# APPROXIMATIONS OF PRACTICE IN THE PREPARATION OF PROSPECTIVE ELEMENTARY SCIENCE TEACHERS

by

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# DEDICATION

For my first and best teachers,

Denton & Shirley Nelson

who continue to teach me
the most important lessons in life,
like never giving up…

…those Michigan football season tickets.
Go Blue!

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TABLE OF CONTENTS

LIST OF FIGURES

Figure

## LIST OF TABLES

Table

LIST OF APPENDICES

Appendix

ABSTRACT

Elementary teacher education involves learning to teach science. Even in elementary school, teaching science is demanding work—teachers must orchestrate a complex set of teaching practices to support students' science learning. This dissertation examines the application of Grossman and colleagues' (2009) cross-professional learning framework, highlighting approximations of practice in the form of simulated teaching experiences, to support prospective elementary teachers in learning to teach science. Specifically, approximations of practice focused on investigation lessons or lesson portions were designed and incorporated into an undergraduate elementary science teaching methods course. Using qualitative research methods, I studied relationships between four prospective teachers' approximations of practice and their instructional approaches, ideas about, and confidence in teaching elementary science investigation lessons. I also examined prospective teachers' perceptions of the utility of approximations of practice in learning to teach elementary science.

Data analyses indicate that approximations of practice served several functions. Less-authentic yet highly-supported approximations of practice provided opportunities to experience investigation lessons from teacher and student perspectives. Other approximations of practice allowed teachers to focus on parts of science lessons in elementary classrooms. Full-length science lessons in elementary classrooms provided learning opportunities aligned with authentic daily teaching responsibilities. All approximations of practice afforded opportunities to develop practice, ideas, and confidence. Prospective teachers' reflections identified benefits and constraints of learning to teach by approximating practice.

Considered individually and together, approximations of practice informed and were informed by prospective teachers' evolving ideas about and confidence for teaching investigation lessons. Curriculum materials and cooperating teachers also influenced prospective teachers' instruction, ideas, and confidence. Findings support a theoretical model that positions approximations of practice, ideas about investigation lessons, confidence for science teaching, and other individually-relevant factors as highly interrelated, dynamic constructs.

This dissertation study shows that approximations of practice supported prospective elementary teachers' development of instructional approaches, ideas, and confidence for teaching investigation lessons earlier than anticipated: *prior to* student teaching. Additionally, study findings provide insights into theory and practice of elementary science teacher education, and teacher education more broadly. Thus, this dissertation provides evidence that approximations of practice support the preparation of well-started beginning elementary science teachers.

# CHAPTER 1

# INTRODUCTION

Prospective elementary teachers face many challenges in learning to teach science. Many have little, if any, experience with teaching and learning science in ways that align with inquiry-oriented, reform initiatives (e.g., Haefner & Zembal-Saul, 2004; Windschitl, 2003). Many have weak science subject matter knowledge (e.g., Abell, 2007; Andersen & Mitchener, 1994). Many are unfamiliar with learners' ideas about science content and scientific practices (e.g., Gomez-Zwiep, 2008; Otero & Nathan, 2008). Many do not have opportunities to witness effective, inquiry-oriented science teaching in their field placement classrooms (e.g., Crawford, 2007; Lotter, 2004; Watters & Diezmann, 2007). For these and other reasons, many lack confidence in their abilities to teach science (e.g., Bleicher, 2006; Hatton, 2008; Howitt, 2007; Sherman & MacDonald, 2007). Part of elementary science teacher education, then, involves supporting prospective elementary teachers in developing the knowledge, skills, and confidence to teach elementary science in ways that are consistent with reform initiatives and authentic to the ways in which science is done, that is, with appropriate fidelity to authentic scientific practices[1] (e.g., Appleton, 2006b; Ford & Wargo, 2007).

[11] Although the most current reform initiatives in science education advocate the teaching and learning of scientific practices (e.g., National Research Council, 2010), at the time when this study was conducted, reform initiatives and methods course instruction promoted the teaching and learning of science as inquiry. For this reason, I will refer to inquiry-oriented science teaching and learning rather than scientific practice-oriented science teaching and learning throughout this dissertation.

Investigations are signature elements of inquiry-oriented elementary science education. Much of elementary science involves learning about the world around oneself, and often this learning takes the form of careful observation and experimentation, two forms of "investigations" (Watson, Goldsworthy, & Wood-Robinson, 1999). Teaching such inquiry-oriented science lessons can be very demanding, even for experienced teachers (Davis, 2003b; Eick, Meadows, & Balkcom, 2005; Jones & Eick, 2007; Luft, 2001). In order to become effective practitioners, prospective elementary teachers should learn the theoretical foundations for inquiry-oriented science at the elementary level, practical approaches to teaching investigation-based science lessons (Appleton, 2006b), *and* be supported in making connections between theory and practice (Allsopp, DeMarie, Alvarez-McHatton, & Doone, 2006).

Prospective elementary teachers should also learn how to support student engagement in authentic scientific practices, such as formulating predictions, making meaning from raw data, and presenting ideas to others (National Research Council, 2010). Often, scientific practices such as these are linked as elements of scientific investigations. For the purposes of this study, I will refer to lessons that contain scientific investigation(s) as "investigation lessons." Ideally, elementary classroom science investigation lessons contain authentic scientific practices adapted to the needs of teachers and students (Ford & Wargo, 2007). Accordingly, I have termed the following investigation lesson elements "five key features of investigation lessons": identifying the investigation purpose; connecting the investigation lesson to students' knowledge, ideas, and experiences; establishing data collection procedures; fostering sense-making with data; and supporting claims with evidence. These key features are described in Chapter 2.

Science education standards documents articulate many scientific practices as science process and/or scientific inquiry-related learning goals (e.g., American Association for the Advancement of Science, 1993, 2009; Michigan Department of Education, 2007; National Research Council, 1996, 2010). While many scientific practices, such as experimentation, are somewhat familiar to prospective teachers, many are not. For example, scientific modeling--the construction, use, evaluation, and revision of scientific models that represent conceptual, evidence-based understandings of phenomena for the purposes of sense-making and communication--is one such typically-unfamiliar scientific practice (Harrison & Treagust, 2000; Justi & Gilbert, 2002; Kenyon, Davis, & Hug, 2011; Schwarz et al., 2009; Windschitl & Thompson, 2006; Windschitl, Thompson, & Braaten, 2008a; Windschitl, Thompson, & Braaten, 2008b).

**Statement of the problem**

University teacher education courses provide much of what prospective teachers need to learn in order to become effective beginning teachers, but they are often criticized for their detachment from the real work of teaching in an elementary classroom (Allsopp et al., 2006; Grossman, Hammerness, McDonald, & Ronfeldt, 2008; Morrison & Marshall, 2003; Smagorinsky, Cook, Moore, Jackson, & Fry, 2004). To foreground the practical aspects of elementary science teaching, I explored an approach to elementary science teacher education that makes use of Grossman and colleagues' cross-professional learning framework (Grossman, Compton, Igra, Ronfeldt, Shahan, & Williamson, 2009a). In this framework, representations, decompositions, and approximations of practice are employed in the service of helping novices develop the skills elemental to their future work as professionals in "relational" practice, or occupations wherein the day-to-day work involves interacting with others (Fletcher, 1998; Grossman et al., 2009a). Specifically, I studied how the use of approximations of science teaching practice in an elementary science teaching methods course could support prospective elementary teacher learning to teach science lessons that involve investigations.

Here, the term “representation of practice” is used to denote the various tools, such as videos of lesson enactments and teachers’ own firsthand accounts of teaching, that portray aspects of teaching for study by learners. “Decompositions of practice” involve the work done in analyzing the representations of practice; breaking apart the work of professional practice into smaller “chunks” and characterizing those chunks in terms that make elements of practice accessible to learners. These two aspects of the framework position the novice to engage in “approximations of practice,” which Grossman and colleagues liken to simulations of varying degrees of complexity and authenticity. Learners engage in approximations of practice to become familiar with and develop skills in the *doing* of practice. For the purposes of this study, I focused on prospective elementary teachers’ approximations of elementary science teaching practice, as these provided evidence of their instructional approaches, ideas about, and confidence for teaching science investigation lessons.

## Research Questions and Study Overview

My study of approximations of practice in the preparation of prospective elementary science teachers capitalized on existing infrastructure in the form of the elementary science teaching methods course. By closely following four prospective teachers as they completed approximations of practice, and interviewing them about their science teaching experiences, I gained in-depth insights into how these approximations of practice supported and limited their preparation as science teachers. Guiding my study were the following research questions:

1. How do prospective elementary teachers engage in approximations of science teaching practice that involve investigation lessons?

> 1a. In the approximations of practice, which key features of investigation lessons are possible and which are evident during enactment? What instructional approaches do prospective teachers use to achieve these key features in their enactments?
>
> 1b. To what extent are the instructional approaches for a key feature of investigation lessons consistent across approximations of practice?
>
> 1c. What relationship, if any, is apparent between the instructional approaches for a key feature of investigation lessons and the degree of authenticity of an approximation of practice?

2. How do prospective elementary teachers' ideas about and confidence for teaching science investigation lessons change as they engage in approximations of practice?

> 2a. What ideas about teaching science investigation lessons do prospective elementary teachers hold and how do these ideas change during the final year of teacher education?
>
> 2b. What are prospective elementary teachers' confidence levels for teaching science investigation lessons, and how do these change during the final year of teacher education?

2c. How do prospective elementary teachers describe changes in their (1) ideas about and (2) confidence for teaching investigation lessons? To what do they attribute these changes?

3. How do prospective elementary teachers' instructional approaches, ideas, and confidence levels compare across their approximations of practice?

4. What do prospective teachers perceive as the benefits and limitations of approximations of practice for learning to teach science investigation lessons?

The study took place during the Fall 2009 and Winter 2010 semesters. The overarching goal of this work was to study how approximations of practice supported prospective elementary science teachers' learning to teach investigation lessons, as evidenced in their investigation lesson instructional approaches, ideas about, and confidences for teaching investigation lessons. Findings from this work may be used in several ways: (1) to inform instructional design and enactment in future elementary science teaching methods courses; (2) as a "proof of principle" in applying Grossman and colleagues' cross-professional learning framework in the context of elementary science teacher education; and (3) as the basis for further theory development in the area of elementary science teacher education and teacher learning more generally.

The remainder of this dissertation is divided into five chapters. Chapter 2 provides a synthesis of the theoretical and empirical work that informed and underlies this study. In Chapter 3, I describe the research materials and methods used to answer the research questions posed in this chapter. Chapter 4 presents the findings from research questions 1 and 2 as case study profiles of four focal prospective teachers' instructional approaches, ideas about, and confidence for teaching investigation lessons and lesson portions in their approximations of practice. Also in Chapter 4, findings from case study teachers are compared and contrasted per research question 3. In Chapter 5, I describe prospective elementary teachers' perceptions of the utility of approximations of practice for learning to teach science investigation lessons, which addresses research question 4. I conclude this work in Chapter 6 with a discussion of the findings and descriptions of the values added by approximations of practice. Also in Chapter 6, I identify the study's unique contributions to elementary science teacher education and teacher education theory and practice, discuss implications of my findings, and briefly outline future research directions grounded in the results of this study.

# CHAPTER 2

# THEORETICAL FRAMEWORK AND LITERATURE REVIEW

## Chapter overview

In this chapter, I review the literature that formed the theoretical underpinnings of this study's design, execution, and data interpretation. My study's theoretical framework borrows from a number of areas of educational theory and research. Here, I show how others' work and perspectives, in combination with one another, provided a foundation for my research and led me to pose the research questions central to this study.

## Learning to teach: factors and theories in teacher education

At the heart of this study lies the question: "How do people learn to become effective beginning (elementary science) teachers?" Prospective teacher learning and development derive from multiple sources and experiences, including university teacher education courses (Beeth & Adadan, 2006; Zembal-Saul, Blumenfeld, & Krajcik, 2000); engagement with curriculum materials (Collopy, 2003; Davis & Krajcik, 2005; Remillard, 2005); interactions with teacher educators, cooperating teachers, and other "more knowledgeable others" (Vygotsky, 1978); peer teaching and microteaching experiences (Allen & Eve, 1968; Bargh & Schul, 1980; Howes & Cruz, 2009; Pauline, 1993); their own histories as learners and participants in an "apprenticeship of observation" (Eick & Reed, 2002; Lortie, 1975); and other activities and experiences that position prospective teachers as beginners within a community of teaching practice (Lave & Wenger, 1991). In these examples, teacher learning is purported to be cognitive, sociocultural, and contextually situated in nature (Putnam & Borko, 2000), notions which are implicit yet integral to the cross-professional learning theoretical framework proposed by Grossman and colleagues (Grossman et al., 2009a). Before exploring this framework and its application to prospective elementary science teacher learning, I briefly discuss situated cognition as it applies to teacher education.

### Situated cognition and sociocultural theory in prospective teacher learning

Knowledge gained is dependent upon activity, context, and culture: three integral and interdependent determinants of learning (Brown, Collins, & Duguid, 1989). Further, learning is a process of enculturation, in which novices carry out authentic activities as part of the learning process (Brown et al., 1989). In examining prospective teacher learning, Putnam and Borko (2000) underscored the importance of prospective teachers' abilities to access and apply situated knowledge in new contexts. Part of the teacher educator's role as a participant in the learning environment lies in shaping prospective teacher learning by providing appropriate guidance and support (Putnam & Borko, 2000).

Learning to teach is a sociocultural endeavor. Novice teachers appropriate the characteristic behaviors of teaching by interacting with, learning from, and approximating the behaviors of experienced teachers (Edwards & Protheroe, 2003; Lave & Wenger, 1991; Putnam & Borko, 2000). Field placement practica and student teaching assignments match prospective teachers with inservice mentor teachers in classroom-based learning-to-teach apprenticeships. Yet completion of a formal teacher education program does not signify the end of this process of learning to teach. Studies show that practicing teachers (of various levels of teaching experience) benefit from orchestrated, community of practice-style approaches to support teacher learning and professional development (e.g., Grossman, Wineburg, & Woolworth, 2001; Palincsar, Magnusson, Marano, Ford, & Brown, 1998).

Applying these concepts to prospective teacher learning in science has illuminated some approaches and guiding principles for teacher educators. Cases are often employed as learning tools in teacher education; prospective science teachers can grow in their knowledge and understanding through guided study of practicing teachers' conceptual case knowledge, procedural case knowledge, and socially shared identities and beliefs (Kim & Hannafin, 2008). Laboratory experiences have also been valuable tools in science teacher education, and some prospective teachers have successfully transferred their own laboratory learning experiences to teaching settings (Sweeney & Paradis, 2004). However, such transfer often does not occur spontaneously; active reflection and explicit support underlie successful transfer of knowledge and skills to new situations (Schwartz, Lederman, & Crawford, 2004). To facilitate development and transfer of knowledge and skills into new teaching contexts, teacher educators could actively support prospective teachers' attempts to practice teaching in a series of increasingly-authentic simulated teaching scenarios (Bransfield, Holt, & Nastasi, 2007). Such an approach to learning to engage in the clinical work of teaching has important similarities to learning to engage in the day-to-day work of other professions (Grossman et al., 2009a).

## What is meant by "practice?"

Those in education, law, medicine, and other professions refer to their work as "practice." In teaching, the term "practice" is used in many different ways with somewhat different meanings, depending on the context (Lampert, 2010). For the purposes of this study, I intend the term "practice" (singular) in the sense conveyed by Lave and Wenger

(1991) and later elaborated by Wenger (1998) in connection with communities of practice. Briefly, a community of practice is characterized as a joint enterprise (what it is about) by members who mutually engage as a social entity (how it functions) with a shared repertoire of communal resources developed by members over time (what capability it has produced) (Wenger, 1998). Considering teaching as the "practice" component of a community of practice, then, equates practice with the shared repertoire of communal resources used by teachers (members) to achieve their education-related goals. But teaching practice is more than a set of communal resources and should not be reduced to what teachers do during the act of teaching. Rather, teaching practice includes social relationships and identities, beliefs and ideas, orientations, and other actions and habits of mind associated with being a teacher (Ball & Forzani, 2009; Nespor, 1987; Smagorinsky et al., 2004).

Teaching "practices" constitute a subset of the communal resources of teachers. This term is often used in connection with instructional methods and rationales underlying pedagogical decisions (see Lampert, 2010). In this study, then, "practices" (plural) may be equated with teaching strategies, techniques, tools, and methods that are central to the work of teaching (Ball, Sleep, Boerst, & Bass, 2009; Grossman, Hammerness, & McDonald, 2009b; Grossman & McDonald, 2008). For clarity, I refer to these as "instructional approaches" rather than "practices;" here, they are the elements of teaching which can be directly observed and whose underlying rationales are made accessible through reflective conversation with the teacher. By contrast, "practice" in this study connotes the collection of instructional approaches in addition to the other social, cognitive, and affective components of teaching.

## Grossman and colleagues' framework for professional learning

In their recent work, Grossman and colleagues describe an approach to teacher education and training that highlights its commonalities with preparation in other professional spheres wherein interaction with others (for the purpose of "human improvement" (Cohen, 2005)) plays a central role in the everyday work (Fletcher, 1998). With roots in the literature on sociocultural theory and the development of performance expertise (e.g., Bruner, 1996; Ericsson, Charness, Feltovich, & Hoffman, 2006), and links to situated cognition and teacher learning (e.g., Putnam & Borko, 2000), this theoretical framework advances three central and interrelated components as elemental to the development of novices' abilities to engage in "professional practice," or the intellectual and technical work carried out by the individual practitioner and members of the professional community, collectively (Chaiklin & Lave, 1996). These three central components are *representations of practice*, *decompositions of practice*, and *approximations of practice*.

