

“So have a diagram.”

“Then I’d ask them, ‘Do you know this part? Do you know this part?’”

Listening to Students and Leading Discussion

April shakes her head then articulates how allowing students to experience science

creates meaning for them, “I don't think I'd have them labeled. After they look at the insect them tell them because it will have so much more meaning to them.” This highlights the commitment to situated learning displayed in the methods course.

“So they'll be making observations and drawing …” Alex drops off as she is writing.

Situated Learning

“answering the question, ‘is this an insect?’” finishes April. “What types of questions can you be asking while they are observing?”

“Like ‘What are you noticing?’” replies Alex.

“Questions to focus them like ‘How many legs, body parts ...’ April prompts, “You also want to be careful with the language you use because you want to say ‘animal’ not ‘insect’ so you're not answering their question for them.”

“Oh that's good information.” Alex answers brightly.

“The second day you'll ask:”

“How do they move, what does this remind you of?”

Questioning and the Language of Science

The three finish their meeting with a discussion about the logistics of using a KLEW chart and where they should record their students’ ideas about adaptations. Alex and Rose seem very uplifted and positive about their teaching when they leave the room.

**Initial Science Teaching Experience.** Alex begins the series of lessons by telling her class they are no longer in their classroom but rather are scientists who are going to be observing things. She revoices the answers her students share to reinforce their importance to the rest of the class. Notice how right away she establishes the use of declarative

statements evaluating her students' responses. Alex's talk patterns tend toward the I-R-E sequence though there is also evidence that she values dialogic sense-making and discussion.

*Alex: Can anyone tell me how they observe?["sci":fr tsts] Jason?*
*Jason: You look at stuff.*
*Alex: You look with your eyes. [revoice:fr tsts] How else do you observe? Paul?*
*Paul: Smell?*
*Alex: You can smell with your nose. [revoice:fr tsts] How else? Jessie?*
*Jessie: Listen with your ears.*
*Alex: Yep you need to listen. [dclr, revoice:fr tsts] Matthew?*
*Matthew: You can touch with your fingers.*
*Alex: You can touch. [revoice:fr tsts] And what's the last one that we are not going to do?*
*Cora: Taste.*
*Alex: Yeah we're not going to taste anything. [dclr:fr tsts]*

(ecb.ad1.teachvid.11/09)

Alex then divides the class into four groups and gives each group a plastic container containing a twig and an unknown organism. She announces that they only have two minutes to observe what is inside the containers and discuss what they see. She uses attention-focusing questions to scaffold her students' abilities to observe important features of the organism. She also asks a reasoning question but then corrects and asks her students to keep their ideas to themselves.

*Jessie: Oh it's a bug!*
*Alex: Do you see anything in there? [attn fcs:phenom] Is anything moving? [attn fcs:phenom] Do you have any idea what it might be? [resn:phenom] (As she asks these questions students raise their hands and begin shouting out answers but Alex tells them to keep their ideas to themselves and to only make observations). What else do you notice? [attn fcs:phenom]*

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After this short observation period Alex assures the group they will have more time to observe but that first she wants the class to discuss what they noticed and what they think they know about the organism. She uses a KLEW chart as a visual scaffold to keep track of the class's sense making. This discussion provides Alex with a baseline understanding of her students' prior knowledge on insects which she will refer to throughout the lesson sequence.

By giving the students the opportunity to observe prior to discussion, their thinking is activated and they can participate productively in the brainstorming session. She begins the discussion with a reasoning question then moves on to ask them how they knew if the organism was an insect or not. By doing this she demonstrated a commitment to building an argument using the scaffolds provided by the KLEW chart. At this point she does not use declarative statements to evaluate her students but rather records accurate conceptions on the KLEW chart. Alex revoices her students' contributions and corrects from an evaluative statement to a question; pushing her students to think about what the word 'exoskeleton' means. This is evidence that she recognizes her students should be co-constructing meaning rather than simply telling them what terms mean. She also demonstrates a commitment to forming testable questions when she pushes her students to turn their ideas into questions to add to the KLEW chart.

*Alex: I'm gonna write that down under Know [klew:arg bld] (writes on KLEW chart and says out loud) Insects have six legs. [revoice:arg bld] Do we know anything else? [prmt:phenom] Reese?*
*Reese: Um I think that all insects have an exoskeleton.*
*Alex: Oooh that's a- [dclr:vocab] what does exoskeleton mean? [recall:vocab]*
*Reese: Like their skeleton's on the outside of their bodies.*
*Alex: OK so insects have an exoskeleton [klew:arg strc] (adds to KLEW chart) and does anyone have any other ideas about what having an exoskeleton means? [prmt:phenom] Avery?*
*Avery: For this one, for what we're looking at the exoskeleton helps it blend in and it gives them a harder shell against birds that would eat it.*
*Alex: Is that something we know? [explct resn:arg strc] Is that why it has an exoskeleton [explct resn:arg strc] er is that maybe a Wondering we have about if that's the reason? [klew:arg atrc] So how cold we make that a question?[rewrd:arg strc] Lily?*
*Lily: Do bugs, do all bugs have exoskeleton's?*

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When it is time for the second observation Alex redistributes the containers and gives the class a worksheet on which to make a detailed drawing of the organism. Prior to this

interaction Alex tells the class they will be making, "Detailed, detailed, detailed drawings" as part of this observation but as soon as she joins a group of students she tries to focus their attention on how the organism moves when she blows on it even though she admits they are going to talk about movement the following day. The students repeatedly try to talk about the body parts they are seeing and to make sense of the anatomy of the organism but Alex does not seem interested in their observations and tries to redirect their discussion to how the organism moves. There are several openings in this discussion where Alex could have used student interest to discuss data on insect body parts but she does not address that. When the group continues to show interest in the organism's anatomy she puts down the specimen and leaves the group.

*Alex: (Picks up the twig) I want you guys to watch it and see how it moves. [declr, attn fcs:phenom]*
*Jessie: It looks like that's its face right there.*
*Alex: Where?*
*Jessie: Right there (she points with the end of her pencil).*
*Alex: Now watch I'm going to do something and I want you to watch it then tell me what you think about it. [demo: phenom] We're going to talk more about this tomorrow but … (blows on the organism).*
*Jessie: That's its belly (points) and that's its face.*
*Alex: um hmmm …*
*Paul: What's that?*
*Jessie: You can see its eyes.*
*Cora: Are they under there?*
*Paul: (leaning very close to organism) Those are antennae.*
*Alex: Yup. [declr: phenom]*
*Cora: It's face is under there (points to the bottom of the organism)?*
*Alex: Yep its face is under there. [declr, revoice:phenom] OK I'll come back (she put down the twig). Draw everything you see and write down everything you think you know. [ntbk:dta]*

(ecb.ad1.teachvid.11/09)

When she visits the next group of students she begins by focusing their attention on the organism's movement but then follows their interest in its anatomy though she continues to be very focused on what the students do rather than on what they are thinking, as seen when

she cuts off Noah's enthusiastic interjection about the scorpion to make sure the students are writing down their thoughts.

*Alex: Now I want you to look. Watch how he is moving. [declr, attn fcs:phenom]*
*Noah: He looks like he is about to strike.*
*Alex: What do you think about its tail? [prmt:phenom] Have you ever seen anything-*
*Brooke: A scorpion.*
*Noah: Yes, yes he looks-*
*Alex: Write that down, that's an observation. [ntbk:dta]*

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She moves on to the next group who has been observing a much larger specimen than the other groups. Alex immediately swaps out containers and take the larger organism for the other groups to observe. A student protests by saying, "Everything's going too fast, I can't draw fast enough." But Alex tells her to draw a little one and she will bring the large one back soon. She rejoins the first group with the larger specimen and uses a series of reasoning questions to push her students to think about why the insect has the specific adaptations it does.

*Cora: Wow he's cool!*
*Jessie: His tail's different than the last one.*
*Cora: Yeah the other one's are curved.*
*Alex: What do you think that means?[resn:clms evd]*
*Jessie: It means when they get older their tails change.*
*Cora: It flattens out.*
*Jessie: And they get darker.*
*Alex: They do get darker, [revoice:phenom] why do you think they get darker? [resn:clms evd]*
*Jessie: I don't know.*
*Alex: Let's think about that, do you think, well what's their coloring for? [resn:evd clms]*
*Cora: Camouflage? It looks like they are camouflaged in the leaves.*
*Alex: Write it down. [ntbk:dta] (She starts to get up then sits back down) Do you think their color changes?[resn:prdt]*
*Jason: It might because if you camouflage something its color can change.*
*Paul: Like chameleons and octopi.*
*Jason: Yeah.*
*Alex: Write it down. If that's a question write it down. [ntbk,arg stc:dta]*

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When she brings the larger specimen to the second group she begins by using attention-focusing and comparison questions to lead her students to notice certain adaptations. Alex continues to revoice student contributions and seems surprised when Paige shares that she thinks the insect looks like a Walking Stick. Alex indicated her agreement with a declarative statement. She seems unwilling to engage in a conversation about her students' observations but rather continue to prompt them to write down their ideas for later.

*Alex: What do you notice about this one?[attn fcs:phenom]*
*Cora: It looks like a leaf.*
*Alex: It looks like a leaf. [revoice:phenom]*
*Paige: It looks like a Walking stick.*
*Alex: What does it look like?[clr:phenom]*
*Paige: A Walking stick.*
*Alex: It does look like a Walking stick! [dclr:phenom] You need to be writing these down, on the lines at the bottom. [ntbk:dta] Can you see up close on its face? [attn fcs:phenom]*
*Cora: Oh it has little chewing stuff!*
*Alex: It has chewing things.[revoice:phenom]*
*Harry: Can we feed it?*
*Alex: It's actually eating the leaves that it's in (points to a container across the room) Now what have you noticed about its legs? [attn fcs:phenom] What do its legs look like? [cmp:phenom]*
*Parker: Spikes.*
*Alex: They look like spikes. [revoice:phenom]*
*Parker: They look flat.*
*Alex: They look flat.[revoice:phenom]*
*Grace: and leafy.*
*Alex: and leafy, [revoice:phenom] very good. [dclr:phenom]*
*Drew: It looks like a mix of-*
*Alex: Don't tell me I want you to write it down. [ntbk:dta]*

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After the other two groups have had a chance to observe the larger specimen, Alex gathers the class on the carpet to discuss what they have learned. But when Harry asks a question about where the insects come from Alex avoids his question saying, "I'll tell you at the end of class." But Harry is very insistent he knows the answer so Alex allows him to guess then

does not engage him in discussion but rather uses an abrupt declarative ending the conversation.

*Harry: I have a question. Where do they come from?*
*Alex: I'll tell you at the end of class.*
*Rowan: I know.*
*Alex: You THINK you know.*
*Rowan: No I know.*
*Alex: Where do you think they are from?[explt resn:phenom]*
*Rowan: Africa.*
*Alex: Nope. [dclr:phenom]*

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Alex has been pushing the class to come up with questions which shows a commitment to using the Wonderings scaffold of the KLEW chart but after the class comes up with several questions Alex seems to realize she has been neglecting other aspects of their argument structure by not having discussed what they think they know about the insect. She connects the discussion to the evidence they have collected through observation and asks the class to think about anything else they think they know about their insects.

*Alex: Does anyone, after our new observations, does anyone have anything that we think we know. [klew:arg bld] (Points to Know section of the KLEW chart) We need to add more things to here or else we don't know anything.*
*Paul: I'm not sure about this.*
*Alex: you don't have to be sure it says, 'What we think we know'.*
*Paul: Well we know that, that our bug eats leaves.*
*Alex: We know that bug eats leaves. [revoice:arg bld] (Writes in the Know section of the KLEW chart) Does somebody else have- go ahead. [prmt:arg bld]*

(ecb.ad1.teachvid.11/09)

Students share ideas about the insect's mouth parts, its ability to defend itself, and the differences between the legs of the smaller and larger specimens. Alex seems to be selectively adding ideas to the KLEW chart and continuously pushing for "anything else". Finally she interjects with her own question and pushes students to think about the idea using a reasoning question. She then revoices student contributions and prompts them to apply their

own reasoning to Kenley's reasoning to come to a class consensus which she then adds to KLEW chart indicating they have reached an accurate conception. It is notable that Alex uses the language of the KLEW chart argument scaffold by asking her students, "Do we *think* we know that?" and she also told Paul in the last example that is was ok if he wasn't sure that the KLEW chart was for mapping what they thought they knew but in the end she only adds accurate scientific concepts to the chart.

*Alex: I have a question because I don't know but some of you might know. How many body parts did you notice? [msr cnt: dta] Paul?*
*Paul: Three.*
*Alex: Three body parts, [revoice: dta] do you think that just this insect maybe has three body parts or do you think all of them do? [resn:arg bld]*
*Kenley: All of them.*
*Alex: All of them?[revoice:arg strc] Do we think we know that? [klew:arg strc]*
*Group: Yes (Alex writes, 'Insects have three segments' on the Know section of the KLEW chart).*

(ecb.ad1.teachvid.11/09)

To wrap up the day Alex projects a drawing she has made of the specimen and asks the group to try to label its parts based on their observations. It is notable for this to be at the end of the lesson. The class has had a chance to interact with the specimens and make sense of their observations before she attaches names to its parts. She also asks the students to contribute to the naming of the parts based on their experiences. The students have an understanding of the concept of the organism prior to having to discern abstract vocabulary and label it as an insect or not. Alex uses the scientific phenomenon to help the students understand the terminology rather than using the terminology to understand the phenomenon. The students have already had a chance to interact with the organism and the labels serve to enhance their understanding. If she had begun the lesson with a diagram of the insect and simply told her students what the parts were the discussion would not have been student centered and they would not have been co-constructing their understanding of insect body

parts. Alex opens the discussion by asking her students to contribute the labeling process and remains committed to the labels coming from the students rather than herself. She revoices student contributions and pushes the class to be involved in the discussion. It is also noteworthy that she is willing to say, "I don't know that's what we are trying to figure out." She is letting her students know that she is not the keeper of knowledge but that they are able co-construct understanding as a group. Members of the class tell Alex where the antennae are located, and that the organism has six legs. Alex then directs the class's attention to the KLEW chart and prompts them to reason about what they have added to the What we Think we Know section and the Wonderings section. She urges them to use the evidence they have gathered to answer the question they formed earlier and to make claims addressing their questions.

*Alex: So this has six legs, antennae and three body segments? Does that go with things we know (directs the class's attention to the KLEW chart). [ag/dsag:arg bld] Do you think we can make a claim about this? [resn:evd clms] About something we learned? [resn:evd clms] We were trying to figure out if this is an insect and we just labeled the different parts that we said we thought we knew that an insect had. So do we think (Alex gets up and approaches the KLEW chart) Do we think that because it has all of this (points to each line in the Know section) that it's an insect? [resn:evd clms]*
*Brian: What is it we said about the hard outside?*
*Paul: Exoskeleton.*
*Brian: Ah exoskeleton. I did not get that.*
*Alex: So can anyone make a claim about our observations today?[resn:evd clms]*
*Jessie: It's an insect.*
*Alex: It is an insect? [revoice:evd clms] Ok- so which question did we answer? [dclr:arg bld]*

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Alex moves toward the Wonderings section of the KLEW chart but no one says anything. She begins pointing to each question on the Wonderings list then realizes there is no question on the chart asking if the specimen is an insect. She adds it to the bottom of the list then tells the class that was the question they were trying to answer. She uses a declarative statement

to affirm that they were observing an insect and continues to push for connections to evidence.

*Alex: Alright so we're answering this question. Is this an insect? What did we learn based on our observations? [resn:expln] Harry?*
*Harry: We learned that it is because we found all of the parts that we thought an insect had.*
*Alex: Ok so yes this is an insect (writes on the Learned section of the KLEW chart) and I'll tell you in a second what it is. What's our evidence? [explt resn:evd clms] Paige?*
*Paige: It has six legs, a thorax, head and abdomen and antennae. (Alex writes in the Evidence section of the KLEW chart)*
*Alex: Six legs, three body parts, antennae what else? [prmt:evd clms] What did we say was the most important thing an insect has? [recall:dta]*

(ecb.ad1.teachvid.11/09)

As the discussion continues Alex demonstrates how she holds certain verbal objectives she wants her students to share by evaluating their contributions and continuing to push until they share the answer she is looking to hear.

*Paul: Camouflage?*
*Alex: No [dclr:evd clms]*
*Paige: Its antenna? (Alex shakes head no)[dclr:evd clms]*
*Alex: Jason?*
*Jason: Six legs?*
*Alex: It has six legs. [revoice:evd clms] Look (points to Know section) Six legs, three body segments and what else?[revoice:evd clms]*
*Paul: Invertebrate.*
*Alex: Ok it is an invertebrate because …. [prmt:evd clms]*
*Paul: Exoskeleton.*
*Alex: Exoskeleton! [dclr:evd clms]*
*Jessie: How do we know it has an exoskeleton?*
*Alex: Because you got to touch it (class begins talking about this) Shhhh! So our claim is, 'This is an insect because (moves pointer from Learned to Evidence section of KLEW chart) it has six legs, three body parts, antennae and an exoskeleton' Tomorrow we are going to be doing more with them.*

(ecb.ad1.teachvid.11/09)

Alex begins the second day of the lesson sequence by asking the class to remind her what they did the day before. She then has different students tell her one characteristic of an insect based on their findings from the previous day. The objective of this class is based on the previous day's Wonderings. They are going to investigate if all insects blend into their

surroundings, and if they change color for their environment or weather. The class divides into the same groups they worked in previously. Once again they observe the Walking Sticks but are giving specific directions to think about how they are moving, what their coloring is and if they look like anything else as well as anything the students find unique and interesting about them. While the groups are observing, Alex circulates from group to group asking attention focusing questions such as, "Do you notice anything about them that you didn't see yesterday?" She encourages the students to make observations of things they find interesting but once again she tells the students to write down their observations and not share them with her.

After this initial observation time Alex collects the Walking Sticks and calls for the students' attention. She asks them if they have ever heard of the words mimicry, adaptation and camouflage but other than Jeffery not many students raise their hands. Jeffery has taken a summer course in Entomology and so has a deeper understanding of the topic then many of his classmates. During the methods course Alex had raised this as one of her concerns about teaching the unit and had asked for advise on how she could include Jeffery without having him dominate the class. In response to Jeffery's raised hand Alex says, "Other than Jeffery. I know you know a lot about this."

She passes out a piece of paper then asks the class to brainstorm with a partner and write down what they think each word means. The class all begins talking and Alex moves from group to group asking them what they think the words could mean and pushes them to give her reasons why they think the way they do. A few minutes later Alex announces that the students will be working on creating a list of features they noticed during their observations and then to think about what the function of that feature could be and why does

that help them survive. Alex works through an example with the class which serves as evidence for Alex's commitment to the co-construction of meaning with her students. She uses the same terms she asked the class to think about such as 'feature and function' which serves to scaffold their abilities to make sense of the science terms and revoices contributions before adding on to the ideas with her own interpretation.

*Alex: Could somebody give me something they noticed about the Walking Stick? [prmt:dta] Cora.*
*Cora: They are camouflaged because their legs look like leaves.*
*Alex: So a feature would be that its legs look like leaves. [revoice:dta] What do we think the function of that is? [resn:expln] To blend in to their environment maybe? [resn:expln]*
*Jeffery: Camouflage.*
*Alex: So how does that help them survive if they blend in or are camouflaged in their environment? [resn:expln]*
*Paul: Well if a bird is looking for dinner it helps them hide.*
*Alex: If a bird is looking for dinner it helps them hide. [revoice:expln] Right. [dclr:expln] So it can help them hide from predators.*

(ecb.ad2.teachvid.11/09)

Each group receives a container with an insect; they are allowed to talk about their thoughts with their group members as they create their lists. Alex pulls Jeffery aside and asks him to use the computer to look up the definitions of the terms adaptation, mimicry, and camouflage, as well as examples of each, then to use what he finds to create a poster teaching the class about the terms. She then confidently moves from group to group asking the other students about what they are seeing and pushing them to think about how each feature could help the Walking Sticks survive. She reminds the class that the observations they are making will serve as evidence for a claim they are going to make and urges them to write everything down in order to remember their ideas. When a student asks her why having spikes on its legs could help the Walking Stick survive instead of answering the question straight out she crafts a questions to push the students thinking about why the insect could have that adaptation.

*Alex: What do you think when you see something with spikes? [resn:expln] Do you think it's something good and you think you should go there?[resn:expln]*

(ecb.ad2.teachvid.11/09)

The groups work together, observing, brainstorming and recording their ideas for five more minutes. When the time is up Alex turns on the overhead projector and asks the students to share what they saw. She records their ideas and prompts them for further participation. One group shares their idea about the leg spikes being a warning to predators not to eat the Walking Stick, someone else mentions they have a straight body which helps them blend in because they look like Sticks and can hide in twigs from predators. Alex revoices ideas and pushes for clarification before asking them reasoning questions about why the insect could have certain adaptations. She also evaluates Rowan's response with a declarative statement which served as further evidence that Alex was especially interested in discussing this certain adaptation.

*Alex: Can anyone give me another one? Paige? [prmt:dta]*
*Paige: I noticed that it has like thickish antennae.*
*Alex: Ok so thick antennae. [revoice:dta]*
*Paige: And with the straight body it might look like little pieces of branch on a bigger branch. It would look like two pieces of another twig on the bigger branch.*
*Alex: So they look like small twigs?[revoice:dta]*
*Paige: Yeah.*
*Alex: How does that help them survive?[non-pro resn:expln]*
*Paige: They hide from predators.*
*Alex: They hide from predators. [revoice:expln] Kay can somebody give me another one? Rowan?*
*Rowan: It sways.*
*Alex: It sways. [revoice:dta] That's a good one I hope everyone noticed that one. The swaying is a really good feature [ire:dta] so I'm going to wait to talk about that one. What else?*

(ecb.ad2.teachvid.11/09)

Students share their ideas about how the Walking Sticks mouth parts work, why they have tiny claws on their feet, what their curling tail could be for, how the tail looks like a scorpion's tail and straightens when the insect gets picked up and that they are colored

brown. But she ultimately returns to the swaying to highlight for the class how it can serve to help Walking Sticks survive. The swaying is an adaptation that has intrigued Alex since she found out about it, she talked about it during lesson plan conferences and pointed it out to students during their first round of observations. What is notable about this is that she gives evidence that she has a clear outcome she wants the students to come to. She does not give them the opportunity to discuss alternatives ideas about why Walking Sticks may sway but rather corrects Rowan and adds her own reasoning which she uses as the base for the next set of reasoning questions she asks the students.

*Alex: Now I want to go back to what Rowan said about the swaying. The function, what did you say the function was?[non-pro resn:expln]*
*Rowan: I think they could be finding a better balance.*
*Alex: They could find a better balance, that's a good idea but I'm going to say it sways to blend in. [ire:expln] Now it helps them survive because let's think about where they live. We said they live in trees, on leaves. Why do you think they would need to sway like that?[resn:expln] What about swaying in trees and on leaves. [resn:expln]*
*Paul: Don't the leaves sway?*
*Alex: When what happens?[explct resn: expln]*
*Paul: The wind blows.*
*Alex: When the wind blows the leaves sway! [revoice:expln] So when the leaves sway they can't just stay stationary because then they won't blend in anymore right? So they have to sway with the leaves. [dclr:expln] Now we're going to go over what adaption, mimicry and camouflage actually mean. Everyone give their attention to Jeffery because Jeffery looked them all up for us.*

(ecb.ad2.teachvid.11/09)

While Jeffery is giving his presentation Alex jumps in and shares that adaptations happen over time and that it is not like a chameleon changing colors to blend in with their surroundings but announces they will talk more about that the next day. Jeffery finishes his presentation and Alex immediately begins to question the class. She has them use the language of science to make a claim addressing some of their Wonderings on the KLEW chart and revoices their contributions. When a student has trouble answering a question about adaptations she has him consult his data sheet instead of directly addressing his question

which is a way to help him make sense of the information on his own. But once again there is evidence that she wants her students to say a particular claim rather than consider alternative claims. She uses a declarative to evaluate Harry's contribution and indicates he has shared the conception Alex was looking for.

There is no evidence on whether the class is familiar with the term "claim" and the process of making scientific claims based on evidence but the following example shows that even if the class is familiar with the term they are not used to the practice of forming claims and using evidence from an investigation. Alex struggles to prompt her students to form the specific claims she is looking for.

*Alex: Now we need to go back to our Wonderings and can we make a claim about any of our Wonderings? [resn: evdn clms] Paul what claim can you make? [prmt:evd clms]*
*Paul: Well um they blend in but not all insects blend in.*
*Alex: Not all but what about the Walking Sticks?[prmt:evd clms]*
*Paul: Yeah, yeah.*
*Alex: Can we say the Walking Sticks blend in with their surroundings? [resn:evd clms] So the Walking Sticks … what's the word?[prmt, vocab:evd clms]*
*Paul: camouflage.*
*Alex: Camouflage [revoice:end clms] thank you! [declr:evd clms] (Writes in the Learn section of the KLEW chart) Walking Sticks use camouflage and what's our evidence that they use camouflage? [explct resn: evd clms] Paige?*
*Paige: They are brown and blend into the trees cause they look like bark.*
*Alex: Yeah they use camouflage because they look like leaves and Sticks. [dclr:evd cms] I want you think about our other word of the day, adaptation. What can we say about adaptation? [non-pro resn:evd clms] Harry?*
*Harry: adap- um what do you mean?*
*Alex: What are adaptations used for? [recall:dta] What does it say on your sheet? [ntbk:dta]*
*Harry: Looking like your surroundings that could, getting used to their surroundings, like let's say they move to Antarctica, they would eventually adapt-*
*Alex: They would?[clr:expln]*
*Harry: It would take a long time but-*
*Alex: Because why? Why would it need to adapt? [explt resn:expln]*
*Harry: They'd get used to-*
*Alex: It would help them … [prmt:expln]*
*Harry: survive.*
*Alex: Right so adaptations help things survive. [dclr:expln]*

(ecb.ad2.teachvid.11/09)

On the final day of her teaching sequence Alex takes her students outside to the school's courtyard where she has set-up a Predator-Prey Simulation Activity. Alex made different colored Walking Sticks out of pipe cleaners and they are spread throughout the grass in the courtyard. The fourth graders are to act like birds fly into the courtyard, pick up the first Walking Stick they see, and then fly back to their nest, as shown in figure 6.4. In the nest another bird is waiting to collect the Walking Stick and record its color on a data sheet. After the class finishes the simulation they return to their classroom to tally the whole class's data and discuss their findings. Alex follows the pattern she has established earlier of asking her students reasoning questions then revoicing their contributions but she extends this to include talk moves to have her students explicate their reasoning while also seeming to hold a very specific idea of what she wants her students to share. This becomes very noticeable when Michael does not understand the question Alex has asked and instead of clarifying her idea she immediately says, "Anyone else?" as well as when Jason starts analyzing the data in terms of the "medium" number in each trial and Alex redirects the conversation to the "conclusion we're coming to".

**Figure 6.4**: Student Collecting Data during an Adaptations Investigation

*Alex: What conclusion can we come to from this data? [resn:expln]*
*Cora: That brown survived the most.*
*Alex: Brown survived the most. [revoice:evd clms] How do you know that? [explt resn:evd clms]*
*Cora: Because it had the least amount that we picked up.*
*Alex: Because it had the least number that we "ate" (Alex uses her fingers to make quote marks while stressing the word 'ate'). So how many times did it take us to get to the brown? [msr cnt:dta] How many trials did we have to go through to finally get to the brown?[msr cnt:dta]*
*Kenley: Three.*

*Alex: Three. [revoice:dta] If we think of these trials as, like a lot of years, ten years, what do you think would happen to the rest of these colors of Walking Sticks? [non-pro resn: expln] Michael?*
*Michael: Maybe the predators would, umm I don't really understand the question.*
*Alex: Anyone else?*
*Adam: They'd be eaten.*
*Alex: They would eventually be all eaten because look if you look at red, yellow and purple those are the ones that we could see the most outside right? Those are the ones that got eaten each time. [dclr:expln] So what do you think would be the best color to be if you were a Walking stick in our courtyard? [resn:evd clms] Aidan?*
*Aidan: I'd say brown.*
*Alex: Brown, you're right. [ire:evd clms] So because the least number of those got eaten there are more of those around. [dclr:expln] How long do you think it would take for the brown to be the dominant color of the species? [non-pro:expln] Paul?*
*Paul: Generations.*
*Alex: Yes generations [ire:expln]*
*Paul: because they're evolving.*
*Alex: Yes evolving. [ire:expln] So what is our conclusion? [resn:expln] Adaptation's … what? [prmt:expln] Cora?*
*Cora: Adaptation is …. mostly good?*
*Alex: Adaptation is good … [dclr:expln]*
*Cora: for those that can camouflage well.*
*Alex: Well camouflage is an adaptation so let's wait, adaptation is good and let's talk about how long it takes to adapt, something about how long it takes. [dclr:expln] Jason.*
*Jason: The medium number of the amount of each trial-*
*Alex: OK. Let's talk about our conclusion we're coming to. [dclr:expln] Adaptation is good … Paul? And it happens ….? [prmt:expln]*
*Paul: Over a long time.*
*Alex: So did we learn that these Walking Sticks didn't just turn brown and get leaf legs in a day?[non-pro resn:expln]*
*Group: No.*
*Alex: Right it took them a long time to do it. [ire:expln]*

(ecb.ad3.teachvid.11/09)

**Learning From Practice: Alex's Self-Analysis**. Alex's self-analysis is focused primarily on her students making claims based on evidence. The formation of claims supported by evidence is an integral aspect of forming scientific arguments and is addressed in the Teaching Science as Argument framework which gives priority to evidence and explanation when communicating scientific findings. Alex's self-analysis contains evidence that she is not only applying the framework in her teaching but also picking up elements of it and

making sense of her teaching in light of what is pushed in the framework. She consistently discussed the claims her students made and the evidence they collected during their investigations.