*Representations of practice* are tools that are useful in portraying the practice to learners; such as video cases and narratives. As Grossman and colleagues note, there is a great deal of variability in what is and what is not accessible to the learner in various representations of practice. For example, a video representation of a teacher enacting a science lesson in which students conduct an experiment to determine mealworms' food preferences could provide prospective teachers with easily-discernible examples of moves made by the teacher to discourage off-task behavior. The same video, however, would likely not reveal the teacher's rationale for choosing certain misbehavior-discouraging moves over other moves. It would also not give prospective teachers insight into the teacher’s approach to planning and modifying the lesson prior to enactment. Others have noted the limitations and affordances of the use of specific representations of practice for the purposes of teaching, studying, and learning teaching practice (e.g., Little, 2003), and some specifically within the realm of science education (Bencze, Hewitt, & Pedretti, 2009; Loughran, Milroy, Berry, Gunstone, & Mulhall, 2001; Watters & Diezmann, 2007)

*Decomposition of practice* involves “breaking down complex practice into its constituent parts for the purposes of teaching and learning” (Grossman et al., 2009a, p. 2069). Part of this work entails using (and if necessary, developing) a common language to identify and characterize those constituent parts. Additionally, maintaining a sense of the grain size is also crucial, as Grossman and colleagues stress that decomposition should yield an element of practice which is simultaneously a unit of analysis unto itself but which is also a key element of the overall practice. For example, teacher educators and prospective teachers may together decompose a science lesson into smaller segments, such as the lesson initiation, the learning activity, and the lesson conclusion. Further decomposition of the lesson conclusion segment might involve careful examination of what happens when students are asked to compare experimental results with their predictions. While this is a discrete element of a science lesson, its meaningfulness as a unit of instruction exists in its relationship to the lesson as a whole. In other words, prospective teachers can analyze how teachers support students in comparing their experimental findings with their predictions for the purposes of learning how to teach this particular portion of a lesson. Although this portion of science instruction can be isolated, studied, and practiced for learning purposes, it cannot stand alone as a comprehensive example of science teaching.

Decomposition of practice necessarily involves highlighting certain aspects of the practice to facilitate novices' learning. Here, the role of the mentor is crucial in helping novices to create boundaries around "studyable" units of practice and to recognize the salient features of those units of practice. For example, a teacher educator might highlight the use of probing questions by a "representation of practice" teacher when she is eliciting students' ideas about new science content. In this scenario, prospective teachers' attention is drawn to a specific use of questions by the representation teacher, and away from other aspects of the representation teacher's enactment, such as behavior management techniques or encouraging shy students' verbal participation.

"Approximations of practice refer to opportunities for novices to engage in practices that are more or less proximal to the practices of a profession" (Grossman et al., 2009a, p.2058). Thus, approximations of practice may be thought to "simulate practice," and occur along a continuum from less authentic to more authentic simulations. The degree of authenticity in the approximation of practice may be determined in part by how closely the approximation resembles the actual practice in a variety of ways, including the demands upon the practitioner, the nature of the simulated practice in which the novice engages, the environment itself, and/or the participants. For example, a less-authentic approximation of teaching practice might have the novice teacher plan a science lesson for a hypothetical class of third graders as part of a methods course assignment. In this example, the lesson planning activities may involve some authentic practices, such as learning activity selection and curriculum materials modification, but the nature of the approximation demands that these be done without knowledge of the learners or classroom context. Also, the novice teacher carries out only a part of the work of teaching in the lesson planning approximation of practice; the unit of practice--lesson planning--is disembodied from the corpus of work involved in enacting the science lesson with third graders. Finally, given the nature of the work as a methods course assignment, the novice teacher may expect to receive feedback on her planning from the methods course instructor—something that is absent in the authentic practice.

In their work, Grossman and colleagues focused on approximations of practice that take place in university settings (2009a). Under these conditions, feedback in the form of coaching and instruction by practitioner educators serves an invaluable role in the preparation of novices. With the support of these “experts,” novices learn to attend to salient aspects of practice as they are evident in the work of exemplars (i.e., representations of practice) (Bransfield et al., 2007; Ericsson, 2006; Little, 2003). With appropriate coaching, novices also learn to focus attention and effort to developing these facets of their own nascent professional practice (e.g., Bransfield et al., 2007; Ericsson, 2006). Such “knowledgeable other”-facilitated practice development borrows heavily from sociocultural theories of human learning and development (Vygotsky, 1978).

**Application of Grossman and colleagues’ framework to learning to teach science**

Methods courses, in which prospective teachers learn subject-specific pedagogies and their application in teaching situations, provide a ripe environment in which to explore the utility of Grossman and colleagues’ framework. Here, prospective teachers can both learn *about* and learn to *do* many aspects of teaching a science lesson: planning, enacting, modifying on-the-fly, and managing time appropriately, to name a few.

Coordinating knowledge of science education theory, inquiry-oriented teaching methods, and science content knowledge *and* managing relationships with and between students, curriculum materials, and other members of the teaching environment *while* enacting instruction within a given time window is a tall order for any beginning teacher. Not surprisingly, prospective teachers often struggle when faced with so many simultaneous demands. The following sections discuss the often-daunting challenges for prospective elementary science teachers, and provide some rationale for aligning the Fall 2009 Elementary Science Teaching Methods course with Grossman and colleagues' professional learning framework.

**Learning to teach elementary science: Prospective teachers' challenges**

Prospective elementary teachers face a multitude of challenges in learning to teach science (Davis, Petish, & Smithey, 2006). Many prospective elementary teachers lack strong content knowledge in science (Andersen & Mitchener, 1994; Appleton, 2006a) and confidence in their science knowledge and science teaching abilities (Bleicher, 2004, 2006; Howitt, 2007; Watters & Ginns, 2000). Calls for science education reform advocate the teaching and learning of science by inquiry methods and authentic scientific practices (American Association for the Advancement of Science, 1993, 2009; National Research Council, 1996, 2010), which are often unfamiliar pedagogies for prospective teachers (Newman, Abell, Hubbard, McDonald, Otaala, & Martini, 2004; Smith & Anderson, 1999; Windschitl, 2003). As defined in *Inquiry in the National Science Education Standards*, classroom inquiry has five essential features:

- Learners are engaged by scientifically oriented questions.

- Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions.
- Learners formulate explanations from evidence to address scientifically oriented questions.
- Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding.
- Learners communicate and justify their proposed explanations.

(National Research Council, 2000, p.25)

In order for learners, particularly at the elementary level, to satisfy these aspects of classroom inquiry, teachers must effectively support them in doing this work. Many prospective teachers learn inquiry-oriented pedagogical approaches in their teacher education courses (Britner & Finson, 2005; Haefner & Zembal-Saul, 2004; Newman et al., 2004; Tamir, 1990; van Zee, 2006), yet they often complete these courses lacking a strong understanding of what inquiry-oriented science teaching means and/or how to implement it in the classroom (Crawford, 2007; Gee & Gabel, 1996; McGinnis, Parker, & Graeber, 2004). Such practical inexperience has important consequences for beginning teachers' development, both personally and professionally (Fuller, 1969; Luehmann, 2007). Accordingly, many have called for an increased focus on practice in the preparation of future teachers (Avraamidou & Zembal-Saul, 2010; Ball & Cohen, 1999; Ball & Forzani, 2009; Ball et al., 2009; Lampert, 2010).

Initial science teaching experiences elucidate other challenges prospective teachers face. Often, prospective teachers are bounded by the constraints (real and perceived) of their field placement classrooms and cooperating teachers (Appleton &

Kindt, 1999; Crawford, 2007), and may not have a chance to directly observe or enact inquiry-oriented science lessons (van Zee, Lay, & Roberts, 2003). Many beginning science teachers rely heavily upon curriculum materials that are provided (or required) in their classrooms (Davis et al., 2006), which adds to existing constraints on beginning science teaching practices (Roehrig & Luft, 2004). Another challenging factor is the dearth of time allotted to science instruction at the elementary level. Instructional time in math and reading is often privileged at the cost of instructional time in science, which results in a weekly average decrease of 75 minutes of science instruction (Center on Education Policy, 2008). As many have indicated, inquiry-oriented science instruction is challenging and costly in terms of classroom time (Anderson, 2002; Hammrich, 1997; Lotter, 2004; Newman et al., 2004), and often eschewed in favor of more traditional teaching methods (Costenson & Lawson, 1986).

**Prospective elementary teachers and inquiry: Scientific investigations**

Inquiry-oriented science in the elementary classroom takes on many forms that resemble the work done by scientists. One authentic scientific practice that is typically subsumed under inquiry-oriented science instruction is the *scientific investigation*. Investigations in science, as described by focus group classroom science teachers, involve students in "investigational procedures" such as planning, measuring, observing, analyzing data, and/or evaluating procedures, and can vary in the amount of students' (working in groups or individually) autonomy to make decisions about how the investigation is carried out (Watson et al., 1999, p. 102). In many instances in the science education literature, "inquiry" and "investigation" are terms that are used interchangeably. A typology of classroom science investigations has been proposed by

Watson, Goldsworthy, and Wood-Robinson (1999), and includes six major categories: classifying and identifying, fair testing, pattern seeking, exploring, investigating models, and making things or developing systems. Characteristic investigation activities include making and recording observations, controlling variables, grouping objects based on similar or different features, gathering data, and forming model-based predictions, and are described in more detail in Table 2.1.

Table 2.1

*Key features of different categories of investigations*

| | | *Classifying and identifying* | *Fair testing* | *Pattern seeking* | *Exploring* | *Investigating models* | *Making things or developing systems* |
|---|---|---|---|---|---|---|---|
| **Stages in the process of the Investigation** | 1 | Recognise characteristics to identify or classify. | Identify independent, dependent and control variables. | Identify dependent variable and possible causal factors. | Observe phenomena for a scientific purpose. | Identify what counts as evidence. | Identify significant features of artefact or system to be designed. |
| | 2 | Select characteristics which discriminate, and develop a strategy. | Decide how to observe and measure variables. | Plan how to measure variables as they occur naturally. Select a large enough sample to provide reliable data. | Select observations to make and the number and frequency of observations. | Collect evidence. This could be by classifying, identifying, fair testing, or searching for patterns. | Plan designs and select the best fit to the design specification. |
| | 3 | Apply tests that display characteristics. | Change values of independent variable and carry out observations/measurements under controlled conditions. | Carry out observations and measurement. Note any uncontrolled conditions that may be significant, or carry out statistical analyses to look for strength of relations between variables. | Use the observations to raise scientific questions. | Critically evaluate in the light of the model(s). | Make the artefact or system. |
| | 4 | Draw conclusions by a process of successive discrimination. | Interpret and evaluate data to identify, describe and interpret relationships between variables. | Interpret and evaluate the data collected in order to seek patterns of relationships. | | Use the models to predict. Collect evidence to test predictions. | Test the artefact or system and evaluate its fitness for purpose. |
| | 5 | Use identification to access information in secondary sources. Classification can be used to predict in new situations. | | If possible, identify, through laboratory tests, causal links between correlated variables. | | | |
| **Examples** | | What is this chemical? How can we group these invertebrates? | What affects the rate at which sugar dissolves? What affects the time it takes for a paper spinner to fall? What conditions do woodlice prefer? (choice chamber) | Where do we find most snails? Do people with longer legs jump higher? What caused the salmonella outbreak? What conditions do woodlice prefer? (ecological sampling) | How does frogspawn develop over time? What happens when different liquids are added together? | How can the cooling of a hot body, insulated by layers of material, be modelled? How can the movement of a trolley be modelled? | Can you find a way to design a pressure pad switch for a burglar alarm? How could you make a weighing machine out of elastic bands? |

(Watson et al., 1999, p.105)

As Table 2.1 suggests, different forms of investigation are appropriate for the teaching of different science content and achieving different learning goals. While the study of some phenomena may lend itself to conducting controlled-variable experiments, the study of other phenomena, such as weather, cannot be investigated by the same means.

In considering Table 2.1 in conjunction with the essential features of classroom inquiry mentioned previously (National Research Council, 2000), and in connection with the foci of the elementary science teaching methods course in which this study took place (see Chapter 3), I identified the following as key features of investigation lessons, regardless of investigation type:

- Identifying the investigation purpose(s)
- Connecting the investigation lesson to students' prior knowledge, ideas, and experiences
- Establishing data collection procedures
- Fostering students' sense-making with investigation data
- Supporting students in making claims with evidence gathered from investigation(s)

Briefly, *identifying the investigation purpose(s)* entails making explicit the reasons for engaging in the investigation work. For example, teachers might explain that they are having students make observations of seeds and plants to understand the stages in a plant's life cycle (learn science content) and to practice making careful and detailed observations in science (develop scientific practice and/or inquiry skills). In *connecting the investigation lesson to students' prior knowledge, ideas, and experiences*, teachers and students make explicit connections between in-school and outside-of-school examples that relate to the science topic or phenomenon in question. *Establishing data collection procedures* entails deciding what constitutes data, and how data will be collected and recorded during the investigation. *Fostering students' sense-making with investigation data* occurs both during and after the investigation, and involves the teacher helping students to make meaningful interpretations of raw data in order to understand relevant science concepts. Finally, *supporting students in making claims with evidence gathered from investigation(s)* entails formalizing the sense-making process through the creation of explicit conclusions or claims that are rooted in the empirical investigation data. These key features are examples of classroom practices aligned with authentic scientific work (Ford & Wargo, 2007).

Each of these key features may be realized through a variety of instructional approaches that vary from more traditional, teacher-directed methods to more reform-oriented, student-centered teaching strategies. Such approaches are intimately connected with orientations toward science teaching, which are described in the following section. Whether instruction is more teacher-directed or more student-directed in nature, investigation lessons usually contain examples of instructional approaches associated with each of these key features.

Prospective elementary teachers typically struggle with the tasks associated with teaching inquiry-oriented science lessons (Bhattacharyya, Volk, & Lumpe, 2009; Crawford, 1999; Davis et al., 2006; Gee & Gabel, 1996; Haefner & Zembal-Saul, 2004; Newman et al., 2004). Although there are few empirical studies that directly examine beginning elementary teachers' approaches to teaching science investigation lessons (e.g., Avraamidou & Zembal-Saul, 2010), other studies suggest several factors that might plausibly contribute to prospective elementary teachers' unease and difficulty with teaching science investigations. For example, prospective science teachers are known to have concerns relating to classroom management, the depth of their own science content knowledge, and their own performance as beginning teachers (e.g., Bleicher, 2006; Fuller, 1969; Hatton, 2008; Lotter, 2004; Ramey-Gassert, Shroyer, & Staver, 1996; Roehrig & Luft, 2004; Watson, 2006). Additionally, beginning and experienced science teachers struggle with teaching that involves scientific explanations, investigation questions, and working with students' ideas in science (Beyer & Davis, 2008; Forbes & Davis, 2010a; Otero & Nathan, 2008). These issues, coupled with external pressures owing to policy demands and constraints on science instructional time and resources (e.g., Center on Education Policy, 2008; Marx & Harris, 2006) make successful execution of inquiry-oriented elementary science a considerable challenge for beginning teachers.

**Integrating approximations of practice into prospective teacher learning to teach inquiry-oriented science with investigations**

To address some of these struggles that prospective teachers experience in learning and teaching inquiry-oriented science involving investigations, Dr. Betsy Davis and I designed the Fall 2009 Elementary Science Methods Course to incorporate opportunities for prospective elementary teachers to learn about and practice inquiry-oriented elementary science teaching. We based much of the course design on Grossman and colleagues' cross-professional learning framework, with the specific goals of using this framework to facilitate prospective teacher learning *about* and to *engage* in science teaching practice. Through the use of *representations and decompositions of practice*, which included analysis and discussion of science lesson videos and teaching narratives, for example, we facilitated and guided prospective teacher learning about how science investigation lessons can be taught. By engaging prospective teachers in a series of increasingly-authentic *approximations of elementary science teaching practice*, we provided a means by which to support prospective elementary teachers in learning to enact science instruction involving investigations in gradually more authentic (and thus, gradually more demanding) teaching situations. Briefly, the least authentic approximation of practice, peer teaching, entailed prospective elementary teachers engaging in microteaching experiences using reform-oriented elementary science lessons (Allen & Eve, 1968; Kenyon, Schwarz, & Hug, 2008; Pauline, 1993). This approximation of practice maintained the features of university-based approximations of practice as described by Grossman and colleagues. In short, it involved coaching and feedback from teacher educators during the enactment of bounded elements of science teaching in a low-stakes environment for the purposes of learning pedagogy (Grossman et al., 2009a).

Because prospective elementary teachers struggle to enact inquiry-based science lessons in their field placements (as described above), I expanded upon Grossman and colleagues' notion of approximations of practice in the design of three more-authentic, elementary classroom-based approximations of practice. In "bite-sized science teaching experiences," or BSSTs, prospective elementary teachers enacted the beginning, middle, or end of a science lesson in their field placement classrooms, and the cooperating teacher enacted the remaining two portions of the lesson. Reflective teaching assignments engaged prospective teachers in teaching entire science lessons to elementary students in their field placement classrooms. Finally, student teaching semester science lessons also involved prospective teachers enacting full-length science lessons in the field; however, these took place outside of the methods course and were not part of any methods course assignments.

In order to analyze the impact of approximations of practice on prospective elementary science teachers' instructional approaches, ideas about, and confidence for teaching investigation lessons, a more comprehensive view of the system is warranted. First, I describe key constructs used in this study. I then relate these key constructs in Figure 2.1, which presents a theoretical model that incorporates possible relationships between the study's key constructs.

## Study constructs

In addition to approximations of practice, the notions of ideas, confidence, authenticity, and complexity are central to this study. Below, I offer brief descriptions of each of these constructs within the context of this study.

### Ideas

Teachers of every level of experience hold certain knowledge and orientations with regard to teaching (Abell, 2007; Appleton, 2006a; Choi & Ramsey, 2009; Grossman, 1990; Magnusson, Krajcik, & Borko, 1999; Nespor, 1987; Pajares, 1992; Schneider, Krajcik, & Blumenfeld, 2005; Shulman, 1986; Smith & Neale, 1989). Science teaching-related knowledge exists in many forms, including abstract and experiential, and encompasses a variety of domains including subject matter knowledge, knowledge of pedagogy (both science-specific and general), knowledge of curricula, and knowledge of students' understandings of science content and processes (Magnusson et al., 1999).

Together, these and other types of knowledge inform how teachers think about science teaching.

Also important to teachers' thinking and practice are science teaching orientations (Friedrichsen, Van Driel, & Abell, 2011). Magnusson and colleagues identify nine science teaching orientations, or "general way(s) of viewing or conceptualizing science teaching," (1999, p. 99): process, academic rigor, didactic, conceptual change, activity-driven, discovery, project-based science, inquiry, and guided inquiry. As Friedrichsen and colleagues argue, science teaching orientations are informed by teachers' beliefs about the goals and purposes of science teaching, views of science, and beliefs about science teaching and learning (Friedrichsen et al., 2011). Additionally, orientations are not mutually exclusive; teachers may hold beliefs and demonstrate teaching strategies consistent with more than one orientation in the course of teaching a science lesson. Particularly relevant to this study are those orientations associated with prospective teachers' own science learning experiences (e.g., didactic), their initial and developing science teaching orientations (e.g., activity-driven, discovery, and inquiry) and science teaching orientations promoted in the elementary science teaching methods course (e.g., guided inquiry).

Rather than attempt to tease apart these often-intertwined constructs, I chose to group them under the broader category of teachers' *ideas*. In this study, then, "ideas" is intended to convey the amalgam of an individual teacher's knowledge and orientations with regard to science teaching. The decision to refer to these constructs collectively as "ideas" was intentional and represents an attempt to facilitate the consideration of teachers' cognitive resources within the larger scope of the study and its findings.

## Confidence

Studies of prospective teachers' feelings of confidence and self-efficacy for science teaching are numerous (Appleton & Kindt, 1999; Bleicher, 2006; Howitt, 2007; Palmer, 2006; Ramey-Gassert et al., 1996; Schoon & Boone, 1998). As a construct, self-efficacy represents feelings of capability with regard to something that is domain- or task-specific (Bandura, 1994). For example, one may have self-efficacy for teaching an investigation lesson about the path of light. To refer to self-efficacy in general terms (i.e., lacking a specific referent) is incongruent with its definition.

Confidence has cognitive, emotional, and performance-related aspects and is a feeling of capability that can change according to the situation (Norman & Hyland, 2003). For example, one may develop confidence in one's ability to teach elementary science. In this example, the referent has a wider scope than in the self-efficacy example. To cover both constructs, I used instruments that measured self-efficacy for teaching investigation lessons and instruments that assessed confidence for teaching science lessons more generally (see Chapter 3). For simplicity, I refer to both constructs collectively as "confidence."

## Authenticity

One dimension of an approximation of practice is its authenticity. Briefly, this construct is intended to capture the gross level at which the approximation of practice resembles the *in situ* practice. Unless otherwise described, authenticity represents the relative degree of similarity between approximations of practice and elementary classroom science teaching practice. Approximations of practice were designed at three levels of authenticity: low, medium, and high, with respect to actual elementary classroom science teaching practice. Peer teaching lessons were low-authenticity, BSSTs were medium-authenticity, and reflective teaching and student teaching semester science lessons were high-authenticity approximations of practice in this study.

**Complexity**

Another dimension of an approximation of practice is its complexity. By complexity, I mean both the scope and the types of work involved in the approximation of practice. For example, a peer teaching lesson has reduced complexity relative to actual elementary science teaching because the scope of the work involves teaching a portion of a science lesson rather than teaching an entire lesson or unit. Also, the types of work involved in peer teaching are different and fewer, since peer teaching mainly focuses on engaging simulated elementary students with the material intellectually, and lacks the behavior management component (among other components) of elementary science teaching.

Figure 2.1 illustrates a model of how key constructs in this study interrelate for typical prospective elementary teachers entering the elementary science methods course. The model in Figure 2.2 depicts hypothetical interrelationships between study constructs for prospective elementary teachers who have completed the elementary science methods course and approximations of practice described in this study (see Chapter 3). In both models, bold text denotes those elements whose contributions are thought to be particularly prominent.

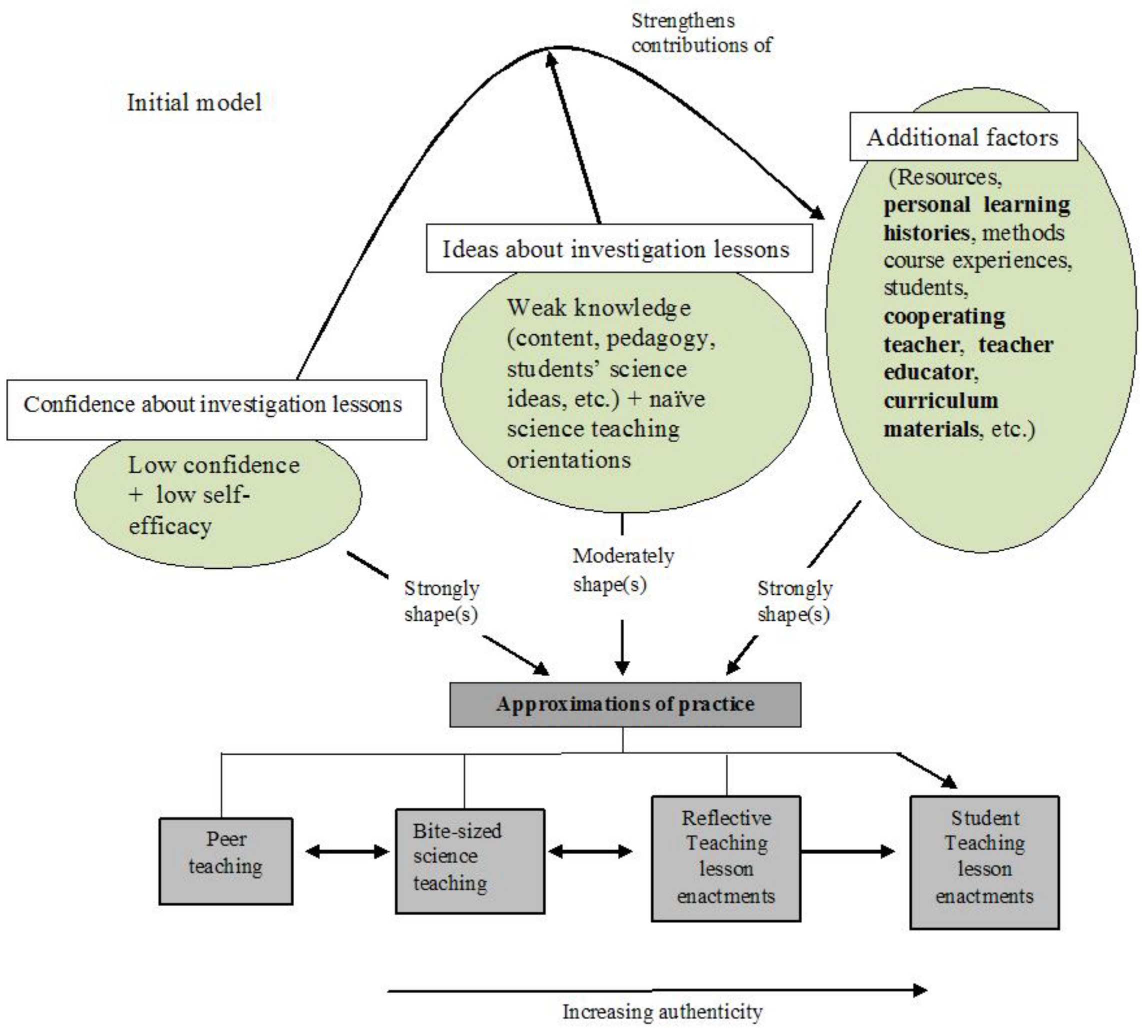



*Figure 2.1.* Theoretical model illustrating relationships between prospective teachers' initial ideas about and confidence for teaching investigation lessons, and approximations of science teaching practice.

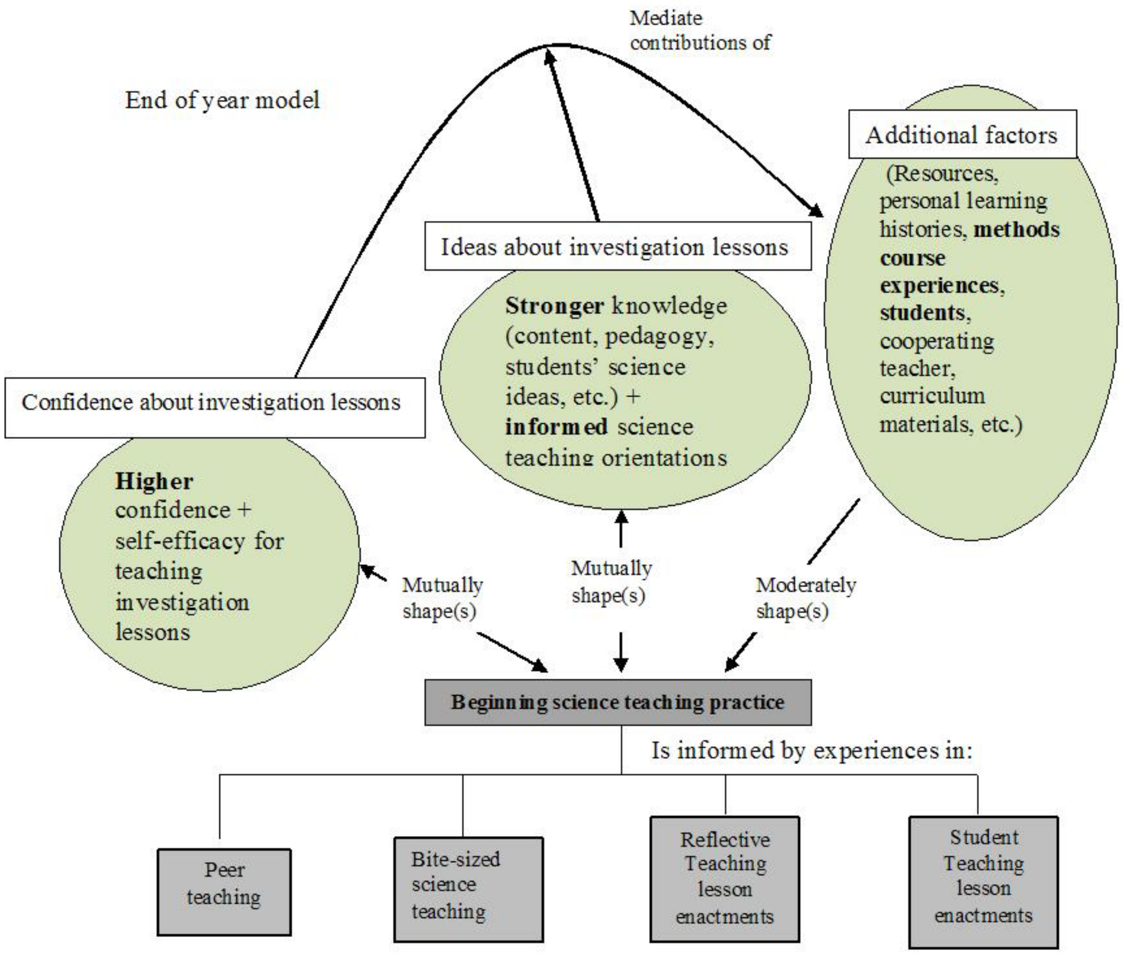



*Figure 2.2.* Theoretical model illustrating relationships between prospective teachers' ideas about and confidence for teaching investigation lessons, and beginning science teaching practice following completion of methods course and approximations of practice.

**Descriptions of theoretical models**

When prospective teachers enter the elementary science methods course, they bring with them ideas (knowledge and orientations) and confidence about teaching science investigation lessons. Prospective elementary teachers are also influenced by a host of additional factors, including their own personal histories as science learners, relationships with their cooperating teachers, the curriculum materials at their disposal, and numerous other contextual and historical considerations. These constructs are interrelated and continue to change as prospective teachers progress through their teacher preparation coursework and teaching experiences. The model proposed in Figure 2.1 represents interrelationships between these constructs for the typical novice elementary science teacher. As previously described, prospective elementary teachers often possess weak knowledge for science teaching. They may be heavily influenced by their own experiences as science learners in forming initial orientations toward science teaching (Appleton & Kindt, 1999; Eick & Reed, 2002; Friedrichsen et al., 2011). They also typically lack confidence for science teaching (Appleton & Kindt, 1999; Bleicher, 2006; Sherman & MacDonald, 2007) and may defer to authorities such as cooperating teachers and teacher educators (Smagorinsky et al., 2004; Strangis, Pringle, & Knopf, 2006). As depicted in Figure 2.1, prospective elementary teachers' initial approximations of practice may reflect and inform these constructs in ways that are consistent with the literature base. For example, prospective elementary teachers' typically low confidence levels and weak ideas about teaching investigation lessons may render other factors, such as their own science learning histories and their cooperating teachers' guidance, stronger influences on their initial approximations of practice.

Prospective elementary teachers' ideas, confidence, additional factors, and approximations of practice are envisioned as dynamic constructs whose interrelationships also change throughout the duration of this study. Presumably, methods course concepts and experiences will have consequences for prospective teachers' confidence, ideas, and teaching practice. Within the set of approximations of practice depicted in Figure 2.1, I hypothesize that the peer teaching and bite-sized science teaching (BSST) assignment enactments shape and are shaped by the reflective teaching lesson enactments (due largely to the order in which they occur), and the reflective teaching lesson enactments, in turn, shape the ways in which prospective teachers teach science during their student teaching semesters. I also envision that the BSSTs may have an impact on the enactment of lessons prospective teachers teach during their student teaching semester.

Additionally, changing interrelationships between study constructs may be direct and/or they may be mediated by interactions between other constructs. For example, a methods course learning activity may shape a prospective teacher's ideas for teaching a science investigation lesson, which in turn changes her self-confidence for teaching that science investigation lesson in an approximation of practice. While individual prospective teachers' trajectories as they progress through the methods course and student teaching semesters are likely to be unique due to the situated natures of their approximations of practice, I anticipate some common end points among prospective teachers who have completed the methods course and approximations of practice described in this study. These common end points are depicted in the model in Figure 2.2.

Briefly, Figure 2.2 proposes that the typical prospective elementary teacher's beginning science teaching practice (i.e., her science teaching practice following the student teaching semester) is shaped by increased confidence in her ability to teach investigation lessons, stronger ideas about science teaching, and some differences in the additional factors that inform her teaching practice. At this point, approximations of practice are thought to serve as teaching experiences that inform science teaching practice, and also shape confidence and ideas about science teaching. Finally, prospective teachers' practice is projected to be shaped to a much lesser degree by additional factors such as cooperating teachers' guidance and curriculum materials' recommendations, since prospective teachers presumably now have the beginnings of a personal teaching experience base upon which to draw.

**Study aims**

This research study attempts to integrate the literature cited above in the pursuit of empirically-grounded answers to the research questions posed in the previous chapter. In this manner, I aim to build on and extend the knowledge base about prospective teacher learning and development through the use of approximations of practice. Findings will impact evidence-based knowledge in several domains, including practice-oriented teacher education and theories of teacher learning and development, in elementary science and more generally. The overarching goal of this work is to generate a better, empirically-based understanding of how approximations of teaching practice can contribute to the preparation of effective, well-started beginning elementary science teachers.

## Chapter summary

In this chapter, I have identified the relevant empirical and theoretical work that forms the foundation for my dissertation study. Extant theory, knowledge, and evidence about teacher learning and development, in science and other subject areas, informed and guided my study's design. In this work, I aim to build on the theoretical foundation described here and contribute new and valuable findings to both theory and practice regarding prospective teacher learning, development, and practice in elementary science. Toward these goals, I outline the research methods used in this study in Chapter 3.

# CHAPTER 3

# RESEARCH METHODS

## Chapter overview

This chapter provides details of the context and research methods of this study, in which I examined prospective elementary teachers' instructional approaches, ideas about, and confidence for teaching investigation lessons or lesson portions under different circumstances. As described in the previous chapter, Grossman and colleagues' cross-professional learning framework, and particularly their approximations of practice, was used as the primary tool to guide and inform this study's design and execution. In the following sections, I describe the study's components, contexts, and caveats as they relate to research methods.

## Case study design

I employed a case study research design to gather and analyze as much in-depth, detailed information as possible regarding prospective teachers' experiences with and impressions of approximations of practice in an elementary science teacher education capacity (Yin, 2006). To this end, I collected and analyzed qualitative data that revealed prospective teachers' instructional approaches, ideas about, and confidence for teaching investigation lessons or lesson portions as approximations of practice. Observations, written records, and other artifacts of focal prospective elementary teachers' instructional approaches during approximations of practice were collected, analyzed, and used to identify similarities and differences among case study teachers. Also, I conducted numerous interviews with the four prospective elementary teachers' that afforded me access to their ideas about and confidence for teaching investigation lessons, as well as their impressions of the benefits and limitations of these approximations of practice as experiences that fostered learning to teach elementary science. The following sections describe in more detail the methods, contexts, and components of this study's case study research design.

## Study contexts

### Elementary science teaching methods course

The dissertation study I describe was integrated with the structure and content of the Fall 2009 Elementary science teaching methods course (EDU 421) at the University of Michigan and was supported by National Science Foundation grant #0628199. In this required course, prospective elementary teachers were taught theoretical and practical aspects of teaching elementary science consistent with guided inquiry and inquiry teaching orientations, with a particular focus on four main learning goals for prospective teachers:

- to develop an understanding of scientific inquiry and scientific practice more generally—including supporting students' sense-making—and how to incorporate these ideas into effective elementary science teaching
- to develop the ability to anticipate, assess, identify, and work with students' ideas in science
- to develop the ability to make science accessible to *all* students, including through connecting it to their lives

- to develop the ability to analyze and adapt curriculum materials so they're more effective (especially with regard to supporting students' sense-making, working with students' ideas, and making science accessible), and to use those curriculum materials in practice

and the following overarching learning goal for prospective teachers:

- to develop the ability to prepare, teach, and analytically reflect on elementary school science lessons

To support prospective teachers in meeting these learning goals, course designers divided the semester-long course into two learning cycles composed of segments dedicated to planning, enactment, and reflection (Karplus, 1980; Zembal-Saul et al., 2000). The enactment segment of each learning cycle was tripartite by design, and emphasized three elemental components of science lesson enactment: initiating a science lesson, conducting the learning activity, and closing the lesson. This modular design allowed the course instructors to connect the theory and practice of several different teaching methods in science with their temporal role in teaching a science lesson. Figure 3.1 depicts the organization of the methods course graphically.