> *Students made claims [arg strc] to answer our wonderings from the evidence they gathered [sts invst] while observing. They were able to double check by observing the insects again. The relationship between learnings (sic) and evidence is very apparent in this lesson format.*
>
> (ecb.asavid.expn1.12/09)

She discusses her students making claims based on evidence four additional times in her self-analysis and uses the formation of claims as an evaluative tool.

> *On the third day of lessons, the claims [arg strc] that we made were a culmination [eval] of the three days. The students were able to draw from what they learned in the previous days and provide evidence for what they thought.*
>
> (ecb.asavid.expn4.12/09)

In addition to the claims and evidence aspects of the framework Alex also addresses interacting with scientific phenomena, collecting data and the central role of testable questions in scientific investigations.

There is evidence that Alex uses questions as a tool to guide investigations as well as a way to scaffold the formation of claims based on evidence.

> *Before the students began observation (sic), I gave them questions [ques] to help them answer their wonderings. After they observed, I felt these questions were helpful because it kept them on track to make claims supported by the evidence [arg strc] they found.*
>
> (ecb.asavid.expl51.12/09)

Here is an example of how Alex discusses the role of interacting with the scientific phenomenon as part of a scientific investigation. She notes how observations helped her students make sense of the science concepts.

> *Students were very engaged in the observation [phenom] aspect of the lesson. They were able to realize key concepts based on this time.*
>
> (ecb.asavid.eng4.12/09)

When Alex reflects on her students collecting data she makes a connection between the data they gathered and how they used this data to make sense of the patterns they were seeing.

> *Students were participating in the experiment by imitating birds and "eating" insects. They were able to collect data [data] on which color of insect would be completely eaten first. When we discussed this aspect as a class, the data from this part allowed the students to see [sts lrn] the decline in colors.*
>
> (ecb.asavid.expl7.12/09)

In addition to using aspects of the Teaching Science as Argument Framework to make sense of her practice Alex also provides evidence that she is reflecting on her discourse moves and the role she plays in helping her students make sense of scientific ideas. She references questions she asked the students and discusses how she prompted her students to provide evidence to support their claims.

> *The students were very good about giving evidence right after they made their claims [arg strc]. Each one of them was prepared to answer my follow-up question [pro ques], "What is our evidence?"*
>
> (ecb.asavid.expn3.12/09)

Her self-analysis also provides evidence supporting the idea discussed in the previous section about her having a very specific outcome she was trying to move her students towards. She discusses how her students were interested in talking about things they thought they knew about the insect they were observing but that she redirected the conversation based on the outcome she wanted.

> *Students were talking about things they thought they knew but I wanted to make these wonderings. Because I knew the outcome I wanted [mng expt], I deciedd (sic) to probe and question the students to see if they could turn these ideas into questions.*
>
> (ecb.asavid.expl2.12/09)

There is further evidence of her need to control the outcome of a discussion when she mentions her students' interest in making observation would have "sidetracked" their discussion.

> *Some of the students would have become sidetracked by their fascination with insects and would have forgotten about the questions we wanted [mng expt] to answer.*
> (ecb.asavid.expl5.12/09)

Though Alex does not discuss student thinking or sense making she provides evidence that she understands many of the central features of teaching science as argument including the need to form testable questions, collect and record data and use data as evidence to support the formation of claims. By focusing on these features in her self-analysis Alex demonstrates that she is beginning to pick-up integral pieces of the framework.

**What can be learned from Alex?** Alex is an example of a preservice teacher who is trying on aspects of the Teaching Science as Argument Framework (TSAF) but who is still making sense of it and its usefulness in the classroom. Alex demonstrates a commitment to integrating Talk Moves and Productive questioning into her discourse repertoire but defaults to the I-R-E discussion model typical in schools (Mehan, 1979). And though she uses productive discourse moves she does not seem committed to the affordances they provide for scaffolding student sense making or she is simply struggling to implement them.

During her self-analysis Alex specifically discusses that she had a "desired outcome" for discussions and knew what she "wanted her students to say". While it is important for teachers to have learning objectives, specific verbal objectives during discussions is not only setting up a guessing game like atmosphere where the students need to discern what the teacher wants them to say it also potentially shuts down student willingness to participate

thus countering the scaffolds provided for sense-making by the Teaching Science as Argument Framework and productive discourse moves.

What is notable about Alex is her willingness to try to integrate productive discourse and her desire to use discourse to co-construct meaning of scientific phenomenon with her students. Because her mentor teacher does not often teach science Alex has not benefitted from the TSAF being modeled in a classroom room rather she has only experienced it as a learner in the methods course. So while she struggles with implementation her struggle is valid and potentially an important step in her learning to teach science in the elementary school classroom. On the final day of the methods course the Interns shared excerpts from their teaching videos and discussed what they had learned from their teaching; Alex shared that at times she sounded, “short” and “sarcastic” while answering her students’ questions and that she wanted to be able to be able to interact with her students more effectively in the future.

# Chapter 7

## FINDINGS AND DISCUSSION

Science education research has documented the challenges faced by preservice teachers (E. A. Davis et al., 2006), the limitations of their field experiences (S. K. Abell, 2006), how they tend to not have a sophisticated understanding of the practices of science (V. Akerson et al., 2006), and how they often have discouraging experiences in their science content courses (Smith & Anderson, 1999). But what often goes unnoticed is what it looks like when preservice teachers get it right and what they are capable of when prepared to teach science in a way that is grounded in research and coupled with effective modeling. In 2009 a paper set was published in the journal, *Science Education*, which outlined a research-based agenda for elementary science teacher educators to focus on during teacher education experiences. The themes consisted of a focus on problems of practice, the need to include dialogue about these problems of practice in preservice elementary science courses, and a commitment to developing tools to help support preservice teachers as they learn to reason about problems of practice (E. A. Davis & Smithey, 2009; Schwarz, 2009; Zembal-Saul, 2009). The research presented in this study builds off of the goals outlined in the paper set and describes what three preservice elementary teachers are capable of achieving in their field placements when prepared to teach using a discursive model of meaning making grounded in a coherent framework for teaching and learning science.

The questions guiding this qualitative case study served to merge each component of the work from the review of pertinent literature to the choice of guiding frameworks, data collection, and analysis. They encompassed and led the direction of the research with each step adding to the complexity and comprehensiveness of the inquiry. Because case studies

allow researchers to maintain the holistic and meaningful characteristics of events, "answers" do not emerge from the data per se but rather findings common to all participants serve as guides to the formation of theoretical propositions generalizable to wider ranging populations (Yin, 2003). The research questions directing this case are:

1) What is the nature of three preservice elementary teachers' learning experiences in their science methods course?
2) In what ways do the preservice teachers use productive discourse strategies to attempt to support students in meaning making of science ideas and practices in their initial science teaching experiences? How else do they attempt to do this?
3) How do the preservice teachers make sense of their initial science teaching experiences through video based analysis of their practice?

In addition to the research questions this case study was also grounded by three starting propositions: 1) what occurred in the methods course influenced how preservice teachers participated in their placement classrooms; 2) preservice teachers are capable of negotiating some of the complex dialogic practices associated with scientific argumentation in their early field experiences; and 3) if the participants had a strong understanding of the affordances of structured discourse practices, they would use their discursive choices as part of their self-analysis as evidence of how they co-constructed scientific explanations with their students.

Using these four questions and three propositions as guide posts, data analysis resulted in the analytic narratives in chapters five and six. Findings emerged from these analytic narratives that address the research questions and inform the meaning of the case. The following section describes, discusses, and provides examples of each finding followed by a chapter discussing how these findings can be theoretically and practically built upon. The study findings are:

1) Throughout the methods course, instructors modeled how the Teaching Science as Argument Framework can be used to negotiate scientific understanding by employing a Discursive Model of Meaning Making.
2) During lesson plan conferences the Discursive Model was emphasized as participants planned classroom discussion and explored possible student responses enabling them to anticipate how they could attempt to increase student understanding.
3) Participants displayed three distinct patterns of adoption of the Teaching Science as Argument Framework (TSAF), involving different discursive practices. They were,
    - Detached Discursive Approach: Use of some discursive strategies without an apparent connection to the TSAF.
    - Connected Approach with a Focus on Student Thinking: Intentional use of the Discursive Model informed by aspects of the TSAF.
    - TSAF Approach: Priority is given to the TSAF supported by substantial application of the Discursive Model.
4) The evidence participants chose to highlight in their self-analysis videos is reflective of their patterns of adoption of the Teaching Science as Argument Framework and their differing discursive practices.

**Finding 1:** Throughout the methods course, instructors modeled how the Teaching Science as Argument Framework can be used to negotiate scientific understanding by employing a discursive model of meaning making.

During the methods course interns participated in science as learners, planned science lessons as teachers, and reflected on their work to inform future practice. Reasoning publicly

and using consistent language from a coherent framework were constant guiding constructs. These constructs were the basis for a discursive model of meaning making that was the foundation of the course and that the participants (Meredith, Hadley, Alex) carried forward into their initial science teaching.

Evidence of a discursive model of meaning making was seen on the first day of the methods course when April (course instructor) asked the group what claims they were able to form about the strength of magnets, then pressed them to provide evidence to back-up their claims.

> *"And what claim were you able to make?"*
> *"Some magnets are stronger than others?" Sarah records this under the L section of the KLEW chart.*
> *"And what evidence did you find to support that claim?" April prompts.*
> *"The large round magnet held five paperclips in a chain and the small round one held two." Sarah adds this to the E section of the KLEW chart and draws a line connecting this evidence with the intern's claim.*
>
> (ecb.day1_fieldnotes.9/15/09)

Reasoning publicly through the formation of claims supported by scientific evidence is the most prominent construct from the methods course and one that the participants showed a strong commitment to in their teaching and reflections. This construct is displayed in each subsequent meeting of the methods course, is discussed during the lesson plan conferences, used in the participants' teaching and discussed in their reflection on their practice.

The course had a consistent frame and explicit focus. Each class session, the instructors introduced a specific science concept and added a deeper layer of meaning by establishing a pedagogical theme giving purpose to and shaping the nature of the investigation. For example, participants investigated circuits and electricity while focusing on accessing and assessing their students' prior knowledge. The instructors (April and Sarah) had the interns

perform a Quick Draw & Write, which is a strategy for teachers to elicit their students' prior knowledge on a topic. "Here's your Quick Draw & Write. You have a baggy with a battery, a bulb, and a wire and you are going to draw how you think they need to be arranged to get the bulb to light" (ecb.day3_fieldnotes.10/6/09). This was done not only for April and Sarah to understand what the interns knew about electricity, but also so the interns would understand how to perform a similar assessment with their students. April then sorted the responses into three piles just as she wanted the interns to do with their students' answers, "When you get them you are going to sort them into piles, the people who are able to use the materials to figure out the problem, those who need more time exploring with the materials, and those who don't know what they are doing" (ecb.day3_fieldnotes.10.6.09). In this way April explained not only how to assess student prior knowledge, but the interns were able to experience why having this understanding as a teacher was important. The importance of understanding students' prior knowledge was also discussed during the lesson plan conferences. Both April and Sarah asked the participants about their students' prior knowledge and discussed how that understanding could be leveraged to increase student investment in the lessons and improve their understanding of the science concepts.

Each class started with a short discussion period where participants shared their successes and concerns from their week in their placement classrooms. The instructors then transitioned the class to perform scientific investigations by posing a driving question that enabled the participants to experience science as inquiry and argument from the perspective of a learner. An example of a driving question used in the methods course was seen when Sarah introduced the investigation on light and shadows. She used her experience as an elementary teacher to add meaning to what the interns were doing, "I start with 'Can we find

shadows in our classroom?' because many first graders often think you only have shadows outdoors, then I'd ask them what would happen if we took the shades down and some think it would be better and some think it would be worse" (ecb.day4_fieldnotes.10/13/09). During the investigation the interns worked on the same problems the instructors' elementary students did. Sometimes this led to frustration as seen here when a group of interns was unable to get a lightbulb to light by using one wire and one battery.

> *"This is what I'm thinking," an intern connects the battery, bulb and wire but it does not light, "Is there really a way to do this? Can it really light?"*
>
> *"Well I feel dumb" says her partner, "let's try it this way." Once again the bulb does not light."*
>
> (ecb.day3_fieldnotes.10/6/09)

Other times it led to feeling of accomplishment as seen when Derek and Meredith were making predictions about how many pennies it took to lift an object using a lever.