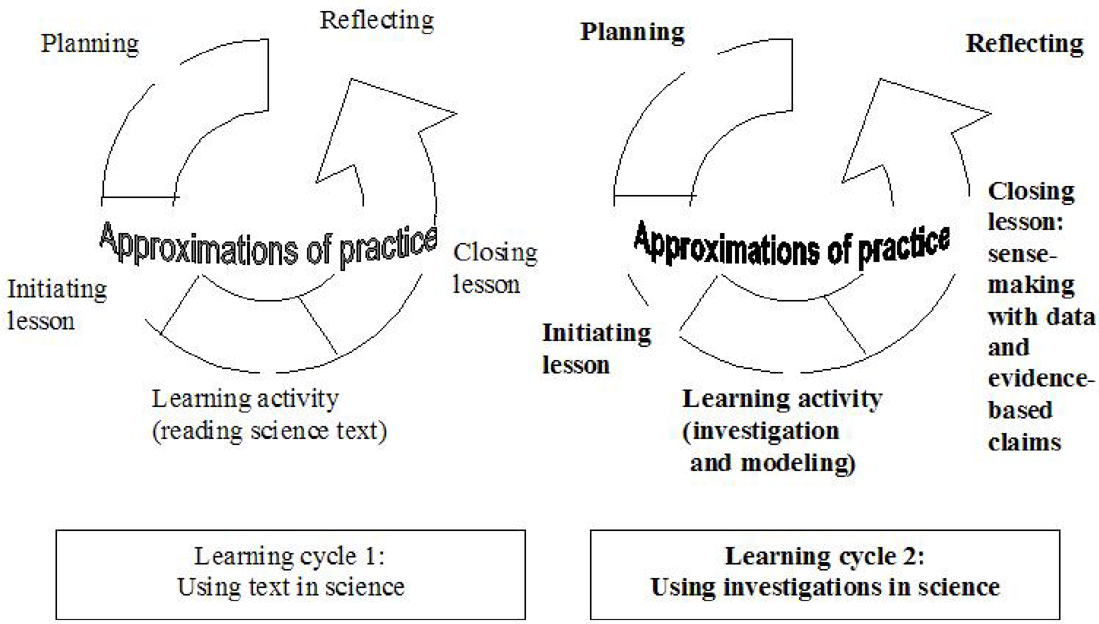



*Figure 3.1.* Learning cycles in the elementary science methods course

Approximations of teaching practice played a crucial role in the enactment-focused portions of each learning cycle, as peer teaching experiences provided prospective teachers supported experiences with science teaching and learning methods (Pauline, 1993). For example, during the second learning cycle class dedicated to introducing an investigation lesson, the peer teaching approximation of practice entailed "teachers" instructing a science lesson portion in which a small group of "students" created initial models representing assigned alternative ideas about how condensation occurs. The focus of this approximation of practice was to study and experience what it means to elicit students' initial ideas about new science content using scientific models as a medium to convey ideas. Alternatively, lesson introductions may involve the prospective teacher eliciting students' initial ideas about the new science content through a whole class brainstorming session. In this manner, prospective teachers explored several lesson introduction instructional approaches. The use of various learning activities, such as conducting experiments to gather data and reading science texts, and lesson closure methods, such as facilitating group sense-making with data and crafting evidence-based claims, were explored in a similar vein.

The first learning cycle focused on the use of texts in science teaching and learning. The second learning cycle focused on the integrated uses of scientific modeling elements and investigations in science teaching and learning. Figure 3.1 highlights the elements most relevant to my dissertation work in bold font; that is, the second learning cycle.

Each learning cycle entailed several assignments, including lesson plan analyses, a reflective teaching assignment enacted in the field placement classroom, and approximations of practice during the methods course itself. For the course syllabus, please see Appendix A.

**Methods course instruction about investigations.** Beginning in the sixth week of the methods course, my co-instructor and I focused on how prospective teachers can teach lessons with investigations to help their students learn both science content and scientific practices. Scientific practices are described as the domain-general procedural work done by scientists, and include collecting data, analyzing data, and sharing findings (Duschl, Schweingruber, & Shouse, 2007). Methods course instruction about investigations in elementary science teaching and learning covered common types of investigations typically found in elementary science curricula, such as observing and classifying rocks and minerals, and experimenting with variables that influence plant growth. Prospective teachers were assigned to read chapters from *Ready, Set, Science!*

(Michaels, Shouse, & Schweingruber, 2008) that address investigations. The key features of investigation lessons framework in this study was not part of methods course instruction.

Methods course instructors provided prospective teachers with examples of effective guided inquiry teaching strategies to support elementary student learning during investigations. For example, video segments of first grade students engaging in investigations of seeds and eggs were viewed and discussed in light of instructional approaches used by the first grade teacher to support students' investigative learning in the video (Abell, 2003). Taken together, the assigned readings and videos constituted representations of science teaching practice. Decompositions of investigation-based science teaching practice occurred during methods course discussions about the reading and videos. Additionally, prospective teachers engaged in peer teaching approximations of practice during the methods course to gain experience with various aspects of teaching investigation-based elementary science lessons, including managing materials and student behavior, and scaffolding student data collection and sense-making. Each prospective elementary teacher served as a peer teacher once during the semester; in all other peer teaching lessons, s/he acted as a peer "student." Elements of Grossman and colleagues' cross-professional learning framework and how they were instantiated in the methods course are discussed in the next sections of this chapter.

**Representations of science teaching practice in the methods course**

Part of the teaching and learning in the methods course involved the use of representations of practice. Videorecorded science lesson enactments, narratives of science lessons, and modeling of instructional methods (with meta-talk about teaching moves) by methods course instructors are some examples of representations of science teaching practice used to facilitate prospective teachers' study and learning of science teaching. By their nature, representations of science teaching practice render some aspects of science teaching visible—such as classroom management techniques--while others—such as materials preparation for investigations--remain largely invisible to prospective teachers (Davis, under revision; Grossman et al., 2009a; Little, 2003). To address the visible and invisible elements of science teaching practice, we reframed and decomposed representations of practice to highlight important aspects of instruction, and engaged prospective teachers in substantive discussions about the advantages and disadvantages offered by each representation of practice as a tool for learning about science teaching practice. For example, using the "Seeds and Eggs" videos (Abell, 2003), we asked prospective teachers to attend to the ways in which Mrs. Schwartz used questions to support her students in making detailed observations of their samples. As a class, we discussed the aspects of this work that were not evident in the video—namely, instructional planning and the teacher's cognitive processes during instruction.

**Decompositions of science teaching practice in the methods course**

At a gross level, methods course instructors had already deconstructed science teaching practice into large-bin categories of lesson planning, introducing lessons, engaging students in learning activities, and concluding lessons. Further decomposition of science teaching practice took place in the form of analyzing representations of science teaching practice during the methods course, as described in the previous section. As part of whole-class discussions and small group work, methods course instructors and prospective teachers closely examined different instructional approaches to elucidate what they did and did not offer teachers and learners in the service of initiating instruction, enabling student learning during learning activities, and fostering student sense-making during lesson closure. By breaking apart what it means to, for instance, support student sense-making with data using a scientific modeling approach, prospective teachers had the opportunity to identify key elements and characteristic moves of science teaching practice that they later re-synthesized and integrated into increasingly more complex recreations, or approximations, of science teaching practice. For example, teacher educators and prospective teachers focused on the introduction of scientific terminology in elementary science lessons. They examined how the timing and use of scientific terminology could render scientific understandings more or less accessible to students, and considered issues relating to student literacy and potentially conveying the erroneous message that learning science could be reduced to the memorization and proper use of terminology.

**Approximations of science teaching practice in the methods course and beyond**

I turn now to a description of how approximations of practice were used in the methods course and during the student teaching semester. In applying Grossman and colleagues' cross-professional learning framework to this study, my colleagues and I designed four increasingly-complex approximations of teaching practice in which prospective teachers participated.

**Peer teaching.** During the methods course, prospective teachers engaged in teaching a portion of a science lesson with their peers. Termed "peer teaching," (and abbreviated PeerTch), this approximation of practice most closely resembled microteaching as described by Pauline (1993), and most closely aligned with Grossman and colleagues' description of a university-based approximation of practice. Briefly, prospective peer teachers met with their methods course instructor to co-plan a short science lesson, which they later taught to their peers, who assumed the roles of elementary students. Teacher educators functioned in a coaching capacity during peer teaching lesson enactment by providing real-time feedback and encouraging prospective teachers to "rewind and redo" instructional moves in different and more effective ways. Following the lesson enactment, teacher educators and prospective teachers engaged in prompted co-reflection to analyze the peer teaching experience.

**Bite-sized science teaching.** As methods course assignments, prospective teachers also experienced "bite-sized science teaching," in which they enacted portions of lessons—one beginning (BSST1), one learning activity (BSST2), and one conclusion (BSST3)—on different occasions in their field placement classrooms. Intermediate in terms of complexity and authenticity, this approximation of practice allowed the prospective teacher to "try out" a portion of a lesson with real elementary students in collaboration with a practicing classroom teacher, the cooperating teacher. Lessons from which bite-sized science teaching experiences, or "BSSTs," were derived did not always involve investigations; however, they did permit prospective teachers to focus on the elements of a single portion of a science lesson. Prospective teachers were encouraged to co-plan and coordinate with their cooperating teachers to carry out this field-based assignment. As part of this assignment, prospective teachers submitted lesson plan sketches and brief written reflections. For the assignment descriptions of the peer-teaching and field placement bite-sized science teaching experiences, please see Appendix B.

**Reflective teaching.** The most complex and authentic approximation of practice required *during* the methods course semester was the reflective teaching assignment (RT). Prospective teachers were asked to conduct two full-length science lessons in the field: one approximately halfway through the semester and one toward the end of the semester. For both RT assignments, prospective teachers submitted detailed lesson plans and written post-enactment reflections in response to a set of common prompts. In the first reflective teaching assignment, prospective teachers were encouraged to teach investigation lessons, which two of the four focal prospective teachers were able to do. In the second reflective teaching assignment, prospective teachers were required to teach an investigation lesson in their field placement classrooms. Prospective teachers were encouraged to incorporate modeling as part of the investigation lesson as appropriate; however, modeling was not a required element of the assignment. Appendix C consists of the reflective teaching assignment description.

Some may contend that enacting an entire science lesson in a field placement classroom amounts to *actually doing* science teaching; however, I maintain that these are approximations of practice for several reasons. First, the cooperating teacher was present in the classroom. If and when the prospective teacher struggled in teaching the lesson, the cooperating teacher could step in and assist. Second, prospective teachers taught a single science lesson. Authentic elementary science teaching practice involves teaching many sequential science lessons over time as part of a coherent instructional unit. While some prospective teachers in this study taught entire science units during their student teaching semesters, others did not. Finally, prospective elementary teachers were not required to teach lessons in other subjects immediately before or after teaching a science lesson.

Inservice elementary teachers, on the other hand, coordinate instruction in and transitions between lessons in multiple subject areas on any given day. In essence, then, *actual* science teaching practice involves additional layers of complexity, which were beyond the scope of methods course assignments and student teaching semester requirements.

Placing this second reflective teaching experience as the final methods course assignment-cum-approximation of teaching practice positioned prospective teachers to draw upon their experiences from previous approximations of practice. As Chapter 4 reveals, these prior science teaching and learning experiences contributed positively to prospective teachers' instructional approaches, ideas about, and confidence for teaching investigation lessons.

**Student teaching semester science lessons.** The most complex, authentic, and voluntary approximation of practice in this study involved prospective teachers teaching science lessons during their student teaching semester (ST). Fortunately, all four case study teachers had opportunities to teach science during their student teaching semesters, and I was able to observe two full investigation lessons taught by each case study teacher. Again, these experiences were considered approximations of practice for the reasons outlined for reflective teaching lessons.

Figure 3.2 illustrates these approximations of practice in relation to one another.

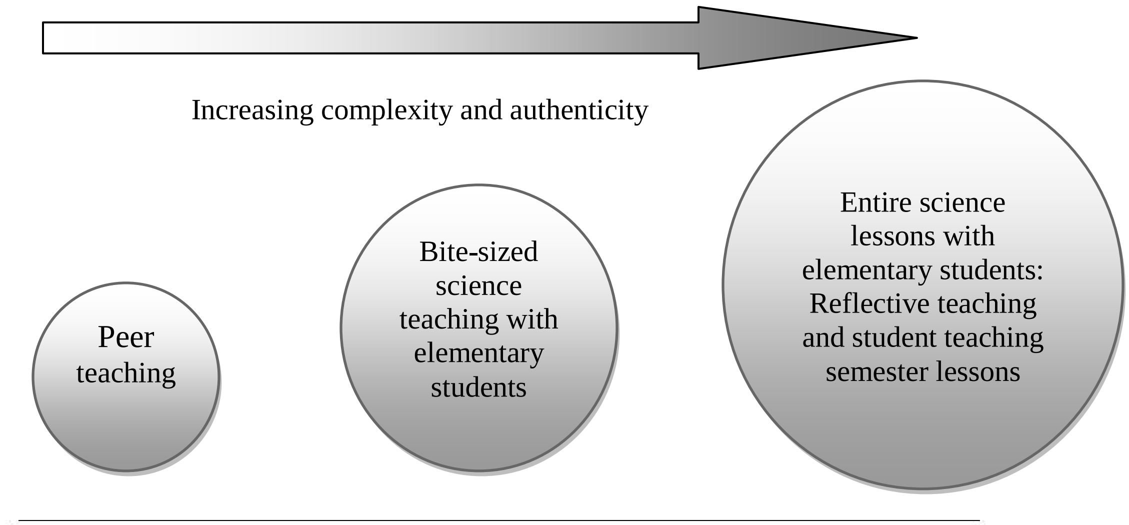



*Figure 3.2.* Approximations of elementary science teaching practice in this study

As Figure 3.2 suggests, the relative “sizes” of the different approximations of elementary science teaching practice increase from left to right; this is intended to convey increases in both the complexity and authenticity of the teaching experience. In this manner, prospective teachers’ approximations of practice have been designed to scaffold their entry into actual elementary science teaching practice.

Due to methods course peer teaching scheduling constraints, prospective teachers’ entry into elementary science teaching practice did not always begin with the initial, and least-complex, approximation of science teaching practice--enacting a portion of a science investigation with their colleagues. However, this did not preclude study of case study teachers’ learning, since the focus of the study was not about a logically-scaffolded progression of approximations of practice, but rather, the utility of approximations of practice in supporting prospective teachers’ instructional approaches, ideas about, and confidence for teaching investigation lessons. As the data in Chapter 4 show, each case study teacher experienced the approximations of practice in a different sequence. In the approximations of practice that took place within the methods course setting, case study teachers taught portions of investigation-with-modeling science lessons to a group of their peers; that is, they each carried out a different approximation of practice during the second learning cycle. Affordances of this peer teaching approximation of practice include a low-stakes teaching environment, real-time coaching from a teacher educator, semi-structured self-reflection on the experience, and constructive feedback from the simulated students and the methods course instructor.

### Study participants

Participants in this research study were undergraduates in their third semester of a four-semester teacher education program. Candidate study participants were selected using increasingly-selective qualifying criteria. Potential case study teachers in one section of the course were identified on the basis of their willingness and ability to participate, both in written and audio/visual capacities (n = 21). From this group, candidate case study participants were selected on the basis of elementary school field placement characteristics, including the science curriculum used in the classroom (Science Companion (Chicago Science Group, 2000-2010)), historical trends in the cooperating teacher's willingness and flexibility in allowing prospective teachers to teach science lessons, and associated science content (n = 13). Prospective teachers' field placement grade level and peer teaching preferences were used to narrow this pool (n = 8).

From this set, six case study prospective teachers were selected. These six case study teachers were placed in second, third, or fourth grade classrooms in one of two local elementary schools, and indicated a preference for peer teaching during different weeks of methods course instructional cycle two. They were purposely chosen to represented a range of subject matter knowledge (four non-science major/minors and two science minors) and levels of initial confidence for science teaching (four “confident” and two “unsure” about science teaching). All six were studied throughout their methods course and student teaching semesters. Due to scheduling conflicts and other unforeseen difficulties, complete lesson observation data sets were not obtained for all six case study teachers. In the interest of providing the richest and most complete findings, two of the six case study teachers were excluded from this dissertation. See Appendix D for a flowchart depicting the selection of case study teachers.

Briefly, the final four prospective teachers represented in this study are Bridget, Hannah, Natalie, and Polly. Bridget was a language arts major and social studies minor in a second grade field placement classroom. At the beginning of the study, Bridget expressed confidence in her ability to teach elementary science despite lacking experience and considering herself “not a science person.” Hannah was a language arts major and math/integrated science minor in a third grade field placement classroom. Unlike her colleagues, Hannah had science teaching experience in a museum prior to taking the methods course, and she expressed high levels of confidence in her subject matter knowledge and her ability to effectively teach science. Natalie was a language arts major and math minor in a second grade field placement classroom. Natalie felt secure in her science knowledge and indicated a focus on students’ ideas, but did not have science teaching experience prior to the methods course. Finally, Polly was a language arts major and social studies minor in a third grade field placement classroom. Polly expressed some trepidation about teaching science for the first time, largely because she did not enjoy learning science as a student and did not recall much of the science she had learned. Additional, detailed information about each of these case study teachers is provided in Chapter 4.

Data collected for this study consisted of interviews, methods course artifacts, and records of teaching practice gathered during the methods course. The study also made use of interviews and records of practice collected during case study prospective teachers' field-based science teaching experiences in the methods course and student teaching semesters. In essence, then, the study occurred in two primary sites: the elementary science teaching methods course and the elementary school field placement classrooms of the case study prospective teachers.

## Design-based research and the role of the researcher

For three primary reasons, I pursued a design-based approach to conducting this research. Design-based research studies are typically outlined on the basis of prior research findings documented in the literature, but recognize the uncertainty inherent in social science research, and thus permit the research study design to evolve to account for and adapt to unforeseen changes in the study context and participants (e.g., Brown, 1992; Collins, Joseph, & Bielaczyc, 2004). One challenge that arose early in the study's design and execution concerned the order in which case study teachers would experience approximations of practice. Initially, I had envisioned a logical progression from least to most authentic approximation of practice. However, negotiating schedules of peer teaching within the methods course and field-based approximations of practice, which had to be scheduled around standardized testing and other elementary classroom constraints, rendered a study of logically-sequenced approximations of practice unrealistic. To maximize flexibility for all involved, I chose to study case study teachers' approximations of practice regardless of the order in which they occurred.

Another reason I opted for a design-based study approach concerns my own participation in the study. As one of the course designers and a course instructor, I participated in the study in a dual capacity: as researcher and as teacher educator (Cochran-Smith & Donnell, 2006). I anticipated that there would be times when I would experience tensions arising from these sometimes-competing responsibilities. In such situations, I deferred my researcher role to my role as instructor, thereby privileging equitable learning opportunities for the prospective teachers. For example, when Bridget asked me to provide feedback about her RT2 lesson plan, I suggested that she could infuse some discussion about the role of scientific models into her lesson enactment. Here, I privileged the role of teacher educator by helping Bridget integrate aspects of her learning from the methods course into her field-based practice. Acting purely as a researcher, I would have chosen to not influence Bridget's lesson planning and enactment to provide a better picture of what Bridget could do unaided. In addition, case study teachers often asked me to provide feedback about their lesson enactments immediately following the lessons. In these situations, I tried to offer both encouragement for aspects of the lesson enacted well and suggestions for future improvements. Aside from these examples, I did not experience other notable conflicts between the two roles that required me to compromise the integrity of one role in the service of the other.

Finally, a design-based approach to this study permitted flexibility and responsiveness in real-time to prospective teacher learning. Since I was a new instructor, co-designer, and co-implementer of a novel approach to elementary science teacher education in the methods course, I felt that it was in the best interest of prospective teachers, course designers, and course instructors to engineer a degree of flexibility into this research design. In this manner, the study was conservatively reshaped during progress to best serve the interests of the prospective teachers, first and foremost, as well as to accommodate unforeseen changes, demands, and responsibilities of the course designers and instructors. For example, conventional, or "firsthand," science investigations were not always possible in the case study teacher's field placement classroom. Hannah taught her BSSTs with lessons that involved "secondhand" investigations in the form of conducting text reference material-based research (see additional explanation in Hannah's case study in Chapter 4). Although this was not what was intended by "investigation lessons," observations and interviews from these approximations of practice were included in Hannah's data set because the lessons preserved features of firsthand investigation lessons, and contributed to Hannah's growing experience base for classroom science teaching.

## Data sources

As previously described, this research was conducted using a case study methodology (Yin, 2006). In carrying out the study, I utilized a variety of qualitative data sources (Green, Camilli, & Elmore, 2006). In Table 3.1, I outline the data sources I used to answer my research questions.

Table 3.1

*Research questions and data sources*

| **Research Question** | **Sub-question** | **Data sources** |
|---|---|---|
| RQ1: How do prospective elementary teachers engage in approximations of science teaching practice that involve investigation lessons? | RQ1a. In the approximations of practice, which key features of investigations are possible and which are evident during enactment? What instructional approaches do prospective teachers use to achieve these key features in their enactments? | Observations: BSSTs, PeerTch, RT(s), and student teaching lessons |
| | RQ1b. To what extent are the instructional approaches for a key feature of investigation lessons consistent across approximations of practice? | Same as above |
| | RQ1c. What relationship, if any, is apparent between the instructional approaches for a key feature of investigation lessons and the degree of authenticity of an approximation of practice? | Same as above and post-enactment interview data |
| RQ2: How do prospective elementary teachers' ideas about and confidence for teaching science investigation lessons change as they engage in approximations of practice? | RQ2a. What ideas about teaching science investigation lessons do prospective elementary teachers hold and how do these ideas change during the final year of teacher education? | Interviews<br>RTs<br>Pre/posttest |
| | RQ2b. What are prospective elementary teachers' confidence levels for teaching science investigation lessons, and how do these change during the final year of teacher education? | Interviews<br>Pre/post test |
| | RQ2c: How do prospective elementary teachers describe changes in their (1) ideas about and (2) confidence for teaching investigation lessons? To what do they attribute these changes? | Interviews |
| RQ3: How do prospective elementary teachers' instructional approaches, ideas, and confidence levels compare across their approximations of practice? | (no subquestions) | Comparative analysis of interviews, observations, and pre/posttest data |
| RQ4: What do prospective teachers perceive as the benefits and limitations of approximations of practice for learning to teach science investigation lessons? | (no subquestions) | Interviews<br>Pre/post tests |

## Approximation of practice observations

Whenever possible, I observed case study teachers' approximations of practice. Anticipating that this would not always be possible due to scheduling conflicts, I developed an observation guide to standardize field note-taking by the approximation of practice observer (i.e., myself or a field instructor). This observation guide was based on an existing classroom observation protocol and adapted to reflect the particulars of my study (Weiss, Pasley, Smith, Banilower, & Heck, 2003). Briefly, field notes consisted of rough transcripts of lesson enactments, focusing on classroom discourse but documenting other elements of lesson enactment, including student behavior management, time and materials management, and spatial arrangements. Rough transcripts were used to indicate and provide evidence of instructional approaches associated with each of the five key features of investigation lessons. Prompts on the observation guide the indication of instructional approaches for each key feature of investigation lessons, and offer some suggestions of potential instructional approaches. Completed observation guides were entered electronically as Word files and imported in NVIVO for coding (see below). The approximation of practice observation guide is included as Appendix E.

## Interviews

Interviews were conducted throughout the methods course semester and student teaching semester with the six selected case study prospective teachers (Brenner, 2006). Two types of interviews were conducted for this study: initial and end-of-semester interviews, and post-enactment interviews.

**Initial and end-of-semester interviews.** In combination with pretest data, initial interviews were used to establish prospective teachers' baseline experience, ideas about, and confidence with respect to teaching investigation lessons. Subsequent interviews at the end of the methods course semester and the end of the student teaching semester gauged prospective teachers' changing ideas and self-confidence in these same areas. In initial and end-of-semester interviews, STEBI-B items and STEBI-B items reworded to specify investigation lessons were used to assess self-efficacy for science teaching and for teaching investigation lessons, respectively (Bleicher, 2004, 2006). For example, case study teachers were given STEBI-B type items in written form and were asked to rate their level of agreement with each item, for example: I will find it difficult to support students' sense-making using data they gathered in science investigations (strongly disagree, disagree, unsure, agree, strongly agree). Following completion of the written survey items, we briefly discussed the reasons underlying the case study teacher's item response. Similarly, prospective teachers were asked a common set of interview questions pertaining to their ideas about science teaching and investigations. (e.g., "What do investigations in elementary science lessons entail from the teacher's and students' perspectives?") End-of-semester interviews contained questions not present in previous interviews; this was intentional and usually entailed verbally-prompted reflections on approximation of practice experiences, something that was not possible in the initial interview. Initial and end-of-semester interview protocols are included as Appendices F (Initial F09 interview protocol), G (End F09 interview protocol), and H (End W10 interview protocol). Efforts to insure instrument validity and reliability focused on the use of identical questions across interviews and evaluation of interview audiorecordings and transcripts for consistency of interview item wording and delivery.

**Post-enactment interviews.** Post lesson-enactment interviews with case study teachers were also used to elucidate reasons for instructional decisions made during approximations of practice, and to discuss factors contributing to instruction and confidence. For example, I asked case study teachers if they had made any changes to the lesson or lesson portion during enactment, and if so, to describe the adjustments and reasons for these adjustments. Post-enactment interviews were conducted as soon as possible following peer teaching, bite-sized science teaching, and reflective teaching approximations of practice. Due to demands on case study teachers' time, post-enactment interviews for student teaching semester science lessons were not conducted. The post-enactment interview protocol is included as Appendix I. Efforts to insure validity and reliability of this instrument were the same as described for beginning and end-of-semester interviews.

### Pre/post test

A pre/post test was used in combination with interviews and other written data sources to probe prospective teachers' changing ideas about and confidence for teaching science investigation lessons. Briefly, pre/post test items asked prospective teachers to rate their confidence levels regarding their science knowledge and abilities to effectively teach elementary science, provide a one-word descriptor of their feelings about teaching elementary science, and list their concerns about teaching elementary science. By administering this same set of items in the pre- and posttest, I gathered data that gave me insight into how prospective teacher thinking changed during the science teaching methods course semester. In addition, the posttest, or final exam, contained items that prompted prospective teachers to write about the affordances and limitations of each approximation of practice. For relevant pre/post test items (which were not graded, but were used to collect study data), see Appendix J. Interview questions in which case study teachers were asked to elaborate upon their pre/post test responses served as a check on pre/post test item validity and reliability (see Appendices F and G).

**Peer teaching**

In the context of the methods course, the peer teaching assignment (abbreviated PeerTch) provided an opportunity for prospective teachers to try out aspects of science teaching in a relatively low-risk learning environment. Video data from these peer teaching enactments provided reviewable evidence of what prospective teachers did when tasked with enacting a portion of science instruction with their peers. Videos of case study peer teachers' lessons were later reviewed and field notes were taken using the observation guide in Appendix E. Prospective students' brief written reflections on the experience of teaching or learning in this setting provided some insight into their learning from the peer teaching experience (see Appendix K for the peer teaching reflection worksheet used by prospective teachers). Taken together, these data informed claims regarding prospective teacher learning to teach science investigation lessons in a low-authenticity simulated teaching environment.

**Bite-sized science teaching**

These data source served a similar function to the peer teaching assignment, with some notable differences. First and foremost, prospective teachers were asked to enact a portion of a science lesson with actual elementary students. Using prospective teachers' written reflections on the bite-sized science teaching experiences (BSSTs) and records of practice (in the form of lesson observation field notes and post-enactment interviews), I characterized prospective teachers' instructional approaches, ideas about, and confidence for teaching science in this simulated teaching experience of intermediate authenticity. Descriptions of the peer teaching and bite-sized science teaching assignment are provided in Appendix B. I observed BSSTs and recorded field notes of the lesson enactments using the observation guide in Appendix E.

**Reflective teaching**

As with the peer teaching and bite-sized science teaching assignments, reflective teaching (RT) assignments afforded a window into both the developing thinking and science teaching practice of prospective teachers, under more highly-complex and authentic circumstances. Unlike the previous two approximations of practice (peer teaching and BSSTs), the RT assignment asked prospective elementary teachers to orchestrate several components of teaching a science investigation lesson with actual elementary students. Whereas the first RT assignment encouraged prospective teachers to teach an investigation lesson, the second RT assignment required that an investigation be taught; I used both as data sources when pertinent. Text-based discussions were not considered investigations and were not included in the data set. Written reflections and observation field note data from the reflective teaching assignments, along with post-enactment interview data, provided insight into and evidence of prospective teachers' instructional approaches and ideas in the context of a science investigation lesson in an elementary classroom. Together, these data revealed how prospective teachers integrated their ideas and skills to orchestrate student learning when teaching a science investigation lesson. These data also revealed which aspects of teaching science investigation lessons were difficult for prospective teachers, and why. For the RT assignment description, see Appendix C.

**Student teaching science lesson records of practice**

Data collected during the student teaching semester demonstrated how prospective teachers taught science once the support structure of the methods course was no longer in place. Due to constraints on prospective teachers' time, this data source was limited to lesson observations (captured as field notes) of two separate science investigation lessons taught during prospective teachers' student teaching semester. These records of practice were created using the classroom observation guide in Appendix E.

## Data collection timeline

Table 3.2 shows the timetable for the collection of data associated with this study.

Table 3.2

*Data collection timeline*

| **Time (relative to methods course)** | **Data collected** |
|---|---|
| Week 1 | Pretest |
| Weeks 2-3 | Initial F09 interview with case study prospective teachers |
| Weeks 6-10 | Reflective teaching 1 assignment (observations and interviews) |
| Weeks 6-10 | Peer teaching assignment (observations and interviews) |
| Weeks 6-12 | Bite-sized science teaching assignments (observations and interviews) |
| Week 11-12 | Reflective teaching 2 assignment (observations and interviews) |
| Week 12 | Posttest (a.k.a. Final exam) |
| End of Fall term | End F09 interview with case study prospective teachers |
| Jan – Apr Winter 2010 term | Science lesson observations of case study prospective teachers |
| End of student teaching semester | End W10 interview with case study prospective teachers |

Using the lesson observation guidelines (see Appendix E), detailed field notes of science lesson enactments in elementary classrooms were taken by the author. In one case, I was unable to observe an approximation of practice, and so the case study teacher's field instructor observed the lesson and gathered field notes using the lesson observation guide.

## Data coding and analysis

Coding for each data source was approached using a combination of anticipated and emergent codes (Boyatzis, 1998; Corbin & Strauss, 2007). In the following subsections, I describe how the different forms of data were coded and analyzed.

### Approximation of practice enactment data

Transcripts of observed lessons were used to identify instructional approaches associated with the key features of investigation lessons per the observation guide (Appendix E). Data were compiled in NVIVO and were coded using an initial coding scheme based on anticipated prospective teacher instructional approaches for key features of investigation lessons, using methods course content, research literature, and prior experience working with prospective teachers to guide the development of the coding scheme. For example, the key feature "Supporting claims with evidence" contained the following codes: using written supports, discursive, scientific model-based, not done, and other. When multiple instructional approaches for a key feature were present in a lesson enactment, all pertinent codes were logged for that lesson observation. Adjustments were made to the coding scheme on the basis of trends in the data; in some cases, codes were combined and in other cases, codes were eliminated (Miles & Huberman, 1994). The final coding scheme for approximation of practice instructional approach data is provided in Appendix L. Inter-rater reliability testing of these data revealed approximately 80% agreement (Cohen's kappa = 0.7), and coding differences were resolved through discussion (Meadows & Morse, 2001).

Instructional approach data across approximations of practice were tabulated for each case study teacher and each key feature of investigation lessons. Individual case study teacher data were analyzed for consistency of instructional approaches across approximations of practice for each feature of investigation lessons using the tabulated data. Gross inconsistencies in instructional approaches across approximations of practice were noted and related back to the lesson enactments to identify lesson-level differences that might explain anomalous data. Similarly, consistencies in instructional approaches across approximations of practice were also related back to lesson enactments and, when possible, lesson plans to identify potentially explanatory similarities.

**Determining possible key features of investigation lessons in approximations of practice.** In research question 1a, I asked which key features of investigations were (1) possible and (2) evident in the enactments of science investigation lesson approximations of practice. To determine which features were possible, I considered the lesson or lesson portion holistically in terms of what the enacted lesson or lesson portion could entail. For entire investigation lessons, I posited that all five key features of investigations were possible. For bite-sized lesson portions, I assigned the five key investigation features to the following lesson portions on the bases of when they were most likely to occur. For reference, BSST1 denotes the lesson introduction, BSST2 denotes the learning activity, and BSST3 denotes the lesson conclusion.

Table 3.3
*Key features of investigation lessons aligned with bite-sized science teaching lesson portions*

| Key feature of investigation lesson | Most likely to occur in: | Rationale |
|---|---|---|
| Identifying the purpose(s) | BSST1 | Provides a reason for students to engage in the investigation at the outset of the lesson |
| Connecting to prior knowledge, ideas, and/or experiences | BSST1 and BSST3 | Activates student thinking and facilitates mental connections between lessons and the investigation |
| Establishing data collection | BSST2 | Foundational to conducting the investigation |
| Fostering sense-making with data | BSST2 and BSST3 | Important for clarifying student confusions during the investigation and instrumental for learning from the investigation after it has concluded |
| Supporting claims with evidence | BSST3 | Requires generation of investigational data and some sense-making using those data |

The guidelines in Table 3.3 were applied to all case study teachers' bite-sized science teaching lesson enactments to determine which investigation features were anticipated. To determine which key features of investigations were possible in the peer teaching assignments, the relevant peer teaching lesson plans were considered in terms of their alignment with the BSSTs. For example, Bridget's peer teaching lesson entailed a culminating modeling activity that took place after students had made initial models of condensation (Hannah's peer teaching lesson), gathered investigation data (Natalie's peer teaching lesson), and engaged in a sense-making discussion to synthesize understandings of data across investigation stations (Polly's peer teaching lesson). Therefore, Bridget's peer teaching lesson most closely aligned with a BSST3, Hannah's peer teaching most closely aligned with a BSST1, Natalie's peer teaching lesson most closely aligned with a BSST2, and Polly's peer teaching lesson most closely aligned with a BSST3. Because these peer teaching lessons did not immediately follow previous peer teaching lessons, some weekly recapping and reviewing were necessary, and were accounted for as additional key features of investigation lessons that might be present in the peer teaching lessons.

**Interviews and written methods course artifacts**

Interview data for each case study teacher were transcribed in full and parsed by topic. Typically, topics were determined by the interview question, and data parsing was straightforward. Similarly, written methods course artifacts were grouped topically. Case study teachers' statements were often reduced for clarity and brevity. Case study teachers' interview and written responses were also summarized and paraphrased for inclusion in summary tables. As a check on the validity of data reduction, the transcripts of one case study teacher's feelings during and after teaching her approximations of practice served as the basis for an inter-researcher data reduction comparison. Comparison of reduced data from both researchers revealed substantive agreement for all reduced data points.

**Development of case study profiles and end of year models**

Case studies for each of the four focal teachers were developed around the three major study constructs (instructional approaches in, ideas about, and confidence for teaching investigation lessons) by grouping data according to the relevant construct(s). Triangulation  among similar data from different time points and in different data formats led to the development of initial claims, which were verified through a search for confirming and disconfirming evidence within the data sets (Eisenhardt, 1989; Yin, 2006). Member checking of case study profiles was used to insure accurate representation of case study prospective teachers overall, as well as accurate representations of teachers' ideas about and confidence for teaching investigation lessons (e.g., Mays & Pope, 2000).

End of year models were developed on the basis of case study descriptions and study data from each case study teacher. Briefly, the generic end of year model proposed in Chapter 2 served as the basis upon which each case study teacher's data were evaluated holistically to identify similarities and dissimilarities. Revisions were made to the generic model to generate individual case study teachers' end of year models that were consistent with study data.

**Cross-model and cross-case data analyses**

Using the end of year models developed for each case study teacher, I compared features across cases to identify similarities and differences. These model-level similarities and differences were briefly described, and framed further cross-case data comparisons and analyses.

Cross-case study data comparisons were made for each of the three main study constructs: instructional approaches, ideas about, and confidence for teaching investigation lessons. Briefly, I compiled data across individuals for each construct and looked for the existence of patterns or themes among the compiled data, taking into consideration the literature concerning prospective elementary teachers when looking for themes (Eisenhardt, 1989). Cross-case study comparisons of instructional approach data revealed three themes among these data: fidelity to lesson plans, areas of instructional focus, and influences on instruction. Similarly, cross-case study comparisons of idea data revealed two themes among these data: lessons learned from approximations of practice, and sources of change in case study teachers' ideas about investigation lessons and science teaching, more generally. Finally, cross-case study comparisons of confidence data suggested two themes: confidence during approximation of practice enactment, and confidence measured more generally at the beginning of the study versus the study's end. Similarities and differences among case study teachers with respect to each construct's themes were identified, described, and supported with example data in Chapter 4.

## Chapter summary

In this chapter, I have described the elements of my dissertation in greater detail. The study was situated within the larger context of the elementary science teaching methods course, and the relationships between the study and the course were described above. Full case studies were carried out with four prospective elementary teachers selected on the basis of their backgrounds, teaching placements, and other factors. Data sources used in this study included structured interviews and approximation of practice records of practice in the forms of observation field notes and case study teachers' written reflections. Additional data were gathered from pre- and posttests. Approximation of practice observation data were coded according to instructional approaches associated with each key feature of investigation lessons, and these data were subjected to inter-rater reliability testing. Interview data and written course artifact data were coded by topic. Coded and categorized data were used to construct case study profiles of each of the focal prospective teachers, which subsequently informed construction of a case study teacher end of year model that reflected interrelationships between study constructs. Data analyses included intra- and inter-individual comparisons of instructional approaches, ideas about, and confidence for teaching investigation lessons across approximations of practice and over time. Data were also analyzed for similarities and differences among case study teachers' perceptions of approximation of practice affordances and limitations as opportunities to learn and develop science teaching practice.

In the following chapters, I present findings from the data collection and analysis described in Chapter 3. First, I present case study data that address research questions 1 and 2. Also in Chapter 4, I present cross-case study data comparisons that address research question 3. Data pertaining to research question 4 are presented in Chapter 5.