> *"Yup." Derek assures, "Good call!" Meredith's prediction of adding three pennies to the end of the lever is working.*
>
> *"I can't help it if we're geniuses!" Meredith gushes.*
>
> (ecb.day10_fieldnotes.11/10/09)\

But ultimately the investigations illustrated to the interns how much they did not learn during their own K-6 science learning. The goal of these experiences was not to frustrate the interns, but rather to demonstrate effective science teaching and learning. More specifically, the investigations engaged students in public reasoning and group meaning making through a discursive model that showed how students learn science and can become excited to investigate natural phenomenon. Interns reflected on the influence of these experiences on their emerging perspectives about teaching science,

*"I've grown to have a better appreciation for science. I never really liked it in school but now my mentor wants me to take over teaching science when we come back because the kids are so engaged and want to learn."*

(ecb.day12_fieldnotes.12/1/09)

*"I always remember science being boring but one of my kids said, 'I learned stuff but I still had fun doing it!'"*

(ecb.day12_fieldnotes.12/1/09)

During investigations the participants worked in cooperative groups and the instructors moved from group to group engaging them in discussion about what they were noticing and how their observations could inform their responses to the driving question. During these times the instructors consistently used productive questioning techniques to press the interns' thinking. For example, when the interns were investigating cockroaches, April used productive questioning to scaffold the interns' abilities to make sense of what they were seeing.

*April approaches group, "So what are you noticing?"*
*"It uses its antennae to sense what's around it."*
*"How do you know that?" pushes April.*
*"It reacts with its antennae when I touch them and it doesn't seem to like being touched on them."*
*"So what differences are there in the antennae?"*

(ecb.day2_fieldnotes.9/22/09)

After each investigation the group unpacked their work from the perspective of a teacher using an integration of talk moves and language from the TSAF. For instance, after the group investigated the properties of matter, they discussed public reasoning, forming explanations, using KLEW charts as a way to scaffold meaning making, and the importance of having students experience the practices of science.

*"What elements of teaching science as inquiry did Sarah do?" April questioned.*
*"They had to explain their thinking." mentioned an intern.*

*"They had to come up with the definitions", says another, "Sarah didn't tell them."*

*"But it took a long time do you think it was worth it?" posed April.*

*"Yeah because they really knew it."*

*"Did you notice," Sarah inquired, "when I put up the K part of the KLEW chart? I didn't just say 'What do you know?' but I gave them a chance to sort (the materials) then once they had that experience we went back and added to the Know section."*

(ecb.day12_fieldnotes.12/1/09)

Finally, each class concluded with either a video vignette of actual classroom practice or opportunities to work in groups to plan, reflect on, or revise their own teaching units. After viewing a video of a first grade classroom investigating magnets, the group discussed what they saw.

*"What did you see happening that made you think the class was a community of scientists?" The interns respond in a very open discussion without raising hands.*

*"Asking many questions such as 'Do you have something to share?'"*

*"Using the language of science like 'evidence', 'wondering', and 'claim'"*

*"Gave students wait time."*

*"Asked if any other students saw the same pattern."*

(ecb.day1_fieldnotes.9/15/09)

**Elementary Teachers as Instructors.** In addition to a discursive model of meaning making, the instructors also used examples from their experiences as elementary school teachers to illustrate how such practices were possible and fruitful when working with elementary school students. Videos of science talks conducted in their classrooms were analyzed and the participants were able to inquire directly about what they were seeing and how it impacted student understanding. To demonstrate student learning, the instructors used examples of student work to illustrate what is possible for elementary school students to accomplish at different grade levels.

Not only did the participants experience scientific practices as learners, they were able to visualize these practices in action in elementary school classrooms. The practices of the methods course were images of what was possible in elementary science lessons. A complaint often heard from beginning teachers is that what is taught in methods courses is great "in theory," but it would never work in real classrooms (Sadler, 2006). Because the methods instructors in this study held duel positions as university instructors as well as elementary school teachers they were able to overcome the impression that similar practices would not work in real classrooms. The perspective provided by the instructors enabled the participants to understand that the implementation of scientific practices, as called for in the New Framework for K-12 Science Education (NRC, 2011), is not only possible but also worthwhile and beneficial in terms of supporting meaningful science learning. Video evidence of elementary students participating in similar science talks served to bolster the participants' understanding that such experiences were not only integral to their own learning but for their students as well.

The methods course brought preservice teachers in contact with instructors who were experienced elementary school teachers deeply committed to teaching investigation and discussion based science in their classrooms. These instructors modeled productive discourse moves while leading investigations and the participants experienced the power of a discursive model of meaning making while engaging in science talks. Lave and Wenger (1991) articulated how learning is not the passing on of a body of factual information, but rather a process of participation emphasizing the whole person where agent, activity, and the world are intertwined. The participants in this study were not told to teach science using a discursive model of meaning making, but rather they experienced the power of public sense-

making while engaging in scientific investigations and subsequently took up these constructs for use in their own teaching.

The first starting proposition for this study was that what occurred in the methods course influenced how preservice teachers participated in their placement classrooms. The data from the participants' teaching sequences and self-analysis provide clear evidence supporting this proposition, and will be discussed in findings three and four.

**Finding 2:** During lesson plan conferences the discursive model was emphasized as participants planned classroom discussion and explored possible student responses enabling them to anticipate how they could attempt to increase student understanding.

During lesson plan conferences the participants (Meredith, Hadley and Alex) and methods course instructors (April and Sarah) discussed elements that might be typical of lesson planning, including mechanics, classroom management, anticipated problems, and the tone of the lessons. What stood out, however, was that these elements were not the main focus of the conferences. The groups concentrated on questions the participants could ask while leading investigations, listening to students, using student ideas during discussion, as well as specific claims students could make and how they could respond to student comments. This sort of planning allowed for the preservice teachers to offer guidance and assistance appropriate to their students' abilities and understandings (Wells & Chang-Wells, 1992).

An example of instructors and participants planning for student discussion is shown below. In this example, April asked Meredith what claims she would like to hear from her students about the angle of shadows. She then expands the scope of the discussion by posing

follow-up questions Meredith could ask her class. Finally, April suggests how the interns could respond if their students said that the shadows changed because the sun moved. April took their discussion beyond the planning of questions to include how the interns could potentially respond to their students during class discussions. By doing this she helped the interns smooth out the mechanics of the lesson and freed them to focus on their students rather than on what they themselves should be saying.

*"And what kind of claims would you like them to make about angles?"*
*"That the shadow is on the opposite side."*
*"They've had a chance to experiment and you bring them back and say, 'How did you change the shadows?', 'You moved the what?'"*
*"lightsource" states Meredith.*
*"And what happened outside?" asks April.*
*"They'll probably say the sun moved." replied Evelyn.*
*"So" says April, "you'll ask them, 'How can you change the shadow by moving the surface?' And that is your segue into talking about day and night and using the earth to make shadows?"*

(ecb.day6_fieldnotes.10/20/09)

During Hadley and Sarah's first conference they also planned specific questions and potential responses Hadley could use during her teaching. In the following example, Sarah discussed a conversation sequence that could potentially take place during Hadley's teaching. She stated questions Hadley could ask, posed how students could potentially respond, and added how Hadley could follow-up with the student.

*"I want you to think about some questions and what they will say and how could you turn that into them looking closer and it's all about getting them to learn more about the cockroach and think about what we did (in class) that day, maybe the cockroach isn't moving and you'll ask, 'Why did you think it isn't moving?' and they might say, 'I think it doesn't like the light' and you'll say, 'Well here's a box, how could you figure it out?'*

(ecb.day5_fieldnotes.10/19/09)

Sarah also asked Hadley to draft a KLEW chart and include specific claims her students could make based on what they observed during the lessons. This exercise helped to keep Hadley on track during her teaching and gave her permission to not take on every point her students brought up; helping her to remain focused on specific preplanned science concepts.

*"And I want you to turn in an actual KLEW chart you draft with your lesson plans because that will help you know the learning you want them to have and the evidence you want them to see and it will help you to remember to ask certain questions."*

(ecb.day5_fieldnotes.10/19/09)

For Alex, planning questions took the form of an open brainstorm between her and April.

*"So they'll be making observations and drawing …" Alex drops off as she is writing.*

*"answering the question, 'is this an insect?'" finishes April. "What types of questions can you be asking while they are observing?"*

*"Like 'What are you noticing?'" replies Alex.*

*"Questions to focus them like 'How many legs, body parts …' April prompts, "You also want to be careful with the language you use because you want to say 'animal' not 'insect' so you're not answering their question for them."*

*"Oh that's good information." Alex answers brightly.*

*"The second day you'll ask?"*

*"How do they move, what does this remind you of?"*

(ecb.day8_fieldnotes.10/29/09)

Regardless of how the individual discussions took shape it is important to note that each participant was not only encouraged to use a discursive model of meaning making, they also planned for what they could as their students, how their students might respond to their questions and even how the participants could respond to the students. They also discussed how they could help their students focus on specific pieces of data that could be used to address the lesson's driving question(s).

Evidence the participants utilized the questions planned during their conferences can be traced between their discussions during the conferences and the discussions they have

with students during their teaching sequences as seen in the following example beginning with conversation during the lesson plan conference between April and Meredith.

*April says to Meredith, "They've had a chance to experiment and you bring them back and say, "How did you change the shadows? You moved the what?"*

(ecb.day6_fieldnotes.10/20/09)

On the second day of Meredith's teaching she participates in the following exchange with one of her students.

*Ava: Because our shadows were bigger.*
*Meredith: Why were they bigger? [resn: id ptts] Was there something different about where the light was?[cmp: id ptts]*
*Ava: Yeah the flashlight was up high.*

(ecb.md2.teachvid.11/09)

Planning discussion in this way is significant because pre-service teachers often use simple, authoritative talk patterns, and there is not always a correlation between talk type and the content and objectives of the lesson (Viiri & Saari, 2006). Planning elements of classroom talk created opportunities for the participants to focus on how discussion could help students negotiate the meaning of explanations underlying the scientific phenomenon they were observing, rather than focus on whether their questioning was on track. Evidence for this was seen in how Alex reflected on her practice when she said, "Students made claims to answer our wonderings from the evidence they gathered while observing … The relationship between learnings and evidence is very apparent in this lesson format" (ecb.asavid.expn1.12/09). Hadley discussed the value of student sense-making through discourse in her self-analysis. "I realized the less I talk and the more the student does, the stronger his understanding became" (ecb.hsavid.expn2.12/09). Meredith also referenced the value of student talk in her self-analysis by presenting a clip of students talking and then

reflecting on their talk by saying, “They are beginning to explore the relationship between the shadow’s shape and the location and the position of the sun in the sky” (ecb.msavid.expl2.12/09).

April and Sarah both indicated that students made sense of the science concepts through talk and encouraged the participants to have students interact with science phenomena using questioning to focus student attention prior to introducing science terms and/or labeling diagrams. April tells Alex not to hand out a pre-labeled diagram of the anatomy of a walking stick but rather to wait, “After they look at the insect them tell them (the names of the parts) because it will have so much more meaning to them” (ecb.day8_fieldnotes.10/29/09).

The instructors’ commitment to having students experience science takes on a more explicit form during the conference between Hadley and Sarah. Hadley asks,

> *“And I feel like if they don't have an activity or actual worksheet then it isn't a lesson but you seem to be saying that observations are fine?”*
>
> *“So some people are not comfortable with that,” replies Sarah, “and you could say have them observe for five minutes and then gather them together and ask them what they noticed about the cockroaches legs and say, ‘look at those legs, what do you think they can do with those legs?’ and then go figure it out by saying, ‘Come up with two to three things you think the cockroach can do with their legs.’*
>
> (ecb.day5_fieldnotes.10/19/09)

The need for students to experience science and then make sense of their observations through discourse is more implied for Meredith than for Alex and Hadley. This may be due to Meredith being April’s intern, so she has first-hand experience with how April conducts science lessons.

> *“So they are going to collect data one day but you're not going to be able to talk about it so you'll need another day to talk about it and maybe that could be on the*

*back, 'What did you notice?', 'What's going on with the shadow?', 'Is it skinny, is it wide?' and I hear (from my students) all sorts of things they can add to the KLEW chart …"*

(ecb.day6_fieldnotes.10/20/09)

April and Sarah also shifted the focus of the conferences from what the participants would be "teaching" ie. telling, to what the students would be doing and saying. This included the utilization of students' prior knowledge and how student thinking could be used during class discussions. This shift in focus enabled the participants to think about students' ideas and visualize the outcome of the lessons rather than simply focusing on the particulars of the lesson. This sort of shift exemplifies learning according to the sociocultural perspective where learning is a process of interaction, conversation and activity (Minick, 2005; Vygotskiĭ, 1978; Wells, 1999; Wells & Chang-Wells, 1992).

During the lesson planning conferences each instructor asked the participants about what their students already knew about the science topic, and referred to an assignment the participants had completed where they interviewed students about their prior knowledge. April immediately went beyond the mechanics of lesson planning by saying to Meredith, "So I had a chance to look at your Concept Interview and now I want you to give me an impression of what will be important in your lessons" (ecb.day6_fieldnotes.10/20/09). By saying this she urged Meredith to think about the science concepts her students should understand by the end of her teaching. April was also very explicit when asking Alex about her students' prior knowledge. "From your Concept Interviews what do you think is going to be important to get your kids to form some claims?" (ecb.day6_fieldnotes.10/20/09). Sarah integrated the need to use student ideas throughout her conference with Hadley but did not specifically inquire about what her students already knew. "… we want to value what your students think and not just randomly collect ideas and not do anything with them"

(ecb.day5_fieldnotes.10/19/09). Utilizing students' prior knowledge and focusing on student thinking is a common theme in methods courses, but an area that is typically overlooked by preservice teachers when it comes time to plan lessons (Zembal-Saul et al., 2000). Each participant integrated students' ideas and prior knowledge into their lessons, at times superficially, such as when Meredith mentioned the Quick Draw & Write assignment they had completed. At other times this took the form of an in-depth discussion, for instance when Hadley worked to understand what her students knew about insects.

*Hadley: Does anyone else know anything about insects? Anyone else? Caleb? [prmt:prdt]*
*Caleb: Some bite.*
*Hadley: Some bite [revoice:prdt] oh that's a good one. [dclr:prdt] (writes on Know section of KLEW chart) Some bite. [revoice:prdt]*

(ecb.hd1.teachvid.11/09)

Of the three participants, Hadley demonstrated the strongest commitment to using student prior knowledge in her teaching. She was very intent on understanding what her students knew about insects and asked them about their prior knowledge at several points in her teaching. She also used her students' ideas to craft questions they could explore when they returned to their investigations. Though her commitment is noteworthy, she needed to continue to improve her integration of talk moves into her classroom discourse. For example, she would often ask about students' prior knowledge then follow-up with a talk move prompting students to explicate their thinking or provide evidence for how they knew what they had shared. Since these discussions occurred before her students had experienced the investigations they did not have evidence to support their ideas and would indicate their confusion with Hadley's questioning by pausing for long periods of time before answering.

*Hadley: Does anyone else know anything about insects? Oh I love all these hands. [clssrm mng:prdt] Daniel what do you know about insects?[prmt:prdt]*
*Daniel: They have six legs.*

*Hadley: They have six legs. [revoice:prdt] How do you know that Daniel? [non-pro resn:prdt]*
*Daniel: um because … (nine seconds) [wt tm:prdt] I don't know.*

(ecb.hd1.teachvid.11/09)

Another noteworthy element of the lesson plan conferences was their focus on data and evidence collection. Each instructor wanted to know what specific data the students would be able to collect, how they would collect it, and what they would do with it once it was gathered. They discussed how to scaffold making sense of the data by using KLEW charts and had the participants map out specific claims the students would be able to form based on the evidence they collected. This helped the participants focus their science talks and lead the discussion in a potentially fruitful direction. Rather than just hoping students would eventually come around to an appropriate claim, the participants had a clear expectation of what claims could be made from the data and they were able to identify points in the discussion that they could leverage to reach those claims as seen in the following exchange during Meredith's lesson plan conference.

> *"And what kind of claims would you like them to make about angles?" April asked.*
> *"That the shadow is on the opposite side." answered Meredith.*
> *April then focuses on lesson mechanics and what the interns can ask their students during their teaching, "They've had a chance to experiment and you bring them back and say, 'How did you change the shadows?', 'You moved the what?'" "light source" states Meredith.*
> *"And what happened outside?" asks April.*
> *"They'll probably say the sun moved." replied Evelyn.*
> *"So" says April, "you'll ask them, 'How can you change the shadow by moving the surface?' And that is your segue into talking about day and night and using the earth to make shadows?"*
>
> (ecb.day6_fieldnotes.10/20/09)

Though it is argued that planning for specific claims students could make enabled the participants to keep the science talks focused on relevant aspects of the investigation, such planning could also have hampered the participants' abilities (or willingness) to listen for students' emergent ideas. This possibility was particularly demonstrated in Alex's self-analysis when she said she, "… knew the outcome (she) wanted …" (ecb.asavid.expl2.12/09) and, "Some of the students would have become sidetracked by their fascination with insects …" (ecb.asavid.expl5.12/09).

In summary, during the lesson plan conferences instructors allowed participants to discuss their struggles concerning the mechanics and management of their lessons, and then refocused their discussions on a discursive model of meaning making. These included preparing specific questions the participants could ask during investigations and planning for claims the students could make based on the evidence they would be able to collect potentially enabling the participants to focus on the meaning-making process rather than on formulating questions on-the-spot. Planning for classroom talk also helped to counter the tendency of preservice teachers to utilize simple, authoritative talk patterns and to merely cope with the classroom situation rather than plan for or interact with students based on mutual input (Viiri & Saari, 2006). Of course, the participants diverged from these planned questions and were able to personalize the lessons, but they had a place to fall back to if they became stuck.

**Finding 3:** Participants displayed three distinct patterns of adoption of the Teaching Science as Argument Framework (TSAF), involving different discursive practices. They were,

- Detached Discursive Approach: Use of some discursive strategies without an apparent connection to the TSAF.

- Connected Approach with a Focus on Student Thinking: Intentional use of the Discursive Model informed by aspects of the TSAF.
- TSAF Approach: Priority is given to the TSAF supported by substantial application of the Discursive Model.

The participants (Meredith, Hadley, Alex) consistently showed commitments to using the discursive model of meaning making in their teaching but how they implemented their commitments varied in practice. They all attempted to adopt a Discursive Model in their teaching and their commitments were demonstrated in the discursive choices they made when negotiating science explanations with their students, as well as when they were guiding students in data collection. Though their attempts to negotiate the complex interchanges involved in discursively making-meaning of science concepts was not always flawless it is important to recognize that each participant used discursive tools to co-construct meaning with their students rather than reverting to a direct instruction method. The descriptions of the participants' initial science teaching represent images of adoption describing which elements of the discursive model of meaning making and the TSAF the interns attempted in their teaching. Please note, in the descriptions of the images of adoption the term "approach" does not imply an intentional choice on behalf of the participants.

This study argues that Alex represents an image of a Detached Discursive Approach. She has integrated some aspects of the language of science into her science teaching and used selected pieces of the Discursive Model. However her use of these constructs does not seem to be connected to the TSAF. Hadley represents a Connected Approach with a Focus on Student Thinking. She integrated several aspects of the TSAF into her science teaching but seemed to struggle with the constructs in practice and was actively involved in making sense

of teaching science as seen in what she chose to highlight as evidence in her self-reflection. Meredith represents an image of a TSAF Approach. She gives priority to the TSAF in her teaching and used the discursive model of meaning making in a consistent and balanced manner.

This finding provides support for the first two propositions guiding this study, 1) what occurred in the methods course influenced how preservice teachers participated in their placement classrooms, and 2) preservice teachers are capable of negotiating some of the complex dialogic practices associated with scientific argumentation in their early field experiences.

**Detached Discursive Approach**. Alex adopted some aspects of the Discursive Model and used selected pieces of the language of science though her use of these constructs seemed unconnected to the Teaching Science as Argument Framework (TSAF). The language of science is highlighted as one of two constructs of the TSAF that connect and encompass the entire framework. According to the sociocultural theory of learning, it is through language that learning occurs and how the co-construction of meaning takes place (Wells & Chang-Wells, 1992). Vygotsky argued that learning takes place through participation in social activities mediated by semiotic tools, language being chief among them (C. D. Lee & Smagorinsky, 2000; Minick, 2005; Vygotskiĭ, 1978). Since the language of science is typically viewed as abstract, conceptually dense and awkward to use (Kelly, 2008) preservice teachers and/or anyone not familiar with it can be considered non-native speakers. Thus they have to practice using the language before they will be able to understand other aspects of the culture of elementary school science. Consequently adopting select pieces of the language of science and some aspects of the Discursive Model are

essential steps in understanding and becoming acculturated into the culture of science in the elementary school.

Evidence from Alex's teaching indicated she recognized her students should be co-constructing meaning according to the Discursive Model employed in the methods course but that she was not able to fully embrace this learning theory during her initial science teaching. In the following example Reese, a fourth grade student in Alex's class, said she thought all insects had exoskeletons. Alex began to respond with an evaluative statement but then corrected and presented Reese with a question, which probed her understanding of the term.

*Reese: Um I think that all insects have an exoskeleton.*
*Alex: Ooooh that's a – [declr:vocab] What does exoskeleton mean? [recall:vocab]*
(ecb.ad1.teachvid.11/09)

During another interaction with her students Alex used productive questioning strategies and talk moves to revoice student contributions. However when it came to the point where the group could have been discussing the meaning of their observations Alex cut them off saying, "Don't tell me." She provided clear evidence that she used some elements of the language of science and certain constructs of productive discourse but did not follow through with the learning theory behind the practices. In the discursive choices Alex chose to employ she showed which sort of socially meaningful role she was enacting. In Alex's case, she is demonstrated she was not fully enacting a social perspective on learning (Gee, 2008, 2011). But it is through talk that students and teachers co-construct meaning (Wells & Chang-Wells, 1992). Learning is a process of discursively making sense of cultural experiences; when a teacher does not engage with his or her students in co-dialog then they are not teaching in accordance with the sociocultural perspective which informs the discursive model and the TSAF.

*Alex: What do you notice about this one?[attn fcs:phenom]*
*Cora: It looks like a leaf.*
*Alex: It looks like a leaf. [revoice:phenom]… ) Now what have you noticed about its legs? [attn fcs:phenom] What do its legs look like? [cmp:phenom]*
*Parker: Spikes.*
*Alex: They look like spikes. [revoice:phenom]*
*Parker: They look flat.*
*Alex: They look flat.[revoice:phenom]*
*Grace: and leafy.*
*Alex: and leafy, [revoice:phenom] very good. [dclr:phenom]*
*Drew: It looks like a mix of-*
*Alex: Don't tell me I want you to write it down. [ntbk:dta]*

(ecb.ad1.teachvid.11/09)

To wrap-up her lesson, Alex asked the class about the number of body parts an insect has. In the methods course this would have been the time when the instructors would have asked the interns to provide claims supported by evidence to address their driving question. Alex did not prompt for claims, rather she asked her students how many body parts the group noticed then asked them if they thought they knew the same was true for all insects. The group did not provide evidence for their claim nor were they prompted to do so. Alex employed productive questioning when she asked what body parts her students noticed rather than simply asking how many body parts an insect had. Nevertheless she cut off the investigation process considering her students had collected evidence on insect body parts and could, if properly scaffolded, have made connections between what they had seen and what the data could mean for all insects. Instead this interaction provided further evidence that Alex is beginning to use the language of science and productive discourse in her teaching by asking for what her students "noticed" but that she had not progressed further in the adoption process by having her students supports their statements with evidence.

*Alex: I have a question because I don't know but some of you might know. How many body parts did you notice? [msr cnt: dta] Paul?*
*Paul: Three.*

*Alex: Three body parts, [revoice: dta] do you think that just this insect maybe has three body parts or do you think all of them do? [resn:arg bld]*
*Kenley: All of them.*
*Alex: All of them?[revoice:arg strc] Do we think we know that? [klew:arg strc]*
*Group: Yes (Alex writes, 'Insects have three segments' on the Know section of the KLEW chart).*

(ecb.ad1.teachvid.11/09)

There is further evidence to support Alex as an image of someone who has adopted some of the language of the Discursive Model but who is not making connections the TSAF. After Alex's students have collected data on how animals adopt over generations, their group discussion did not utilize that evidence to form scientific explanations of the phenomena. Alex seemed to listen for her students to say certain key words like, generations, evolving and adaptation and as soon as those words were shared she moved on to another concept. This sort of talk could be seen as non-productive because there was no way to gauge whether the class truly understood the science concepts.

*Alex: How long do you think it would take for the brown to be the dominant color of the species? [non-pro:expln] Paul?*
*Paul: Generations.*
*Alex: Yes generations. [ire:expln]*
*Paul: because they're evolving.*
*Alex: Yes evolving. [ire:expln] So what is our conclusion? [resn:expln] Adaptation's … what? [prmt:expln] Cora?*
*Cora: Adaptation is …. mostly good?*
*Alex: Adaptation is good … [dclr:expln]*
*Cora: for those that can camouflage well.*
*Alex: Well camouflage is an adaptation so let's wait, adaptation is good and let's talk about how long it takes to adapt, something about how long it takes. [dclr:expln] ….*
*Alex: OK. Let's talk about our conclusion we're coming to. [dclr:expln] Adaptation is good … Paul? And it happens ….? [prmt:expln]*
*Paul: Over a long time.*
*Alex: So did we learn that these Walking Sticks didn't just turn brown and get leaf legs in a day?[non-pro resn:expln]*
*Group: No.*
*Alex: Right it took them a long time to do it. [ire:expln]*

(ecb.ad3.teachvid.11/09)

This study is not arguing that Alex did not teach well or that her teaching was less-than in some way. Rather it is noteworthy for Alex to have attempted to teach in this manner at all considering her mentor teacher did not typically include science in her classroom. What is being argued is that all preservice teachers are Legitimate Peripheral Participants in the elementary school science community and thus have to make sense of the discursive model and TSAF in their own way following their own personal trajectories of understanding and practice (Lave & Wenger, 1991). The theory of Legitimate Peripheral Participation suggests that there are multiple ways of being engaged in the social workings of a community. Each individual travels along learning trajectories or individual pathways of learning as his or her identity within the community develops (Lave & Wenger, 1991). Alex is an image of someone whose learning trajectory involves working to develop competence with the language of the discursive model and the TSAF. Which is arguably an essential first step in the continued adoption of teaching science as a discursive practice of meaning making.

**Connected Approach with a Focus on Student Thinking.** Hadley represents an image of someone who used many aspects of the Discursive Model of Meaning Making in her teaching. She demonstrated a strong focus on probing her students' prior knowledge and misconceptions and pushed to understand how they were making sense of the science phenomena. She showed a strong commitment to using the constructs of the Discursive Model and the TSAF though continued to be challenged by them in practice. It is important to note that struggling with the implementation of teaching practices is a common challenge for preservice teachers (E. A. Davis et al., 2006). What is important is that she very deliberately worked to incorporate the constructs of the Discursive Model into her teaching

and attempted to increase her students' understanding of epistemic aspects of the TSAF. Including why making observations, performing fair tests and forming claims supported by evidence are important parts of science learning. She enacted the discourse of a teacher who is using a discursive model in her teacher and so is displaying the socially meaningful role of an elementary teacher who teaches science discursively (Gee, 2008, 2011). Hadley's individual trajectory differed from Alex's in that Hadley returned to the importance of talk and pushed her students to understand what they could learn from the formation of claims supported by evidence. Hadley also demonstrated how she worked to make sense of the constructs of the TSAF by what she chooses to highlight in her self-analysis of her teaching.

At the outset of her teaching Hadley attempted to understand what prior knowledge her students held about insects. This is very consistent with the Discursive Model used by the instructors to open investigations in the methods course. Where she began to diverge from their model is how she followed-up her question with other questions attempting to get her student to explicate his reasoning. Though in and of itself this is not problematic, tension entered the exchange because the student had not had any experience he could rely on to support what he had shared and so struggled to provide an answer.

*Hadley: Does anyone else know anything about insects? Oh I love all these hands. [clssrm mng:prdt] Daniel what do you know about insects?[prmt:prdt]*
*Daniel: They have six legs.*
*Hadley: They have six legs. [revoice:prdt] How do you know that Daniel? [non-pro resn:prdt]*
*Daniel: um because … (nine seconds) [wt tm:prdt] I don't know.*
*Hadley: Ok would you like help from a friend? (Daniel nods) Ok does anyone know how, does anyone agree with Daniel? Who agrees with Daniel? [ag dsag:prdt] (several students raise their hands) That they have six legs? [revoice:prdt] (Hadley waits six seconds) [wt tm:prdct] Miah how do we know they have six legs? How do we know? [non-pro resn:prdt]*
(ecb.hd1.teachvid.11/09)

During the methods course Sarah discussed why it is important for students to have experiences with the phenomena but while Hadley demonstrated a strong commitment to understanding her students' prior knowledge and using the KLEW chart she also showed that she had not yet fully made sense of how these tools could best scaffold student understanding.