# CHAPTER 4

# CASE STUDY PROFILES AND CROSS-CASE STUDY ANALYSES

## Chapter overview

In this chapter, I present case study profiles of the four focal prospective elementary teachers who participated in this study. In describing each case study teacher, I present data relevant to research questions 1, 2, and 3. Recall that research question 1 concerns prospective elementary teachers' instructional approaches during approximation of practice investigation lessons. Research question 2 concerns prospective elementary teachers' ideas about and confidence for teaching investigation lessons in their approximations of practice. And research question 3 concerns similarities and differences among case study teachers' instructional approaches, ideas about, and confidence for teaching approximation of practice investigation lessons.

To address these research questions, I treat each focal prospective teacher separately at first. Each case study begins with a description of the trajectory and nature of the approximations of practice with respect to instructional approaches for the five key features of investigation lessons that the prospective teacher taught. Next, I present findings that reflect the prospective teacher's changing ideas about and self-confidence for science teaching in general and investigation lessons in particular. Then, I briefly identify the prospective teacher's perceptions of changes in her ideas about and confidence for teaching elementary science lessons involving investigations. On the basis of the findings, I offer a model similar to the model in Figure 2.2 that depicts that prospective teacher’s end of year relationships between study constructs. I explore each of these areas with each prospective teacher: Bridget, Hannah, Natalie, and Polly. Finally, I explore similarities and differences among prospective teachers in terms of their end of year models and the underlying data indicating their instructional approaches, ideas about, and confidence for teaching investigation lessons.

## Bridget

### Overview

Bridget was a language arts major and social studies minor in the elementary teacher education program. In the methods course, Bridget tended to be reserved and did not typically participate in whole-class discussions; however, in one-on-one interviews and when teaching science, Bridget was animated, talkative, and enthusiastic. Bridget was placed in a second grade classroom at Wolverine Elementary in Ann Arbor. Throughout the study, Bridget maintained a strong belief in the importance of hands-on learning in science. Over her last year of teacher preparation, Bridget came to enjoy science teaching and even began a lunchtime science club at her elementary school.

### Bridget’s science background

Bridget took three years of high school science (introductory physical science, biology, and physics) and the minimum number of required, college-level science courses for prospective elementary teachers (i.e., courses in physics for elementary teachers, animal behavior, and geoscience). She did not consider herself to have a strong science background, but expressed confidence in her ability to learn and prepare new material for teaching purposes. When asked about her memories as a science learner, Bridget stated that she enjoyed elementary-level science and recalled *doing* science rather than reading science. She also remembered learning science from television shows.

Bridget stated that she did not have thorough content knowledge about the science topics she taught during Fall 2009 and Winter 2010 semesters.

> I wouldn't say I knew a ton about any of those subjects, but sound was honestly pretty easy for me to teach but it was pretty easy for them to learn too because it's something that's around every day, mostly it was just vocabulary. Learning what do we call these things that we already know about. (Bridget, End W10 interview)

In the above interview excerpt, Bridget suggested a belief that elementary science learning, at least within this topic, was largely associating terminology with already-familiar concepts. Despite this perspective, she described herself as "not a science person":

> …prior to this class [elementary science methods] I hadn't ever taught science, so it was kind of, I'm not a science person, I'm not a science major or minor, I loved science in elementary school but as it got more complex and things like that as I got older it wasn't as fun. (Bridget, End F09 interview)

She reiterated similar sentiments at the end of her student teaching semester, adding that her science teaching experiences over the year were more enjoyable than anticipated.

In sum, Bridget's science teaching and learning-to-teach experiences helped her establish a more positive attitude toward her own elementary-level science background knowledge and ability to effectively teach science to elementary students.

**Bridget's approximations of practice trajectory**

Bridget and her cooperating teacher scheduled the field-based approximations of practice such that Bridget taught science once a week during her methods course semester. The order in which Bridget carried out her approximations of practice is depicted in Table 4.1.

Table 4.1

*Bridget's approximations of practice trajectory*

| | BSST1 | BSST3 | BSST2 | PeerTch | RT2 | ST1 | ST2 |
|---|---|---|---|---|---|---|---|
| Date | 5 Nov. 2009 | 12 Nov. 2009 | 19 Nov. 2009 | 23 Nov. 2009 | 4-5 Dec. 2009 | 21 Jan. 2010 | 4 Mar. 2010 |
| Lesson or lesson portion | Observing rocks and minerals* | Properties of minerals closing discussion | Mineral streak and scratch tests | Consensus model of condensation | Models of mold and cast fossils | Sound investigation stations** | Identifying seed parts |

*Bridget taught the entire lesson
**Bridget co-taught this lesson with another student teacher
Note: Bridget's RT1 was not a science lesson, so it was not included in this study.

As Table 4.1 indicates, Bridget taught lessons and/or lesson portions from three different second grade science units: rocks and minerals, life cycles, and sound. All lessons and lesson portions that were observed as part of this study contained key features of investigation lessons.

**Key features of investigation lessons in Bridget's approximations of practice**

Using the approach described in Chapter 3, I analyzed Bridget's approximations of practice for the possible and actual presence of the five key features of investigation lessons. To determine which key features were possible or "anticipated," I considered whether the approximation of practice was an entire lesson or a lesson portion. Entire investigation lessons could potentially contain all five key features, which were thus anticipated in all RT and ST lessons. Peer teaching lessons and lesson portions were aligned with their corresponding BSST(s), and on the basis of the BSST type (BSST1, 2, or 3), anticipated key features of investigation lessons were determined (see Table 3.3). When available, lesson plans were also considered in the assignment of possible or anticipated key features of investigation lessons. Table 4.2 displays an overview of the findings:

Table 4.2

*Key features of investigation lessons in Bridget's approximations of practice*

Anticipated = A, Observed = O

| Key feature of investigation lesson | BSST1 | BSST3 | BSST2 | PeerTch | RT2 | ST1* | ST2 |
|---|---|---|---|---|---|---|---|
| Identifying the purpose(s) | A, O | O | O | | A, O | A, O | A |
| Connecting investigation lesson and students' knowledge, ideas, and/or experiences | A, O | A | O | A, O | A, O | A, O | A, O |
| Establishing data collection | O | | A, O | | A, O | A, O | A, O |
| Fostering sense-making with data | | A, O | A, O | A, O | A, O | A, O | A, O |
| Supporting claims with evidence | | A | | A, O | A, O | A | A |

*Lesson co-taught with another student teacher

Bridget's approximations of practice contained most of the anticipated key features of investigation lessons. However, Bridget taught investigation lessons in which instructional approaches for supporting claims with evidence were not observed. This is a noteworthy finding because it was a focus of Bridget's peer teaching lesson. Also notable were the key features of investigation lessons that Bridget incorporated into her BSSTs that had not been initially anticipated due to the natures of those BSSTs.

While Table 4.2 provides an overview of Bridget's approximations of practice, it leaves open the question: How did Bridget instantiate the key features of investigation lessons in her approximations of practice? To provide more detail about the data represented in Table 4.2, Tables 4.3 through 4.7 display instructional approaches for each key feature of investigation lessons. Enactment observation data were tabulated as described in Chapter 3 and are displayed and described below.

**Identifying the investigation purpose(s).** Quality science teaching involves supporting learners in understanding the reason(s) for doing particular scientific investigations. While it is typical for this to precede the investigation, many teachers opt to identify the investigation purpose(s) as part of the lesson conclusion. Often, identifying the investigation purpose(s) happens both before and after the investigation, as an instructional device to frame the work. In many of her approximations of practice, Bridget identified the investigation purpose(s) by telling students the reasons for what they were learning and doing. For example, in her RT2, Bridget told her students:

> Today we are going to make mold fossils. We are also going to make cast fossils. We are going to use the models we make to learn how fossils are formed in nature. (Bridget, RT2 lesson observation)

In this example, Bridget introduced the investigation purpose(s) at the beginning of the lesson. Table 4.3 shows instructional approaches Bridget used to identifying the investigation purpose(s) in her approximations of practice. In these and all subsequent tables that display instructional approach data, “X” denotes the presence of a particular instructional approach at any point during the lesson or lesson portion, but does not indicate instructional approach frequency or relative prominence. A holistic impression of teaching orientation with respect to the key feature and instructional approaches is indicated in the bottom (bolded) section of each table.

Table 4.3

*Bridget's instructional approaches to identifying the investigation purpose(s)*

| **Identifying the investigation purpose(s)** | BSST1 | BSST3 | BSST2 | PeerTch | RT2 | ST1 | ST2 |
|---|---|---|---|---|---|---|---|
| Developing authentic process skills | | X | X | | X | | |
| Answering a question or problem-solving | | | | | X | | |
| Scientific modeling | | | | | X | | |
| Telling the purpose | X | X | X | | X | X | |
| Other | X | X | | | | | |
| **Mostly teacher-directed** | X | | X | | X | X | |
| **Mostly student-directed** | | | | | | | |
| **Intermediate** | | X | | | | | |
| **Not done or NA** | | | | X | | | X |

While Bridget did employ instructional approaches other than telling the investigation purpose, such as framing the investigation as work typically done by geologists, these were also largely teacher-directed methods consistent with a didactic teaching orientation. Such teacher-directed approaches to identifying the investigation purpose(s) were observed in almost all of Bridget's approximations of practice, and were typical elements of the Science Companion lesson plans Bridget used to guide her lesson enactments. Bridget tended to follow lesson plan recommendations closely, and so her instructional approaches for this key feature remained consistent across her approximations of practice, regardless of their complexity or authenticity.

**Connecting investigation lessons and students' knowledge, ideas, and experiences.** The second key feature of investigation lessons is making connections between investigation lessons and students' knowledge, ideas, and experiences pertinent to the investigation lesson. During one of her approximations of practice, Bridget began the lesson by saying,

> Do you remember your field trip to the gravel pit? Do you remember seeing some fossils there? How do you think those fossils were made? (Bridget, RT2)

As the above excerpt indicates, Bridget connected her RT2 investigation lesson to students' knowledge, ideas, and experiences through the use of questions to elicit student thinking about the science content. Bridget also made reference to a shared experience (class field trip to the gravel pit) to stimulate student recall of a previous informal science learning opportunity. Table 4.4 displays the instructional methods Bridget used to foster connections between the investigation lesson and students' knowledge, ideas, and experiences in her approximations of practice.

Table 4.4

*Bridget's instructional approaches to connecting the investigation lesson*

| **Connecting investigation lesson and students' knowledge, ideas, and experiences** | BSST1 | BSST3 | BSST2 | Peer Tch | RT2 | ST1 | ST2 |
|---|---|---|---|---|---|---|---|
| Connecting to previous lessons | X | | X | X | X | X | X |
| Connecting to real world examples | X | | | X | X | X | X |
| Elicit student ideas | | | X | | X | X | X |
| Relating to a scientific model | | | | X | X | | X |
| Other | | | | | X | X | X |
| **Mostly teacher-directed** | X | | X | X | | | |
| **Mostly student-directed** | | | | | | | |
| **Intermediate** | | | | | X | X | X |
| **Not done or NA** | | X | | | | | |

Bridget used many strategies, particularly in later approximations of practice, to establish connections between the investigation lesson and students' own cognitive resources. As her approximations of practice progressed, Bridget's approach to connection-making evolved into one that was less teacher-directed and more highly-influenced by the students' contributions.

**Establishing data collection procedures.** A third key feature of investigation lessons is the establishment of data collection procedures. Bridget's methods for this key feature in her approximations of practice were generally teacher-directed. For example, in her BSST2, Bridget introduced a worksheet, gave verbal step-by-step instructions, and physically demonstrated procedures for her students to follow in the collection of mineral streak and scratch test data. Table 4.5 reveals the entire data set for Bridget's approximations of practice with regard to this key feature.

Table 4.5

*Bridget's instructional approaches to establishing data collection procedures*

| **Establishing data collection procedures** | BSST1 | BSST3 | BSST2 | PeerTch | RT2 | ST1 | ST2 |
|---|---|---|---|---|---|---|---|
| Directions | X | | X | | X | X | X |
| Discovery | | | | | | | |
| Teacher modeling | | | X | | X | X | X |
| Directed discovery | X | | X | | X | X | X |
| Supported data recording | | | | | | | |
| Other | | | X | | X | X | X |
| **Mostly teacher-directed** | X | | X | | X | X | X |
| **Mostly student-directed** | | | | | | | |
| **Intermediate** | | | | | | | |
| **Not Done or NA** | | X | | X | | | |

Table 4.5 shows that Bridget consistently combined instructional approaches to establish data collection procedures in her approximations of practice. Bridget also worked to ensure that her directions were clear, manageable, and not confusing for her students. Throughout her approximations of practice, Bridget consciously tried to improve the comprehensibility of her instructions and began to divide investigations into manageable chunks rather than overwhelming her students with too many instructions at once. On this topic, she reflected:

> Students got right to work each time they were given a new set of directions. Breaking apart the activity and giving students one or two steps to work on at a time helped to keep everyone on task and avoided confusion. (Bridget, postBSST2 written reflection)

Observations revealed that Bridget's early approximations of practice entailed many student questions and confusions that Bridget clarified on a student-to-student basis while circulating during the investigation. In subsequent approximations of practice, Bridget infused teacher modeling by demonstrating how to collect and record data. This served to preemptively minimize student confusion, and allowed Bridget to focus her students on the more cognitively demanding task of making sense of the investigation data. As her approximations of practice became more authentic, Bridget's instructional approaches became more effective and demonstrated Bridget's knowledge from previous lesson enactments with regard to this key feature of investigation lessons.

**Fostering sense-making with data.** Fostering students' sense-making with data during and after the investigation was another key feature of investigation lessons. Like her colleagues, Bridget made efforts to support her students' sense-making with data by posing questions, an instructional approach commonly associated with teacher-directed inquiry. For example, during her BSST2, Bridget asked students questions about the data they gathered in mineral scratch tests to prompt students to use their data to figure out which mineral was harder:

> Did you see a scratch? Which mineral had the scratch? Which mineral is harder? Which mineral is softer? (Bridget, BSST2)

Other approximations of practice yielded different instructional approaches, and Bridget's data concerning this key feature of investigation lessons are depicted in Table 4.6.

Table 4.6

*Bridget's instructional approaches to fostering sense-making with data*

| **Fostering sense-making with data** | BSST1 | BSST3 | BSST2 | PeerTch | RT2 | ST1 | ST2 |
|---|---|---|---|---|---|---|---|
| Pattern-seeking | | | | | | | X |
| Relating findings to real world | | | | X | X | | |
| Discourse-based | | X | X | | X | X | X |
| Scientific model-based | | | | X | | X | |
| Telling | | | X | | | | X |
| Other | | | X | X | X | X | X |
| **Mostly teacher-directed** | | | X | | X | | X |
| **Mostly student-directed** | | | | X | | | |
| **Intermediate** | | X | | | | X | |
| **Not done or NA** | X | | | | | | |

Typically, Bridget's instructional approach to supporting students in making sense of investigation data was to pose questions and discuss answers; that is, it was discursive. In her peer teaching lesson, Bridget employed a highly student-directed approach to supporting student sense-making. In more authentic approximations of practice, Bridget's support of student sense-making varied between teacher-directed and mixed teacher-/student-directed methods. In these later approximations of practice, Bridget's use of questions and responses to student answers suggested that she was leading them to a desired endpoint, consistent with a guided inquiry orientation. While sense-making discourse was specific to the lesson, there appeared to be no consistent trend linking instructional strategies for supporting student sense-making and the degree of approximation of practice authenticity.

In addition to supporting students in making sense of their data in relation to content-based science concepts, Bridget also used strategies to help students think about their data in terms of the nature of science (these instances were coded as “other.”) For example, Bridget’s RT2 involved a discussion in which she helped students differentiate between fossil types using models they had generated. Bridget also asked her students why they thought it was useful to study models in science. Other strategies Bridget used to support her students’ sense-making with data that were also coded as “other” included using reference guides to collect information about rock and mineral samples.

**Supporting claims with evidence.** A fifth key feature of investigation lessons focused on supporting claims with evidence. As mentioned previously, Bridget did not always include this key feature of investigation lessons in her approximations of practice. In her RT2, however, she did engage students in a whole-class discussion in which she posed questions and fielded students’ answers until a student provided the answer Bridget desired. Table 4.7 displays the data from her lesson and lesson portion enactments with regard to this key feature.

Table 4.7

*Bridget’s instructional approaches to supporting claims with evidence*

| **Supporting claims with evidence** | BSST1 | BSST3 | BSST2 | PeerTch | RT2 | ST1 | ST2 |
|---|---|---|---|---|---|---|---|
| Discursive | | | | | X | | |
| Scientific model-based | | | | X | | | |
| Using written supports | | | | | | | |
| Other | | | | | | | |
| **Mostly teacher-directed** | | | | X | X | | |
| **Mostly student-directed** | | | | | | | |
| **Intermediate** | | | | | | | |
| **Not done or NA** | X | X | X | | | X | X |

In her peer teaching lesson, Bridget used a lesson plan-supplied worksheet which scaffolded students in writing evidence-based claims about the process of condensation. In this regard, Bridget worked to support her peer students in making evidence-based claims. However, Bridget did not consistently support her actual elementary students in making evidence-based claims in her approximations of practice. Thus, there is insufficient data to make any claims regarding Bridget's instructional approaches for this key feature of investigation lessons across approximations of practice.

**Summary of Bridget's instructional approaches for key features of investigation lessons**

As a data corpus, the findings from Bridget's approximations of practice indicate that in teaching investigation lessons, Bridget employed a variety of instructional approaches. Often, the instructional approaches Bridget used tended to be teacher-directed, and so her approximations of practice seemed to recapitulate elements of traditional science instruction, in which teachers clearly determine the direction, pace, and content of student science learning. While her enactments tended toward the traditional, Bridget held ideas about teaching investigation lessons that were more aligned with reform-oriented science education, in which learners exhibit greater agency in their science learning trajectories.

**Bridget's changing ideas about and confidence for teaching elementary science**

I now consider Bridget in light of my second research question: How do prospective elementary teachers' ideas about and confidence for teaching science investigation lessons change as they engage in approximations of practice? To answer this question, I relied largely on Bridget's firsthand accounts from interviews and written and verbal reflections.

**Bridget's ideas about approximation of practice investigation lessons.** Bridget's evolving ideas about what investigation lessons can and should entail were rooted in her approximation of science teaching experiences. Table 4.8 summarizes (through paraphrasing) the lessons Bridget learned about teaching science from each of her approximations of practice.