*"Did you notice" Sarah inquired, "when I put up the K part of the KLEW chart? I didn't just say 'What do you know?' but I gave them a chance to sort (the materials) then once they had that experience we went back and added to the Know section."*

*"This is why we do the Know section after they've had some experience so if you write 'What do you think you know?' they actually know something and I also say we're not deciding right and wrong right now."*

(ecb.day12_fieldnotes.12/1/09)

Hadley's commitment to understanding her students' prior knowledge and discursively making meaning of their ideas is further demonstrated in the following interaction she has with two first grade boys.

*Hadley: (Sean uses his pencil to identify the antenna) What do you think they do with their antenna? [resn:prdct]*
*Todd: They feel with them like this (uses fingers to mime wiggly antenna coming off of his head).*
*Hadley: Do we know that? That they definitely feel with their antenna? [non-pro resn:evd clms]*
*Sean: Yeah.*
*Hadley: Are you sure? [explt resn:evd clms]*
*Sean: Yeah!*
*Hadley: Do we have any evidence to back it up? [explt resn:evd clms]*
*Sean: Yes.*
*Hadley: What is it?[explt resn:evd clms]*
*Sean: Magic School Bus.*
*Hadley: You saw it on the Magic School Bus. [revoice:evd clms] How about with your eyes? Have we seen it with our eyes?[explt resn:evd clms]*

(ecb.hd1.teachvid.11/09)

Hadley demonstrated that she valued her students' ideas by engaging in a lengthy conversation with them about what they thought they knew about bees, the entire interaction was over two minutes long. But once again the boys had not been provided with the opportunity to interact with lives bees and so did not have evidence to back-up what they said nonetheless Hadley still prompted them to provide evidence. Though this revealed that Hadley has not yet fully made sense of the constructs of the Discursive Model and their connection to the TSAF it is striking that Hadley used this interaction in her self-analysis as evidence of what she learned about student talk. She also included her own discursive choices and made connections between her questioning and student learning. Hadley showed that she is thinking about what took place in her classroom and trying to make sense of it in light of what was modeled in the methods course and what she knew about how students learn. She made sense of how her discursive choices influenced student learning.

*The student in the Steelers jersey noticed the antennas. "What do they do with their anteenas (sic)?" They (sic) boy in the red was convinced that they feel with their antennas. He was using outside resources (TV, Magic School Bus, Field Trips) as his evidence as to how he knew these things. As I asked more probing questions [pro ques], "Are you sure?" or "How do you know?" or "What if they are smelling?" he realizes [sts think] that he really doesn't know for sure and we need more evidence. I realized the less I talk and the more the student does, the stronger his understanding [sts lrn] became.*

(ecb.hsavid.expn2.12/09)

Student talk and her own discursive choices were consistent theme in Hadley's self-analysis. She provided examples of student talk, small group and large group discussions and also from her own questioning. Throughout her analysis she made connections between student talk and learning and reflected on how she mediated the learning process through discussion and questioning. Research has shown that preservice elementary teachers are typically more concerned with keeping their students interested, motivated, and physically

involved in science activities rather than on what sense they are making of the science content. Preservice teachers also do not typically have sophisticated ideas about their students' thinking and do not know what to do with those ideas in practice (E. A. Davis et al., 2006). This study provides evidence that novice preservice teachers can pay attention to student thinking and are concerned with how their students make sense of data while forming claims.

Hadley is the only participant to provide evidence that she actively worked to make sense of her teaching in a manner that went beyond the requirements of the assignment. Indicating that Hadley could have been working to make these practices her own and truly incorporate them into her teaching rather than simply using them to fulfill the requirements of the assignment. Hadley represents an image of someone using a discursive approach connected to the TSAF with a focus on student thinking. She is someone who employed a Discursive Model of Meaning Making in relation to the TSAF but also went beyond those constructs. She thought about her own role in the learning process and made sense of how she could best attempt to increase student learning.

**TSAF Approach.** Meredith exemplifies the well-started beginner (Hollon et al., 1991). She emphasized evidence and explanation throughout her teaching. She engaged students in data collection, pattern finding and simple argumentation. She then extended these practices to include writing explanations and addressing driving questions. The evidence indicated that Meredith gave priority to the TSAF in her teaching and successfully employed a Discursive Model of Meaning Making. She also included elements of student talk in her self-analysis, what differentiates Meredith's self-analysis from Hadley's is that she did not include her own perspective on the value of teaching science as discourse or how she

saw it influencing student learning. This is important to note because one of the propositions grounding this study was that if the participants had a strong understanding of the affordances of structured discourse practices they would use their discursive choices as evidence of how they co-constructed scientific explanations with their students. Meredith demonstrated how she was able to integrate talk moves, productive questioning and argumentation into her teaching but did not include these discursive choices in her self-analysis, other than a minor inclusion of questioning. It is important to note that there was also no evidence indicating this was because she did not reflect on her discourse, but rather it could be due to the self-analysis assignment not requiring participants to include elements of their talk in the write-up. This downside could have possibly been overcome by the inclusion of interviews in the data collection process; however, it was beyond the scope of this study.

Meredith exemplifies what science teacher educators hope their students will be able to do when they leave the methods course. She began her lessons by explaining to her students why they were going to be investigating light and shadows and explained how their data collection would proceed. While her students were outside collecting data she moved from group to group asking them questions about what they saw and had them predict what they would see the next time they ventured outside. Meredith did not provide evaluative statements in response to her students and in this way she was the only participant to truly break out of the I-R-E talk pattern (Mehan, 1979). When she asked her students questions Meredith either posed additional questions, asked for agreement from class members and/or added students' ideas to the class KLEW chart. By doing this Meredith empowered her students to talk, interact and share ideas while co-constructing scientific claims. The

following example is evidence that Meredith used talk moves to facilitate student-student interaction (Michaels et al., 2008). Talk moves are semiotic tools of collaborative meaning making through interaction with peers (Wells & Chang-Wells, 1992).

*Meredith: Do you all agree with that? Thumbs up if you agree. [ag/dsag: id ptts] (Waits for the class to raise thumbs or not) So this was the widest shadow?*
*Eddie: That's not what I was seeing.*
*Meredith: You don't agree Eddie?[ag/dsag: id ptts]*
*Eddie: I'd say it's as tall as the twelve o'clock but not as skinny.*
*Meredith: Timmy?*
*Timmy: I think it was like the same, it was as chubby as the twelve o'clock.*
*Meredith: So it was around the same width?[revoice: id ptts] (several students nod)*
(ecb.md1.teachvid.11/09)

Meredith focused the class on the formation of claims through scaffolded (Bransford et al., 2000) discussion. She reiterated the investigations' driving questions, "How do shadows change throughout the day?" and prompted the students to identify differences in their data. She then questioned her students about the patterns they were sharing and when Ruthie shared a potential claim of wherever the sun goes the shadow is in the opposite direction Meredith performed an on-the-spot demonstration then asked for the class' agreement or disagreement before adding the claim to the KLEW chart. Instead of accepting Ruthie's ideas out right, Meredith involved the rest of the class in evaluation of the claim she also prompted students to look at their data to find evidence to support their ideas. She demonstrated a strong commitment to the co-construction of claims based on evidence and performed the socially meaningful role of participant in, rather than leader of, the meaning making process (Gee, 2008; Gee et al., 2005; Wells, 1999; Wells & Chang-Wells, 1992).

*Meredith: How do you know that?[explt resn: evd clms] Look at your evidence of where you wrote where the sun was and look at where you drew your shadows for those times. Does that back-up what Teah's saying? [ag/dsag:evd clms] Was the sun in the opposite direction*

*of the shadow? [recall: id ptts] (several students nod and answer yes) Does anyone agree with that?[ag/dsag: id ptts]*
*Ruthie: When I look at the data I see that at nine o'clock we have a long shadow and the sun isn't very high in the sky but when the sun is higher the shadows get shorter.*
*Meredith: Do you agree with that, the higher the sun was the shorter our shadows were (most of the class nods)? [ag/dsag, revoice: evd clms]*

(ecb.md1.teachvid.11/09)

What stood out about this interaction was how Meredith made sense of it in her self-analysis. She included this instance as an example of her evaluating student understanding. This is significant because Meredith had not planned for this to be the evaluation for this part of the lesson but she was able to recognize that evaluation can take many different forms and does not need to be a pre-planned quiz or project in order to be useful in understanding student's ideas of concepts.

*The evaluation for the first lesson was in the form of a science talk. I was listening to learn about the connections the students had made about the sun's location in the sky, and the shadow that it makes. In this instance, a student made a claim that the sun is in the opposite direction of the shadow (making a kind of diagonal line). To test their understanding, I gave them a hypothetical situation that the wall clock was the sun, and asked them to point to where my shadow would be. They determined that it would fall to my diagonal left. To further ensure their understanding, I asked the rest of the class to look at the data they had collected to determine if that statement was correct, and they agreed that that was (cut off).*

(ecb.msavid.eval1.12/09)

Meredith not only discursively made sense of data with her students she also engaged them in writing their own explanations for the science phenomena. After the class had collected data, identified patterns, formed claims and made connections with evidence Meredith had the group write explanations addressing how shadows changed throughout the day. The students talked about their claims and made sense of the science ideas prior to being asked to write their explanations; they had a foundation of experience to build from. Which, according the Vygotsky, is how learning takes place. Learning is a social process

based on participation in social activities, in this way learners appropriate and make sense of the culture (C. D. Lee & Smagorinsky, 2000; Wells, 1999).

**Commonalities among the Images of Adoption.** Though it was not the intent of this study to compare the participants there are some striking commonalities that are important to note. The participants all demonstrated a commitment to elements of the TSAF. They allowed their students to interact with the scientific phenomenon, gather relevant data and discuss their findings as a group. The participants explicitly scaffolded their students' thinking by providing them with opportunities to experience science and did not simply tell them what science was (K. L. McNeill, 2011). As such the participants co-constructed scientific meaning with their students and experienced elementary students productively engaging in the discursive practices of science (K. L. McNeill & Krajcik, 2008). This process was not always smooth. Participants experienced some difficulties negotiating all of the complexities introduced to a discussion by the students, but they all remained committed to using discursive strategies to co-construct scientific meaning with their students.

This is significant because engaging students in making sense of science phenomena through discourse is an important element in teaching the practices and discourses of science in the elementary school. Regular experience talking science has been shown to increase student-student interaction, improve students' ability to listen to each other and build off of others' thinking, and communicate convincingly. Students have been shown to be better able to ask questions and to have developed better content knowledge, as well as enhanced self-efficacy and a better understanding of the epistemic aspects of science (Zembal-Saul et al., 2013; Zhang et al., 2010). Benefits to teachers for using science talks in the classrooms include an enhanced understanding of and ability to address student misconceptions, while

corroborating evidence of student learning (Zembal-Saul, et al., 2013). Also new perspectives on proficiency in science learning emphasize scientific discourse and practices including developing explanations based on evidence, using argumentation to critique and evaluate scientific ideas, asking meaningful questions, as well as obtaining, evaluating, and communicating information (National Research Council, 2011).

**Finding 4:** The evidence participants chose to highlight in their self-analysis videos is reflective of their patterns of adoption of the Teaching Science as Argument Framework (TSAF) and their differing discursive practices.

The participants (Meredith, Hadley and Alex) compiled annotated videos highlighting what they considered to be best examples of their practice from their initial science teaching experience. These videos were made of clips taken from three days worth of footage and included self-analysis of their work embedded directly under the clips. The videos consisted of examples of how the participants' engaged their students in science lessons, how their students collected evidence to answer driving questions, how the participants evaluated their students and how they conducted science talks with their classes. The clips the participants chose to include and how they analyzed their work serve as further evidence corroborating the images a Detached Discursive Approach, Connected Approach with a Focus on Student Thinking and a TSAF.

Alex represents an image of someone who adopted some aspects of the Discursive Model and used select aspects of the language of science. She did not provide evidence she understood the connections between the pedagogical reasons for using productive discourse or its connections to the TSAF. What Alex chose to highlight in her self-analysis videos

serves as evidence for how she enacted her role as a science teacher in an elementary school classroom.

Alex seemed like the sort of student who always wanted to do what was "correct". She was very studious in the lesson planning conferences, writing down everything April said and agreeing with her almost automatically. In the methods course Alex became frustrated when she could not determine what the "right" answer was to an investigation question. In her self-analysis assignment she included every aspect the assignment called for including the language of science such as, claims, evidence, predictions, observations and wonderings. But her examples were merely instances that she labeled with connections to the teaching framework. She did not include her interpretations about the clips or what she thought the clips represented in terms of her teaching. She provided a very surface level description which fulfilled the requirements of the assignment.

For example, she discussed the role of questions by saying, "I gave them questions …" this is a very direct instruction view of education where the teacher is the knower and the student is the learner versus both parties being co-participants (Wells & Chang-Wells, 1992).

*Before the students began observation (sic), I gave them questions [ques] to help them answer their wonderings. After they observed, I felt these questions were helpful because it kept them on track to make claims supported by the evidence [arg strc] they found.*
(ecb.asavid.expl51.12/09)

In another example, Alex stated her students were making claims and providing evidence for what they thought but she did not discuss how this supported student learning or how this format was useful to inform understanding.

*On the third day of lessons, the claims [arg strc] that we made were a culmination [eval] of the three days. The students were able to draw from what they learned in the previous days and provide evidence for what they thought.*

(ecb.asavid.expn4.12/09)

Hadley represents an image of someone who actively worked to make sense of the affordances of the discursive model and its connections to the TSAF. She used several aspects of the TSAF in her teaching and consistently employed the language of the discursive model but struggled in her implementation. While she used the language of the discursive model she provided evidence that she did not yet understand the pedagogical connections to the TSAF and how the constructs could inform scientific meaning making.

Hadley very purposefully engaged her students in discussions about the practices of science and why fair tests are important. She asked her students to explicate what makes a claim strong and what they could do as a class to make their claim stronger. Hadley was very deliberate in her discursive choices and worked to incorporate epistemic aspects of science into her lessons.

*Hadley: Now that we did two experiments with two different cockroaches do you think that makes our claim stronger or weaker? [resn:arg strc] That it likes warm? (several say stronger) Why does it make it stronger? [resn:arg strc] Natalie?*
*Natalie: If only one cockroach likes it we can't know for sure. Cause if one cockroach likes warm, and others like warm and cold, they might not all like the same thing.*
*Hadley: Good, good. [dclr:arg strc] So if we had time to do all of these cockroaches and they all liked warm we could definitely say that cockroaches like warm better than cold right? [resn:arg strc]*

(ecb.hd2.teachvid.11/09)

Hadley referred to this clip in her self-analysis as an example of her best work. She included student talk and incorporated her own perspective on why it was an important part of her teaching. Her ability to broaden her scope of reflection beyond the stated requirements

of the assignments provided evidence that she thought about her teaching and worked to understand how the practices of teaching science using discourse and the TSAF help to broker student learning. This is important because studies have shown that preservice teachers tend to have unsophisticated and underdeveloped knowledge and skills related to scientific practices (Bowen & Roth, 2005; Lawson, 2002; Windschitl, 2003). So to see Hadley making connections between the scientific practices her students were engaged in and their science learning is notable.

Meredith represents an image of a TSAF Approach. She consistently used the discursive model in her teaching and provided evidence she understood the pedagogical affordance of the model and its connections to the TSAF. She was very balanced in her approach to science teaching. She distributed class time between data collection, sense making including pattern identification, the formation of claims supported by evidence and having students write formal explanations addressing the lesson's driving questions. In her self-analysis Meredith provides evidence that she could recognize and apply several of the constructs of the TSAF. She included examples of students forming claims and supported their ideas with evidence.

*In this instance, a student, based off her experience working with a flashlight and a pipe cleaner person, is able to make a claim that to make long shadows, the light source has to be low.*

(ecb.msavid.eval4.12/09)

She also used student talk as examples of evaluation and sense making.

*Rounding out the science talk for the second lesson, a student is able to recall (with a little help from a classmate) that for the shadows to move in the direction, and size that do, the light source moves in an arc to the left. At the close of this science talk, I feel comfortable in*

*moving on to the final lesson, because my students have been able to talk about what they observed and make accurate claims about their experience.*

(ecb.msavid.eval6.12/09)

As stated previously, Meredith's analysis did not indicate she made connections between student talk and learning or how her own discursive choices affect learning but this could be due to the nature of the self-analysis assignment.

**Commonalities Among the Participants' Self-Analyses**

Each participant provided evidence that she was attentive to student thinking, making connections between the formation of claims and how students thought about scientific evidence. Research has shown that preservice elementary teachers are typically more concerned with keeping their students interested, motivated, and physically involved in science activities rather than on what sense they are making of the science content. Preservice teachers also do not typically have sophisticated ideas about their students' thinking and do not know what to do with those ideas in practice (E. A. Davis et al., 2006). This study provides evidence that novice preservice teachers can pay attention to student thinking and are concerned with how their students make sense of the data while forming claims.

In their self-analyses the participants also discussed the importance of having students make predictions and think about driving questions to give purpose to their investigations. This is important because teachers need to conceptualize the purpose of investigations in their classrooms (Hart et al., 2000) and understand why students should investigate natural phenomena, as well as be able to focus on the specific learning outcomes of investigations. It is important for teachers to be able to do this because science in the elementary school has

historically been an exercise in following directions, not about making sense of data, designing fair-tests, or forming evidence-based explanations. Without this aim, students have been led to believe that science is about controlling variables and filling in data sheets rather than making sense of the world around them (Hart et al., 2000; D. Kuhn & Dean, 2005). When teachers make the purpose of investigations explicit to their students they are better able to make conceptual links between what they are doing and why they are doing it (Hart et al., 2000).

It is also important to note that each participant included discussion of students' conceptual learning. For example, Meredith addressed how she knew what her students took away from her teaching. Please note when Meredith refers to "worksheets" they were not typical fill-in-the-blank pages but self-designed data collection sheets specific to the investigation.

*As the students participated in science talks, we used a KLEW chart to keep track of what we had learned about shadows, the claims they made, the evidence they used to support those claims, and some of the wonderings that came up in conversation. Specifically looking at the "Learned" and "Evidence" sections of the chart, it was clear to me that my students took a lot out of these three lessons, as the major concepts I wanted the kids to come away with, were written on the chart. Worksheets were another way in which I was able to determine if my student's understanding was on the mark. On each day, students had to draw what they had witnessed, or done, and then write about the experience/outcome. This clip includes the work of the two students who clearly demonstrated their knowledge as they as they completed their worksheets. Their drawings are clearly labeled, and their explanations were written using the information we discussed during our science talks.*

*(ecb.msavid.eval7.12/09)*

While making sense of their teaching, each of the participants used the language of the TSAF in how they discussed their practices. The framework is designed to call attention to the importance of classroom discourse using an argument structure based on claims, evidence and reasoning. The TSAF is a learning heuristic intended to promote teachers'

attention to scientific discourse and reasoning in the context of an investigation based learning community. By utilizing the language of science, it is anticipated that preservice teachers would begin to understand the role of language in learning science, as well as how scientists must coordinate claims with evidence to construct and critique scientific explanations (Zembal-Saul, 2009). In their self-analysis, participants specifically referred to the claims their students were able to make and the evidence they used to make those claims. Hadley stood out because she included students' quotations and delved into the pedagogical purposes of her choices which indicates to me that she was particularly thoughtful about the affordances of the TSAF. In contrast, Alex seemed to merely report that her students were making claims based on evidence and not providing a discussion about how this could be important for their understanding of science concepts. Even so it is significant that each participant used the framework in how they made sense of their work. This points towards the idea that the participants were at least beginning to think about the constructs of the framework and working to understand its affordances in the elementary school classroom; though further study is needed in this area.

**Summary of Findings**

The three findings discussed above lead to a greater understanding of how Meredith, Hadley and Alex represent different images of adoption describing how they employed different pieces of a discursive model for meaning making and took up varying aspects of the TSAF. Taken together, these findings provide evidence that preservice teachers embarking on their initial science teaching experiences are capable of negotiating many of the complex discursive practices used to co-construct scientific meaning with their students. Alex, Hadley

and Meredith all participated in a learning community grounded by a discursive model of meaning making and guided by a research-based framework. They all implemented a multi-day science lesson sequence and used talk and discourse while attempting to make sense of scientific phenomena with their students. This was not always a smooth process but none of the participants discarded their plans or reverted to direct instruction. They also all made sense of their work in terms of the language of science and the constructs from the methods course. How the participants discussed their work and made sense of their practices can be directly traced from their experiences in the methods course through their planning and implementation of lessons to their self-analysis of their practice. Such consistency highlights the utility of teacher learning experiences where a Discursive Model of Meaning Making is the norm.

What remains unknown is how preservice teachers who have participated in a learning community grounded by a Discursive Model of Meaning Making continue to progress as educators after they leave the community. Longitudinal studies are needed to understand whether the TSAF and Discourse Model continue to scaffold science instruction or whether they are largely forgotten. The utility of such studies will be discussed in the implications section of the following chapter.

# Chapter 8

## CONCLUSION AND IMPLICATIONS

This study began with the understanding that learning to teach science in the elementary school is a challenging endeavor (S. K. Abell, 2006; V. Akerson et al., 2006; E. A. Davis et al., 2006; Smith & Anderson, 1999; Zembal-Saul et al., 2000), but that research was being done to lay the groundwork for teacher preparation experiences centered on problems of practice, discourse, and coherent frameworks for teaching (E. A. Davis & Smithey, 2009; Schwarz, 2009; Zembal-Saul, 2009). Building off that work, this study investigated three preservice teachers' experiences in a science methods course which used a Discursive Model of Meaning Making and was grounded by a coherent framework for teaching and learning science introduced by Zembal-Saul (2009).

Additionally new standards for science education (NRC, 2011) call for teachers to explicitly scaffold student thinking using discourse strategies that provide learners with opportunities to engage with the practices and language of science. These scaffolds include productive questioning, talk-moves, and argumentation (Chapin et al., 2009; Elstgeest, 2001; NRC, 2007) – areas which are traditionally a challenge for preservice teachers (E. A. Davis et al., 2006; Zembal-Saul et al., 2000; Zembal-Saul, Krajcik, & Blumenfeld, 2002). Discourse repertoires have been developed to help facilitate effective classroom science talk. Talk moves encourage students to expand their reasoning and arguments while fostering student-student interaction and debate (Chapin et al., 2009). Productive questions are invitations to inquiry and problems in and of themselves calling for students to deepen their understanding by exploring further the science concept under investigation (Elstgeest,

2001; Robertson, 2009). This study examined how three preservice teachers were prepared to teach a three-day mini-unit in science guided by the Teaching Science as Argument Framework (TSAF) (Zembal-Saul, 2009), using a Discursive Model of Meaning Making. It also examined how they implemented their plans in three separate elementary school classrooms and how they made sense of their science teaching in a video-based self-analysis of their practice. Findings showed clear evidence of coherence between the participants' practices during their initial science teaching and their experiences in the science methods course. Such results indicate that science teacher educators should not underestimate the potential of novice preservice teachers to begin to adopt and enact many of the discursive practices of science.

In a 2010 study, Avraamidou and Zembal-Saul investigated two first year elementary teachers to better understanding the nature of their inquiry-based science teaching practices and the development of their pedagogical content knowledge (PCK). In that study further research was called for to illustrate the characteristics and components of effective teacher education programs. This study also addressed that need by investigating how three preservice elementary school teachers were prepared to teach science and what their practice looked like. The main findings are,

1) Throughout the methods course, instructors modeled how the Teaching Science as Argument Framework can be used to negotiate scientific understanding by employing a Discursive Model of Meaning Making.
2) During lesson plan conferences the Discursive Model was emphasized as participants planned classroom discussion and explored possible student responses enabling them to anticipate how they could attempt to increase student understanding.

3) Participants displayed three distinct patterns of adoption of the Teaching Science as Argument Framework (TSAF), involving different discursive practices. They were,
    - Detached Discursive Approach: Use of some discursive strategies without an apparent connection to the TSAF.
    - Connected Approach with a Focus on Student Thinking: Intentional use of the Discursive Model informed by aspects of the TSAF.
    - TSAF Approach: Priority is given to the TSAF supported by substantial application of the Discursive Model.
4) The evidence participants chose to highlight in their self-analysis videos is reflective of their patterns of adoption of the Teaching Science as Argument Framework and their differing discursive practices.

These findings lead to the formation of a theoretical proposition that can be applied beyond the scope of this research. This proposition is called a "Middle Theory." Middle theories are not highly abstract discussions, such as those on identity or efficacy, but they address more than the direct findings of the case. They are not so general as to be impractical, but not so specific as to be meaningless to anything beyond the scope of the case at hand. Middle theories are something in between that contribute new ideas worth considering in light of the class of phenomena being studied (Becker, 1998). The middle theory developed from the findings of this case study is that when learning to teach science in the elementary school, teacher commitment to the practices of science is constructed through participation in a learning community where a discursive model of meaning making is the norm.

The word “model” is used here to describe the discursive practices used by the methods instructors because they have taken a very complex task, that of negotiating the scientific meaning of natural phenomena, and simplified it through the consistent and purposeful use of questioning and discourse. This Discursive Model of Meaning Making is a means for novice preservice teachers to plan for and account for student talk during science lessons in a relatively predictable manner. Of course they cannot know exactly what individual students will say or do in specific situations, but during the lesson planning conferences the instructors prompted the participants to think through potential questions the participants could ask and answers their students could provide. Through the application of this model the participants were able to plan their responses to general types of talk. For example, in the excerpt below April asked Meredith how she thought her students would respond to a specific question then followed up with what Meredith could say in response.

> *“And what happened outside?” asks April.*
> *“They'll probably say the sun moved” replied Evelyn.*
> *“So” says April, “you'll ask them, ‘How can you change the shadow by moving the surface?’ And that is your segue into talking about day and night and using the earth to make shadows?”*
>
> (ecb.day6_fieldnotes.10/20/09)

This type of planning helped interns stay focused on the objectives of the science lesson and gives them permission to not engage with each student’s line of reasoning if it is not going to help move the conversation toward the preplanned learning goal.

The centrality of evidence-based claims to form explanations differentiates this model from good teaching in general. When someone is using a Discursive Model of Meaning Making in science they focus on using the language of science to inform understanding of natural phenomena. Language is central to practices of science (Carlsen, 2007). Students’

actions during scientific investigations must be explicitly scaffolded by teachers using productive discourse and the language of science (Lehrer & Schauble, 2005; Metz, 2004). Such scaffolds include talk moves (Michaels et al., 2008), productive questioning (Elstgeest, 2001), KLEWS charts (Zembal-Saul et al., 2013) and other discursive tools. These scaffolds help to break the I-R-E talk pattern typical of classroom discussion (Mehan, 1979) and help to make the science practices of the New Framework for K-12 Science Education possible (NRC, 2011). These include asking questions, developing and using models, planning and carrying out investigations, analyzing and interpreting data, using computational thinking, constructing explanations, engaging in argument from evidence and obtaining evaluating and communicating information (NRC, 2011). These practices are empowering for children because they equip them with venerable resources for problem solving and making sense of their world (Zembal-Saul et al., 2013). The Discursive Model of Meaning Making scaffolds students' abilities to perform the practices of science as called for by the NRC (NRC, 2011). It also helps preservice teachers make sense of the TSAF in use in science investigations. Each talk move, productive question, and discursive choice the instructors modeled during the methods course was focused on scaffolding the classes' ability to form explanations based on evidence associated with a particular science phenomena. This model represents the constructs of the TSAF in action. It is how teachers can situate the constructs of the TSAF within an actual classroom and plan for their own use of the TSAF.

The Discursive Model of Meaning Making can be considered a cultural model (Gee, 2008) in that it is not an explicit set of rules to be followed, but rather a social practice that instructors and interns participated in together. The cultural model of discursively co-constructing the meaning of science concepts is based on the belief that knowledge is not

simply being able to recite a set of memorized facts, instead it is a process of collaborative meaning making through dialogue and discussion using the language of science.

In order to learn the Discursive Model of Meaning Making, the participants in this study were acculturated (Gee, 2008) into the community of elementary school teachers through being Legitimate Peripheral Participants (Lave, 1991) in the methods course and other teacher learning experiences. The methods course provided a meaningful context and gave purpose to what the participants were doing. The participants did not receive a body of factual knowledge about teaching science; they participated in the practices of the community where a Discursive Model of Meaning Making was the norm. Their developing ability to make choices as elementary teachers, their participation in their community, and their process of becoming part of the larger teaching community were one and the same. Their learning was inseparable from the social practices they were participating in. At times conflicts arose between what the interns thought it meant to be a teacher and what they were experiencing. But by being situated in a learning environment where such a model was the norm, they grew to understand the affordances of discursively negotiating the meaning of science concepts.