Table 4.8

*Bridget's lessons learned from her approximations of science teaching practice*

| Lessons learned |
|---|
| BSST1 |
| • A little bit of chaos is not necessarily bad<br>• Important to have a strategy for getting them back together<br>• Not always easy to explain directions clearly so that students can understand them |
| BSST3 |
| • Students aren't always able to articulate the "big idea" on their own<br>• As teacher, I want to remember to frame the lesson with the big idea |
| BSST2 |
| • Demonstrations can be more effective for generating consistent data<br>• Giving student one or two steps to work on at a time improved on-task behavior and minimized confusion |
| Peer Tch |
| • Think about what materials to use in advance<br>• Structure lesson so that students are more active participants; students will be more engaged<br>• Always think of ways to fill extra time productively |
| RT2 |
| • Plan your time very well, especially with longer investigation lessons |

As Table 4.8 indicates, Bridget extracted a variety of ideas about science teaching from her approximations of practice. While her teaching experiences and learning opportunities were necessarily lesson- and enactment-specific, Bridget typically abstracted her learning to a much broader context. For example, when writing about what she learned from her peer teaching experience, Bridget made a point to apply what she had learned from that experience to her larger schema for science teaching:

> …students are more engaged when they're participating than when I'm talking.
>
> Take-away points about peer teaching:
>
> 1. Let students participate in drawing/writing on the board as much as is feasible… (Bridget, peer teaching written reflection)

Although this approximation of practice entailed creating a consensus model of condensation with her peers, Bridget did not indicate that this instructional approach was limited to the topic of condensation. Rather, her take-away point hints that she will use this experience and the knowledge it generated to inform her teaching in other elementary science topics.

Throughout the methods course semester, Bridget worked to integrate her methods course learning and her approximation of science teaching experiences. Synthesis of these entities contributed to Bridget's changing ideas about elementary science investigation lesson teaching and learning, which are now described in a more global sense.

**Bridget's ideas about investigation lessons more generally.** Throughout her final year of teacher education, Bridget conceived of investigations as including experiments and research driven by questions; however, her ideas became more detailed, theory-supported, and instruction-oriented as the year progressed. For example, initially she did not consider the desired "end point" of the investigation, but by the final interview Bridget emphasized the importance of students reaching a specific goal in their understanding. In her initial interview, Bridget talked about investigation lessons very broadly:

> MN: What do investigations in elementary science entail? From the teacher's perspective? From the student's perspective?
>
> Bridget: I think that a lot of times it involves experimenting and those kinds of things but not always…coming up with a question that you're trying to find an answer to, or you kind of have this direction that you're going as a class...
>
> (Bridget, Initial interview F09)

By the end of the methods course semester, Bridget introduced the idea of a desired endpoint, and said that investigation lessons

> …involve an overarching question that you're trying to answer, and then… you need to think about the kinds of activities that are going to get them to the answer to the question…you have to make sure that the resources you have available to them are going to get them to where they need to be. (Bridget, End F09 interview)

One of the inherent tensions in investigation lessons is whether the investigation can or should be student-directed or teacher-directed. This tension often arises when orientations toward science teaching and learning clash with realities of classroom instruction. Bridget brought up this tension, and initially considered it from a pragmatic standpoint:

> …as a teacher you would have to decide if you were going to let the students come up with their own question or whether you were going to give them a question, I think that sometimes it's important to let them have their own ownership of the learning and let them come up with the question themselves but sometimes it's just not feasible, sometimes you have to feed them a question and

> scaffold them along the way. (Bridget, End F09 interview)

After her student teaching semester, however, Bridget appeared to embrace a more student-centered approach to investigation lessons, stating that they should entail

> … a lot of learner-directed learning. I think that it’s a lot of giving students the materials to work with and letting them kind of decide where to go, of course as a teacher you have that endpoint that you want them to get to, so you want to make sure that as you’re thinking up these investigations, to give them the materials that get them from point A to point B... we did do a few things where they got to explore sound and things like that and it was much more just like…giving them the materials, giving them kind of a concept of OK what should I be doing with these materials, and then just letting them go and see what they come up with. (Bridget, End W10 interview)

Here, Bridget has integrated her thinking about the importance of a set end point or learning goal from the investigation, and the preference for student-directed investigation-based learning consistent with the guided inquiry orientation promoted in the methods course. She supported and reiterated this theme in the context of lessons she taught:

> …the sound unit was taught very well with explorations and investigations … giving them these kinds of goals and letting them figure out how to do it…[T]hat fits right in with my enjoying the investigation and letting students direct their own learning… (Bridget, End W10 interview)

Again, Bridget reiterated the importance of students reaching a desired learning outcome from an investigation lesson, but in a manner that appeared to rely on careful engineering of the investigation so that students would necessarily reach the desired end point, largely of their own accord. Despite this orientation, Bridget's instructional approaches often did not encourage student-directed learning. Bridget did not explicitly acknowledge this inconsistency between her beliefs and her instructional approaches.

After her student teaching semester, Bridget envisioned investigation lessons as composed of discrete elements, as she described in the following quote:

> I keep thinking back to when we were in science methods and the evaporation and condensation kinds of things we were doing and it's more or less… reviewing things that we've learned before, what does this term mean …what are some things that you know about it…getting yourself in the mode to do the investigation. And then giving students the materials … and kind of maybe just pushing them a little bit in the right direction and letting them go, and then coming back together to discuss what students found out or what they saw or they observed. (Bridget, End W10 interview)

Bridget said she drew upon her methods course experiences in her thinking about investigation lessons. Other ideas Bridget expressed were also directly related to her teaching experiences as a student teacher. For example, when asked to explain what constitutes a successful investigation lesson, Bridget stated:

> …being able to talk with them and listen to them actually be able to explain the concepts that you're trying to get after. Going back to our sound unit, having them be able to explain how a sound gets from its source to your ear. If they can do that, then they've got the lesson. …. If they can explain the concepts that they

> were supposed to explain at their level then that's it. (Bridget, End W10 interview)

Again, Bridget drew upon her teaching experience--specifically, teaching a sound unit--to support her ideas about science teaching.

**Summary of Bridget's changing ideas about investigation lessons**

Taken together, these data suggest that Bridget's ideas about investigation lessons highlighted the role of asking questions and changed in nuanced ways regarding students' and teachers' roles and practices in attaining desired outcomes. Bridget's big-picture ideas about science teaching involving investigations were informed, in part, by specific learning opportunities and experiences from her approximations of practice. As shown in the next section, these approximations of practice also informed Bridget's evolving confidence as a science teacher.

**Bridget's confidence for teaching elementary science**

Interviews and methods course artifacts provided insights into Bridget's confidence as an elementary science teacher. First, I present data relating to Bridget's confidence for teaching specific investigation lessons or lesson portions. Then, I share data that reveal Bridget's confidence for teaching investigation lessons more generally.

**Bridget's confidence for teaching approximation of practice investigation lessons.** In our post-enactment interviews, Bridget talked about how she felt during and after having just taught the lesson or lesson portion. Overall, her confidence for teaching science increased with field-based teaching experience but did not translate into comfort in the moment of peer teaching. Table 4.9 displays these data as relevant segments of

Bridget's responses to interview (I) and written assignment (W) questions. A more complete set of Bridget's responses to these questions may be found in Appendix M.

Table 4.9

*Bridget's feelings during and after her methods semester approximations of practice*

| During approximation of practice<br>("How did you feel while you were teaching?") | After approximation of practice<br>("Has this experience had any impact on how you feel about teaching science?") |
|---|---|
| BSST1 | |
| … I was pretty much confident and knew what I was doing. (I) | A lot more enjoyable to me than I thought it was going to be... (I)<br>I am beginning to LOVE teaching science! (W) |
| BSST3 | |
| … it seemed very small to me…it seemed very non-scary, it was like "oh, I'm doing this, oh sure." (I) | The more I do it, the more I like it…. the teaching of it has definitely impacted that, at least. (I)<br>Science is becoming my favorite subject to teach. It was difficult to "stay out of" the teaching of the intro and activity. (W) |
| BSST2 | |
| With the exception of the first minute or two of trying to … getting my bearings… it was like, nothing. I mean, it felt completely natural. (I) | Not any more than the last 2 times we talked about it. (I)<br>Science is becoming my favorite subject to teach. It was difficult to "stay out of" the teaching of the intro and activity. (W) |
| PeerTch | |
| … definitely more nervous than I am with second graders just because they're in the same spot that I am so they can kind of see "oh well you didn't do that right" … (I) | Not really. I like it… (I) |
| RT2 | |
| Yesterday, it was … a little more chaotic than I had pictured. But today it was a lot more calm so I felt a lot better today than I did yesterday. (I) | I definitely really like it… (I) |

In her early approximations of practice, Bridget was almost surprised by how she felt about teaching science; she enjoyed it more than she had anticipated. Linked to this enjoyment is an increasing sense of confidence in her ability to effectively teach science. Bridget elaborated on what contributed to this feeling of confidence in the interview following her second reflective teaching lesson:

> I met my expectations of myself, including my goal of clear explanations. Students rarely or never seemed confused about what I expected of them. (Bridget, post RT2 interview)

Working on delivery of instructions was a semester-long focus for Bridget, and a particularly salient indicator of progress in her science teaching practice. This was one factor that contributed to Bridget's overall increase in confidence for elementary science teaching.

**Bridget's confidence for teaching investigation lessons more generally.** At the beginning of the Fall 2009 semester, Bridget expressed confidence in her knowledge of science and ability to effectively teach elementary science. She attributed this confidence to having curriculum materials and other resources to support her teaching and taking the time and effort to properly prepare:

> …if I'm given some kind of a framework for a curriculum or the kinds of things that I need to be teaching, I'm pretty confident that given a decent amount of time that I could do my own research and find the kind of things that I would want to bring in for my kids to do... I don't think by any means that if I had a class… [and] I had the resources given to me …they would come away learning nothing. And I guess that's where my confidence comes from. (Bridget, Initial interview F09)

Bridget added that although she might not have as strong a science background as some of her colleagues, she felt capable of preparing to teach science.

Her concerns about science teaching centered on efficiency and student learning: striking a balance between giving students information (knowledge transmission) and allowing students to construct their own understandings, and the time considerations of both approaches. For example, Bridget wrote:

> I am concerned about finding a balance between giving my students information and letting them find it on their own. Sometimes time constraints may impede on our goals to let students come to understandings on their own. I think the important thing is to choose our battles as teachers. I am concerned with being able to assess in the moment the costs/benefits of giving my students information vs. making them find it themselves. (Bridget, pretest)

In addition to her presenting her initial concerns about science teaching, Bridget was also highly metacognitive about herself as a science teacher:

> It’s getting to be a little bit more of a clearer picture as to what I’m confident in and what I’m a little unsure of…in order to be a good teacher I’m going to have to know how to adapt a lesson plan, I’m going to have to know how to conduct an investigation, to facilitate a discussion…I’m confident in my ability to be able to learn how to do those things, I may not necessarily 100% be confident in my ability to just pick up and go... (Bridget, Initial interview F09)

Here, Bridget appeared to have a grasp on her areas of need as a novice science teacher beginning the methods course. Table 4.10 summarizes how Bridget’s confidence for various aspects of teaching investigation lessons changed as she progressed through her final year of teacher education.

Table 4.10

*Bridget's evolving confidence for teaching investigation lessons*

| | Beginning Fall 2009 | End Fall 2009 | End Winter 2010 |
|---|---|---|---|
| I will not be very effective in teaching science investigations. | Disagree | Strongly Disagree | Strongly Disagree |
| I will find it difficult to explain to students why science investigations work. | Unsure | Strongly Disagree | Disagree |
| I will be able to evaluate and adapt existing science investigations for use in my classroom. | Agree | Strongly Agree | Agree |
| I will find it difficult to support students' sense-making using data they have gathered in science investigations. | Disagree | Disagree | Disagree |
| I will find it difficult to effectively introduce, monitor, and conclude a lesson that involves an investigation. | Disagree | Strongly Disagree | Strongly Disagree |

Bridget's positive science teaching experiences and witnessing students' successful learning outcomes and engagement in her approximations of practice reinforced her self-confidence as a science teacher. She also cited methods course assignments and teaching experiences as contributing to her increased confidence and in hindsight, recognized that her initial confidence level was naive. Specifically, Bridget stated that she was confident in teaching investigation lessons—she viewed these as the "norm" for science instruction.

> … prior to this class [elementary science methods] I hadn't ever taught science, so it was kind of, I'm not a science person, I'm not a science major or minor…But kind of getting back into that elementary classroom setting with science and working, I enjoyed a lot more and, I've taught 2 full lessons and 3 parts of lessons, so, and seeing that my students do kind of "get it" by the end of class, that obviously I am capable of teaching a science lesson if I put the work into it ahead of time that I need to do. (Bridget, End F09 interview)

In the same interview, I asked Bridget how she felt about teaching a science lesson that involves an investigation. She answered:

> I feel pretty confident about it, actually. I definitely think that that is what I see as a typical science lesson, so yeah, pretty confident. (Bridget, End F09 interview)

As a final gauge on her self-confidence for teaching investigation lessons, I posed the following question to Bridget during our final interview:

> MN: On a scale from "not very confident" (1) to "very confident" (5), how would you rate your comfort level with teaching a science lesson that involves an investigation?
>
> Bridget: I would feel like 4.5. I mean there's that little bit of hesitation if I'm not completely familiar with the material, or I'm not exactly sure how it's going to go, if it's something I've never done before with kids, things can always go out in left field and go in no direction that you intend them to go in, but I do think that I'm fairly confident in my ability to do that. (Bridget, End W10 interview)

As these data indicate, Bridget's overall sense of confidence as an elementary science teacher continued to increase over the course of her final year of teacher preparation. Next, I present data that reveal how Bridget described her changing ideas and confidence for science teaching.

**Bridget's description of her changing ideas about teaching elementary science**

To gain insight into how Bridget perceived her growth as a science teacher, I asked her to comment briefly on her ideas about science teaching and how they had changed over the year of the study. Bridget responded:

> I loved science in elementary school and I hated science in high school. And I've hated science throughout college…And it kind of took getting back into this class [methods course] and getting back into seeing science with the younger students for me to really realize that wait, I actually like science. I'm a language arts major and a social studies minor, science is nowhere in my background at all, but here I am teaching lunchtime science club…so it's definitely something that I have a lot more fun with, that I'm a little more excited about than I was a few months ago. (Bridget, End W10 interview)

In this quote, Bridget revealed that a key component of her thinking about science teaching was affective in nature, and required re-experiencing elementary science to acquire an appreciation of science from a teacher's standpoint. While she did not reflect specifically upon the ways in which her science teaching orientations and instructional approaches changed over the course of the year (see above, Bridget's changing ideas about science teaching), and did not explicitly link these changes to approximations of practice, she did allude to the influence of her approximations of practice as contributors to her changing ideas about teaching science. Bridget also offered further insight into the utility of her approximation of practice experiences, which is discussed in Chapter 5.

**Bridget's description of her changing confidence for teaching elementary science**

In the same vein, I asked Bridget to describe her sense of how her confidence in her ability to effectively teach science had changed over the course of the year. She described the cyclical nature of her growing confidence in the following quote:

> I felt fairly confident in my ability to teach and I felt like my students, I feel that that was affirmed, it was kind of a cycle. I felt confident in my abilities, and I

> would teach a lesson and see that my students learned it, which would kind of boost my confidence even more, so it was just kind of a cycle that kept on going. (Bridget, End W10 interview)

In an earlier interview, when asked what she thought contributed to the change in confidence, Bridget described the importance of structured science teaching practice opportunities in supporting her evolving confidence:

> Definitely the actual teaching of science in the field, and I think that the way the assignments were structured, the things we were asked to look at and think about as we were planning for them definitely helped and then the reflecting afterward, plus, especially with the reflective teaching, that it wasn't the same lesson, that we got to do the full cycle twice and seeing "oh these are the things that I could change" and seeing how that affects the way that it actually goes. (Bridget, End F09 interview)

Although she specifically mentioned the reflective teaching assignments, the essence of Bridget's statement reveals that practice, in general, was a significant driver of her increased self-confidence as a science teacher. As Bridget assumed science teaching responsibilities for almost all of her student teaching semester, the reinforcement cycle she described likely included and reflected science teaching opportunities beyond her approximations of practice in this study.

**Summary and end of year model for Bridget**

In summary, Bridget began the final year of elementary teacher preparation considering herself "not a science person" but, over the course of the year, came to embrace science teaching. By the end of her student teaching semester, Bridget found herself teaching science regularly in her placement classroom in addition to voluntarily teaching a lunchtime science club at her school. Bridget's approximations of practice often contained traditional, teacher-directed instructional approaches associated with key features of investigation lessons. One area in which Bridget made significant and observable progress in her science instruction involved the ways in which she established data collection procedures with her students. In our interviews, Bridget stated that improving this aspect of her science teaching was particularly important to her.

Despite her tendency toward teacher-directed instructional approaches, Bridget's ideas about investigation lessons emphasized the importance of student-directed learning in science. As she gained more science teaching experience, and as these experiences contained more learner-centered features, Bridget increasingly supported her ideas about elementary science instruction with examples from her approximation of practice experiences. In concert with growth in her experience base and ideas about investigation lessons, Bridget's self-confidence in her ability to teach elementary science investigation lessons grew over the year, and was also grounded in her approximation of practice experiences.

In light of the models presented in Chapter 2, Bridget resembled the typical prospective elementary science teacher in most respects. Bridget's beginning-of-study data are largely consistent with the initial model depicted in Figure 2.1. One exception is that Bridget's initial confidence level for teaching investigation lessons was higher than anticipated. Across the study, Bridget's data suggest the end of year model depicted in Figure 4.1.