The main contribution of this study is that it provides an in-depth examination of pre-service teachers' science teaching practices and traces how they were prepared for initial science teaching from the beginning of their science methods course through their analysis of practice. The specific contributions to the literature are: 1) a rich description of research-based science methods; 2) a detailed account of participants' uptake of aspects of a conceptual framework for science teaching in their initial planning and science teaching; 3) analysis of participants' discursive practices aimed at co-constructing science explanations

with their students; and 4) evidence of the ways in which participants used elements of their methods course to make sense of their teaching. These lead to the formation of a Middle Theory addressing a Discursive Model of Meaning Making of science concepts in the elementary school classroom.

While these contributions are noteworthy and begin to counter the deficit model of the challenges faced by preservice teachers, they do not account for any potential long term impact of using a coherent framework for teaching and learning science using a discursive model of meaning making. This limitation points to the need for longitudinal inquiry into preservice teacher preparation and practice. Extending research studies over years rather than semesters will not only broaden understanding of preservice teacher preparation and practice, but also of practice during the first years of in-service work. The participants in this study demonstrated commitments to using key elements of the Teaching Science as Argument Framework during their initial science teaching experiences. However, it is not known is if these commitments continued after they no longer had the explicit scaffolds of their methods instructors guiding them. Investigation also has to be undertaken to determine the ways in which preservice and early in-service teachers make sense of their practice without the direction of a reflective self-analysis assignment. These lines of inquiry would shed light on the impact and practicality of a coherent framework for teaching and learning science using a discursive model for meaning making beyond the scope of the methods course.

## Implications

As discussed in Chapter 7, findings from case study research are not "answers" to the research questions. Because case studies preserve the nature of the lived experiences of participants, the findings cannot be generalized to larger populations. Rather the findings of case study research inform our understanding of the research questions and can lead to the formation of theoretical propositions generalizable to larger populations and future study. Four categories of implications have emerged from this research – theoretical, methodological, curricular, and further research.

In light of the New Framework for Science Education (NRC, 2011) calling for the ongoing involvement of students to participate in a core set of science practices with a focus on discourse, there will be a need for elementary teachers as well as upper grade science specialists to not only understand the discursive practices of science but also be able to capably apply them. This implies that the traditional methods course will need to evolve to incorporate a Discursive Model of Meaning Making as implemented by April and Sarah (methods course instructors). Data analysis showed that the discursive constructs of the methods course were taken up and applied by the participants in both their initial science teaching, as well as in how they made sense of their experiences. This points to the need for preservice teachers to participate in learning communities where they experience science through investigations by collecting their own data, identifying patterns in the data, and make sense of what they are observing through the public negotiation of meaning. They then need to be provided with opportunities to apply their emerging understandings of science in an environment where discursively making sense of scientific phenomena is accepted and encouraged. It has been shown that the traditional field experience does not often provide for

this affordance (S. K. Abell, 2006). Universities may want to shift their hiring practices to include a greater focus on team teaching – combining university faculty with inservice elementary school teachers in the methods classroom. Specifically, if graduates of successful methods courses were identified as teachers who are teaching science as argument, they could be brought back into the methods classroom to work with university faculty. Such hires could leverage their experiences in the elementary classroom as exemplars of what is possible for the typical elementary school student to achieve when their scientific sense making is scaffolded by productive discourse.

In lieu of this, as well as in conjunction with these types of instructors, preservice teachers should be provided the opportunity to visualize discourse-based science in action in elementary schools through the critical analysis of teaching videos highlighting discourse-based sense making of science investigations. Research examining the use of such video cases in methods courses have shown an increase in preservice teachers' attention to scientific argument construction, an increase of participants' appropriation of ideas associated with a Teaching Science as Argument Framework (TSAF), a significant increase in participants' understanding of science teaching, and a coherence between participants' understanding of science teaching as argument and their teaching practices (Zembal-Saul, 2009). Preservice teachers should also be provided the opportunity to critically analyze their own practice, examining their work in light of the constructs they have experienced during their methods courses. Built on this implication is the need for further research examining how preservice teachers who are provided the opportunity to critically examine their own work are able to learn from their practice, and whether they continue to develop as reflective educators after they are inducted into the profession as inservice teachers.

Additional longitudinal studies are needed to examine the impact of a coherent teaching framework outside of preservice teacher education. How does such preparation impact in-service teaching? Do teachers who experience a Discursive Model of Meaning Making during their methods courses apply their understandings in their own classrooms or are the constructs largely forgotten? Specifically, which constructs are applied and how are they made sense of by graduates of a discourse based teacher preparation experience grounded by a coherent research centered framework?

Additional studies are also needed to investigate the impact of the school-university Professional Development School (PDS) partnership on preservice teachers' adoption of the TSAF using a Discursive Model of Meaning Making. Particularly to see if there is a difference between the impact of the Model and the TSAF when used in on-campus science methods course versus in a PDS context.

In order to investigate such questions, researchers will need to broaden their methodological repertoire to include a strong emphasis on Discourse Analysis. As explained previously, the New Framework for K-12 Science Education (NRC, 2011), calls for students to develop explanations based on evidence, using argumentation to critique and evaluate scientific ideas using the language of science (NRC, 2011) . How teachers do this, what discursive choices they make, and how they use language to support their students in public reasoning about and making meaning of scientific phenomena will need to be studied. With such a central focus on language use in the classroom greater attention will need to be paid to how language and learning are social practices (Gee, 2008; Kelly, 2008), as well as how the disciplinary knowledge of science is constructed and assessed through language (Carlsen, 2007). While the connections between teaching, learning, and language in the science

classroom have been examined (B. A. Brown et al., 2005; Gee, 2004; Kelly, 2008; Varelas, Pappas, Kane, & Arsenault, 2008; Zhang et al., 2010), inquiry into the affordances of specific discourse practices as outlined in the TSAF and their impact on student learning, including English Language Learners and students with special needs, require greater development. This implies a need for researchers to understand and apply the methods of sociolinguistics and Discourse Analysis (Dyson & Genishi, 2005; Gee, 2005, 2011) while investigating the practices of teachers and learners of science. The current study has set the groundwork for in-depth discourse analysis of classroom talk in elementary school science lessons but further work in this area needs to be done.

In addition to these curricular and methodological implications, evidence from Meredith, Alex, and Hadley gives us three *Images of Adoption* we can leverage to develop Pedagogical Learning Progressions aligned with standards-based expectations for teaching science in the elementary school. By continuing to track preservice teacher performance and following them longitudinally into their early career teaching experiences, data can be gathered which would allow for the collection of additional images which could lead to the design of Pedagogical Learning Progressions that can be used by elementary teacher educators and early career elementary teachers to critique and advance their pedagogical performances over time (Thompson, Braaten, & Windschitl, 2009). Specifically this could lead to the identification of a baseline of adoption that beginning teachers must reach that serves as a tipping point for continued use of these kinds of practices.

Learning Progressions were envisioned as carefully sequenced steps consisting of skills and knowledge that students must master to achieve a more advanced curricular aim (Popham, 2007). But in order for student learning progressions to be fully realized, they

must be enacted by "educators who themselves understand and can scaffold complex performances around authentic science" (Thompson et al., 2009, p. 1). Currently the field of science education does not have a unified definition of what advanced reform oriented practice looks like. Neither is there a way for teachers to understand how and where their practice lies on a continuum of reform oriented practices. By studying cases like Meredith, Hadley, and Alex and following them into their early career experiences data can be gathered to help design Pedagogical Learning Progressions or a sequence of critical experiences that can be leveraged by science teacher educators to advance the practices of novice and beginning teachers.

In conclusion, the work accomplished in this study and the implications outlined above adds to the science education literature by investigating the nature of preservice elementary teacher preparation to teach science in a school-university Professional Development School partnership where a discursive model for meaning making was practiced. The long term impacts of such a program are currently unknown, but Meredith, Hadley, and Alex's experiences have provided insights into what preservice teachers are able to accomplish when prepared to do so using a coherent research-based framework. The potential of this type of preparatory experiences should not be underestimated.

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6. WILEY shall have the right to terminate this Agreement immediately upon breach of this Agreement by you.

7. You shall indemnify, defend and hold harmless WILEY, its Licensors and their respective directors, officers, agents and employees, from and against any actual or threatened claims, demands, causes of action or proceedings arising from any breach of this Agreement by you.

8. IN NO EVENT SHALL WILEY OR ITS LICENSORS BE LIABLE TO YOU OR ANY OTHER PARTY OR ANY OTHER PERSON OR ENTITY FOR ANY SPECIAL, CONSEQUENTIAL, INCIDENTAL, INDIRECT, EXEMPLARY OR PUNITIVE DAMAGES, HOWEVER CAUSED, ARISING OUT OF OR IN CONNECTION WITH THE DOWNLOADING, PROVISIONING, VIEWING OR USE OF THE MATERIALS REGARDLESS OF THE FORM OF ACTION, WHETHER FOR BREACH OF CONTRACT, BREACH OF WARRANTY, TORT, NEGLIGENCE, INFRINGEMENT OR OTHERWISE (INCLUDING, WITHOUT LIMITATION, DAMAGES BASED ON LOSS OF PROFITS, DATA, FILES, USE, BUSINESS OPPORTUNITY OR CLAIMS OF THIRD PARTIES), AND WHETHER OR NOT THE PARTY HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. THIS LIMITATION SHALL APPLY NOTWITHSTANDING ANY FAILURE OF ESSENTIAL PURPOSE OF ANY LIMITED REMEDY PROVIDED HEREIN.

9. Should any provision of this Agreement be held by a court of competent jurisdiction to be illegal, invalid, or unenforceable, that provision shall be deemed amended to achieve as nearly as possible the same economic effect as the original provision, and the legality, validity and enforceability of the remaining provisions of this Agreement shall not be affected or impaired thereby.

10. The failure of either party to enforce any term or condition of this Agreement shall not constitute a waiver of either party's right to enforce each and every term and condition of this Agreement. No breach under this agreement shall be deemed waived or excused by either party unless such waiver or consent is in writing signed by the party granting such waiver or consent. The waiver by or consent of a party to a breach of any provision of this Agreement shall not operate or be construed as a waiver of or consent to any other or subsequent breach by such other party.

11. This Agreement may not be assigned (including by operation of law or otherwise) by you without WILEY's prior written consent.

12. Any fee required for this permission shall be non-refundable after thirty (30) days from receipt.

13. These terms and conditions together with CCC's Billing and Payment terms and conditions (which are incorporated herein) form the entire agreement between you and WILEY concerning this licensing transaction and (in the absence of fraud) supersedes all prior agreements and representations of the parties, oral or written. This Agreement may not be amended except in writing signed by both parties. This Agreement shall be binding upon and inure to the benefit of the parties' successors, legal representatives, and authorized assigns.

14. In the event of any conflict between your obligations established by these terms and conditions and those established by CCC's Billing and Payment terms and conditions, these terms and conditions shall prevail.

15. WILEY expressly reserves all rights not specifically granted in the combination of (i) the license details provided by you and accepted in the course of this licensing transaction, (ii) these terms and conditions and (iii) CCC's Billing and Payment terms and conditions.

16. This Agreement will be void if the Type of Use, Format, Circulation, or Requestor Type was misrepresented during the licensing process.

17. This Agreement shall be governed by and construed in accordance with the laws of the State of New York, USA, without regards to such state's conflict of law rules. Any legal action, suit or proceeding arising out of or relating to these Terms and Conditions or the breach thereof shall be instituted in a court of competent jurisdiction in New York County in the State of New York in the United States of America and each party

# APPENDIX D

Copyright Clearance Center

***Customer Information***

**Customer:** Elisebeth Boyer
**Account Number:** 3000550063
**Organization:** Elisebeth Boyer
**Email:** xxxxxxxxxxxxxx
**Phone:** xxxxxxxxxxx
**Payment Method:** Credit Card ending in xxxx

Order Details:

Case study research : design and methods

Billing Status: **Charged to Credit Card**

- **Order detail ID:** 62593064
- **ISBN:** 978-1-4129-6099-1
- **Publication year:** 2012
- **Publication Type:** Book
- **Publisher:** SAGE PUBLICATIONS INC
- **Rightsholder:** SAGE PUBLICATIONS INC BOOKS
- **Author/Editor:** Yin, R.K.
- **Your reference:** Boyer, E.C. (2012) PhD Dissertation, Chpt. 4, p. 5

- **Permission Status:** **Granted**
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- **Requested content's publication date:** 08/15/2012
- **Payment Method:** CC ending in 1014

**Rightsholder terms apply** (see terms and conditions)

**Elisebeth Boyer**

## Education

2006-present: PhD Candidate, The Pennsylvania State University (Curriculum & Instruction: Science Education)
2001-2003: M.S. Antioch University New England (Environmental Studies)
New Hampshire Teaching Certification (7-12 grade Biology)
1996-2000: B.A. Green Mountain College (Environmental Studies)

## Professional Experience

2009-present: Instructor Science Education, The Pennsylvania State University, University Park, PA (SCIED 458 Teaching Elementary School Science)
2006-2009: Graduate Assistant, The Pennsylvania State University, University Park, PA (SCIED 458 Teaching Elementary School Science)
2004-2006: Teacher, Chesterfield Elementary School, Chesterfield, NH (7/8 grade science)
2003-2004: Teacher, Newport Middle-High School, Newport, NH (9-12 grade science)

## Professional Development

2009: NARST Summer Research Institute, University of Missouri
2004: Education by Design Level 1 Institute, Antioch University New England

## Participation in Funded Projects

Research Assistant; *Teaching Elementary School Science as Argument (TESSA)*; National Science Foundation; 2006-2008; Principal Investigator, Carla Zembal-Saul

## Selected Conferences and Presentations

Boyer, E. & Zembal-Saul, C. (2012) Preservice elementary teachers use of discourse moves to support the social construction of science concepts. *National Association for Research in Science Teaching 2012 Annual International Conference, Indianapolis, IN.*

Boyer, E. (2010). Mirror Mirror: Preservice Elementary Teachers make sense of their Initial Science Teaching Practices – a comparative analysis. *National Association for Research in Science Teaching 2010 Annual International Conference*, Philadelphia, PA.

Boyer, E. (2009). Beyond the veil: Fostering reflective practice with new tools for digital video analysis. *National Association of Science Teachers 2009 National Conference,* New Orleans, LA.