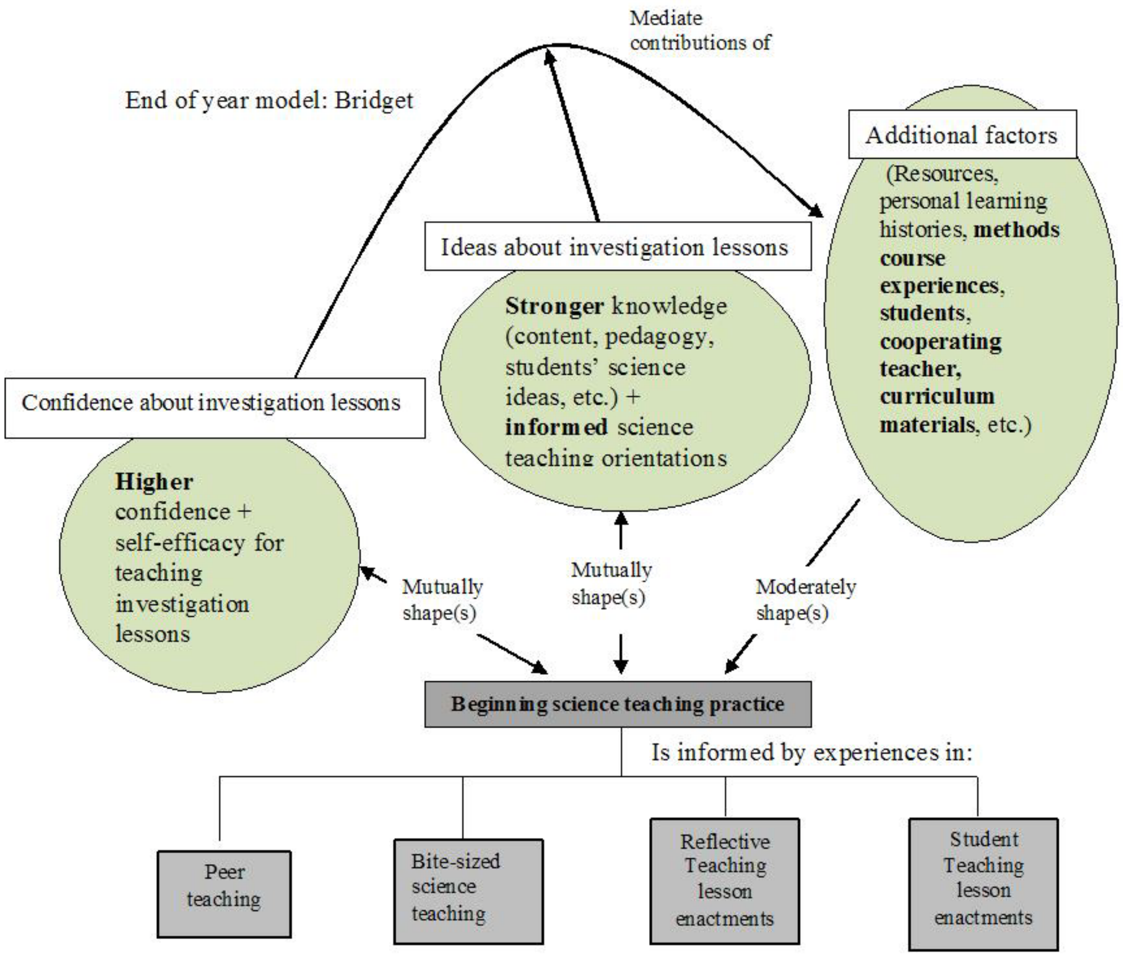



*Figure 4.1.* Bridget's end of year model

Similar to the generic end of year model presented in Figure 2.2, Bridget's end of year model indicates increased confidence and stronger, experience-rooted ideas about science teaching. Unlike the generic model, however, Bridget's end of year model reflects her sustained dependence on curriculum materials and advice from her cooperating teacher in shaping instruction toward the study's end.

I turn now to Hannah, who presented a very different picture of a prospective teacher's instructional approaches, ideas about, and confidence for teaching investigation lessons.

## Hannah

### Overview

Hannah was a language arts major and math/integrated science minor in the undergraduate elementary teacher education program. In the elementary science methods course, Hannah participated actively in whole-class discussions and was someone her peers regarded as knowledgeable about science. Hannah's field placement was a third grade classroom at Monarch Elementary in Ann Arbor. Unlike her peers, Hannah began the methods course with previous science teaching experience.

### Hannah's science and science teaching background

As described, Hannah had an extensive background of science knowledge deriving from her integrated science/mathematics minor within the School of Education, coupled with four years of high school science. She also had informal science teaching experience as a high school senior teaching science to her peers, and teaching science in a local museum.

Hannah attributed her science knowledge to her work at the museum and the collaborative work done inside and outside of her science classes. She also stated that her knowledge of science came, in part, from having taught it.

> … just like through the museum, anything that I had to learn in order to teach it, like electricity is something I never really was very good at in any of my classes, so it was something I had to learn to teach later. (Hannah, End F09 interview)

In this quote, she cited electricity as an example of a science topic she learned through preparing to teach it to others.

More generally, Hannah expressed confidence in her science subject matter knowledge and felt that this knowledge enhanced her work as a science teacher.

> I think that my knowledge of science in general makes me a better science teacher. .. I've learned a lot of science throughout my life… I think my knowledge of the science I teach has given me more options as a science teacher. (Hannah, End W10 interview)

In this study, Hannah is an example of an atypical prospective teacher with strong science background knowledge.

As mentioned previously, Hannah also had science teaching experiences prior to beginning the elementary science methods course. This teaching experience was largely informal, and included high school, middle school, and elementary school level science.

> [I]t started in high school… I taught in 8 different classrooms, one of them was first [grade] … and then I did high school science, I did a middle school science placement…and then I came here and I worked at the museum…the other part that's really important of my science teaching is that because my school was so small and I was the smart kid in my class, I was always teaching [my peers]…sometimes the teachers didn't explain, so I would show people "you know, I look at it like this, and I do it like this" …I grew up teaching my classmates all the time. (Hannah, Initial F09 interview)

Hannah traced her confidence in her science knowledge and ability to explain science to others to formative experiences as a science learner herself.

Unlike the other case study teachers in this study, Hannah began the final year of teacher preparation with a background that included strong science content knowledge as well as prior science teaching experience. She expressed self-confidence with regard to both.

**Hannah's approximations of practice trajectory**

In this section, I briefly outline the lessons and lesson portions that Hannah carried out for her various approximations of practice. Hannah's case provided an interesting challenge in that her BSSTs were part of lessons that involved secondhand investigations, or scientific inquiries that entail the use of text to gather and analyze data previously compiled by others (Palincsar & Magnusson, 2000). Because students were studying the solar system, secondhand investigations were warranted; students could not directly gather relevant data themselves. Hannah's students used the data gathered from a variety of reference material resources to complete a research project about the Sun. In these lessons, many of the key features of investigation lessons were preserved; thus, I included data from secondhand investigation lessons in the data corpus.[2]

Table 4.11 presents a summary of Hannah's approximations of practice trajectory.

[2] Secondhand investigation lessons provided an interesting contrast to Hannah's RT1 lesson, which entailed a text-based discussion using an informational, grade-level appropriate text. Although students were working with ideas embodied in the trade book read by Hannah, they did not use this textual resource in the same ways in which they used textual reference materials to collect data for their Sun research projects. Also, text-based discussion lessons tended to lack many of the key features of investigation lessons. For example, making sense of data was typically not a component of a text-based discussion lesson in science because the trade books commonly used in text-based discussions present data such that its value, or "sense," has already been determined by the author. Accordingly, I did not consider text-based discussion lessons as being investigation lessons for the purposes of this study.

Table 4.11

*Hannah's approximations of practice trajectory*

| | PeerTch | BSST1 | BSST3 | BSST2 | RT2* | ST1 | ST2 |
|---|---|---|---|---|---|---|---|
| Date | 2 Nov. 2009 | 11 Nov. 2009 | 18 Nov. 2009 | 24 Nov. 2009 | 9 Dec. 2009 | 3 Mar. 2010 | 13 Apr. 2010 |
| Lesson or lesson portion | Create initial models of condensation | Intro discussion: Which is more important the Sun or the Earth? | Sun research worksheet wrap-up discussion | Sense-making discussion: Human survival and proximity to the Sun | Making models to explain day and night | How our eyes allow us to see light | Path of light, periscopes, and opaque, transparent, and translucent materials |

*Observed by Hannah's field instructor

As Table 4.11 indicates, Hannah taught lessons and lesson portions about condensation, the solar system, and light in her approximations of practice. I observed all Hannah's approximations of practice with the exception of her RT2, which was observed by her field instructor.

**Key features of investigation lessons in Hannah's approximations of practice**

In conducting her approximations of practice, Hannah employed a variety of instructional approaches for key features of investigation lessons. Table 4.12 displays a summary of the anticipated and observed key features of investigation lessons in Hannah's approximations of practice.

Table 4.12

*Key features of investigation lessons in Hannah's approximations of practice*

Anticipated = A, Observed = O

| Key feature of investigation lesson | Peer Tch | BSST 1 | BSST 3 | BSST 2 | RT2 | ST1 | ST2 |
|---|---|---|---|---|---|---|---|
| Identifying the investigation purpose(s) | A, O | A, O | | O | A, O | A, O | A, O |
| Connecting investigation lesson and students' knowledge, ideas, and/or experiences | A, O | A, O | | A, O | A, O | A, O | A, O |
| Establishing data collection | | | | A, O | A, O | A, O | A, O |
| Fostering sense-making with data | | | A, O | A, O | A, O | A, O | A, O |
| Supporting claims with evidence | | | A | O | A, O | A | A, O |

As Table 4.12 indicates, most of Hannah's approximations of practice contained the anticipated key features of investigation lessons. Similar to Bridget, Hannah taught lessons that appeared to lack instructional approaches for supporting claims with evidence. However, Hannah did incorporate unanticipated key features into her BSST2.

I now consider Hannah's instructional approaches relating to the key features of investigation lessons in her approximations of practice. Enactment observation data were collected, coded, and tabulated as described in Chapter 3 and are displayed and described below.

**Identifying the investigation purpose(s).** Hannah employed a variety of methods to identify the investigation purpose(s) in her approximations of practice. For example, in her BSST1, Hannah posed the following discussion question to her students: Which is more important, the Earth or the Sun? Table 4.13 presents the instructional approach data for Hannah's approximations of practice with respect to this key feature of investigation lessons.

Table 4.13

*Hannah's instructional approaches to identifying the investigation purpose(s)*

| **Identifying the investigation purpose(s)** | PeerTch | BSST1 | BSST3 | BSST2 | RT2 | ST1 | ST2 |
|---|---|---|---|---|---|---|---|
| Developing authentic process skills | | | | X | | | |
| Answering a question or problem-solving | X | X | | | X | X | |
| Scientific modeling | X | | | | X | X | |
| Teacher tells purpose | X | | | | X | X | X |
| Other | X | | | X | | | |
| **Mostly teacher-directed** | X | X | | X | X | X | X |
| **Mostly student-directed** | | | | | | | |
| **Intermediate** | | | | | | | |
| **Not done or NA** | | | X | | | | |

As Table 4.13 reveals, Hannah's instructional approaches to identifying the investigation purpose(s) were typically teacher-directed in nature. In Hannah's approximations of practice, these often took the form of relating students' investigations to the authentic work of scientists. Typically, this occurred before the investigation began or while it was underway. Hannah usually directly informed students of the investigation purpose(s) rather than supporting students in deriving the purpose(s) on their own. In this respect, Hannah was highly consistent across her approximations of practice, regardless of how complex or authentic the approximation of practice.

**Connecting investigation lessons and students' knowledge, ideas, and experiences.** Hannah made concerted efforts to make investigation lessons relevant to students' lives. For example, in her ST2, Hannah reviewed material from previous lessons about the path of light, introduced new terminology, and then elicited students' ideas about opacity, translucence, or transparence by asking students to name classroom objects or materials that were examples of each type. The instructional approaches

Hannah employed to ensure that science investigation lessons were accessible to her students in all her approximations of practice are depicted in Table 4.14.

Table 4.14

*Hannah's instructional approaches to connecting the investigation lesson*

| **Connecting investigation lesson and students' knowledge, ideas, and experiences** | PeerTch | BSST1 | BSST3 | BSST2 | RT2 | ST1 | ST2 |
|---|---|---|---|---|---|---|---|
| Connecting to previous lessons | X | X | | X | X | | X |
| Connecting to real world examples | X | X | | | | X | X |
| Elicit student ideas | X | X | | X | X | X | X |
| Relating to a scientific model | X | | | | X | X | X |
| Other | X | X | | | X | X | X |
| **Mostly teacher-directed** | | | | X | X | | |
| **Mostly student-directed** | | | | | | | |
| **Intermediate** | X | X | | | | X | X |
| **Not done or NA** | | | X | | | | |

Table 4.14 shows that Hannah tended to combine several instructional approaches within one approximation of practice for this key feature. In this manner, she worked to support students in integrating what they had learned in previous lessons with new content in ways that relied upon students' experiences with everyday objects or phenomena. These instructional approaches were consistent with Hannah's learner-centered orientations toward science teaching and learning.

Despite the range of science topics and the complexity or authenticity of the approximation of practice, Hannah consistently incorporated instructional approaches to foster connections between students' knowledge, ideas, and experiences and the scientific content in question. Only her BSST3 lacked an apparent instructional approach with respect to this key feature. Thus, making the science content relatable to students was an element of Hannah's science teaching that essentially did not change across approximations of practice.

**Establishing data collection procedures.** Unlike other case study teachers, Hannah encouraged her students to develop their own data collection procedures. For example, in her ST1, Hannah distributed handheld mirrors to her students and presented them with the challenge: Without leaving your desks or turning your heads, how much of the classroom can you see? In this mini-investigation, students determined what counted as data and designed their own procedures for collecting data. Table 4.15 summarizes the instructional approaches Hannah employed across her approximations of practice to support students in deciding what constituted investigation data and how to record it.

Table 4.15

*Hannah's instructional approaches to establishing data collection procedures*

| **Establishing data collection procedures** | PeerTch | BSST1 | BSST3 | BSST2 | RT2 | ST1 | ST 2 |
|---|---|---|---|---|---|---|---|
| Teacher modeling | | | | | | X | X |
| Directions | | | | X | X | X | X |
| Discovery | | | | | X | X | X |
| Directed discovery | | | | X | X | X | X |
| Supported data recording | | | | | | | |
| Other | | | | X | X | X | X |
| **Mostly teacher-directed** | | | | X | | | |
| **Mostly student-directed** | | | | | X | | |
| **Intermediate** | | | | | | X | X |
| **Not Done or NA** | X | X | X | | | | |

Hannah exhibited a preference for allowing students agency in designing and executing their investigations, which was evident in both her enacted instructional approaches and in the way she talked about students' roles during an investigation lesson.

> …from the student's perspective, I think that investigations are a way for them to kind of like explore their own ideas and figure out their own sorts of questions

> and then test them…just allowing the kids to have freer rein of the materials and really explore... (Hannah, End W10 interview)

Hannah's year-long emphasis on learner-directed discovery—in principle as well as in practice--is taken up further in the discussion of her ideas about science teaching.

**Fostering sense-making with data.** Hannah frequently positioned her students as sense-makers. For example, in her BSST2, Hannah asked her students:

> Do you think we could figure out how hot Mercury and Venus are and that could help us figure out how close we could get to the Sun? (Hannah, BSST2)

This excerpt from Hannah's BSST2 illustrates two ways in which she supported her students in making sense of data gathered in an investigation. First, it shows Hannah's use of a question to prompt her students' thinking about the investigation question ("How close could humans get to the Sun and still survive?"). Second, it illustrates how Hannah supported her students in translating empirical data into something meaningful in the context of their own lives. Table 4.16 reveals additional instructional approaches Hannah used to foster sense-making with investigation data in her approximations of practice.

Table 4.16

*Hannah's instructional approaches to fostering sense-making with data*

| **Fostering sense-making with data** | PeerTch | BSST 1 | BSST 3 | BSST 2 | RT2 | ST1 | ST2 |
|---|---|---|---|---|---|---|---|
| Pattern-seeking | | | | X | | | X |
| Relating findings to real world | | | X | X | | X | X |
| Discourse-based | | | X | X | X | X | X |
| Scientific model-based | | | | | X | | X |
| Telling | | | | X | | | X |
| Other | | | X | | X | X | X |
| **Mostly teacher-directed** | | | | | | | |
| **Mostly student-directed** | | | X | | | | |
| **Intermediate** | | | | X | X | X | X |
| **Not done or NA** | X | X | | | | | |

Hannah employed a variety of instructional approaches to support students in making sense with data in her approximations of practice, as Table 4.16 shows. In general, Hannah's instructional approaches positioned her students to engage in the cognitive work of moving from raw data to meaningful understanding of science content, consistent with discovery, inquiry, and guided inquiry orientations toward science teaching. Table 4.16 indicates that there were no clear patterns in the data with regard to the complexity or authenticity of the approximation of practice.

**Supporting claims with evidence.** Although she did not always include instructional methods for supporting claims with empirical evidence in her approximations of practice, Hannah worked to help her students translate their understandings of data into more general conclusions or claims, as Table 4.17 indicates.

Table 4.17

*Hannah's instructional approaches to supporting claims with evidence*

| **Supporting claims with evidence** | PeerTch | BSST 1 | BSST 3 | BSST 2 | RT2 | ST1 | ST2 |
|---|---|---|---|---|---|---|---|
| Discursive | | | | X | X | | X |
| Scientific model-based | | | | | X | | X |
| Using written supports | | | | | | | |
| Other | | | | | X | | X |
| **Mostly teacher-directed** | | | | X | | | |
| **Mostly student-directed** | | | | | X | | |
| **Intermediate** | | | | | | | X |
| **Not done or NA** | X | X | X | | | X | |

For example, in her RT2, Hannah had her students create three-dimensional models of the Earth and Sun to explain day and night, which they presented to their peers. In this lesson, Hannah's students demonstrated the relative motion of the Earth and the Sun using their models as indirect evidence to explain the mechanism behind day and night. Students also posed questions of their peers to better understand the claims and model-based evidence used to support those claims. While this was an innovative, highly student-directed example of supporting claims with evidence, it was not the norm for Hannah's approximations of practice. Of the four approximations of practice that could have feasibly included supporting claims with evidence, only two contained observable instructional approaches for this key feature. Therefore, there is no consistent finding with respect to the authenticity or complexity of the approximation of practice and Hannah's instructional approach(es) to satisfy this key feature.

**Summary of Hannah's instructional approaches for key features of investigation lessons**

Taken together, Hannah's instructional approaches in her approximations of practice demonstrate few, if any, approximation of practice-specific trends. While

Hannah employed a range of methods to satisfy the key features of investigation lessons, these methods did not follow any apparent pattern according to the qualities of the approximation of practice. However, the presence of certain key features of investigation lessons in most, if not all, approximations of practice—for example, instructional strategies for connecting the investigation lesson and students' knowledge, ideas, and experience were evident in all but one approximation of practice—suggests that these key features were core elements of Hannah's science teaching.

**Hannah's changing ideas about and confidence for teaching elementary science**

In this section, I present data that address Hannah's ideas about and confidence for teaching science investigation lessons, and how these two constructs changed across her approximations of practice. Again, interview responses and written reflections served as data sources in the answering of research question two: How do prospective elementary teachers' ideas about and confidence for teaching science investigation lessons change as they engage in approximations of practice?

**Hannah's ideas about approximation of practice investigation lessons.** Hannah's approximations of practice provided opportunities to learn about and teach elementary classroom-based science lessons, which were distinctly different from her work at the museum. In identifying the lessons she learned from her approximations of practice, Hannah highlighted elements of these experiences that were unlike her museum-based teaching experiences. Table 4.18 summarizes and paraphrases Hannah's self-reported lessons learned.

Table 4.18

*Hannah's lessons learned from her approximations of science teaching practice*

| Lessons learned |
|---|
| PeerTch |
| • More detail-oriented art is easily integrated and can allow for creative expression of ideas<br>• Teamwork is always better in science than individual work<br>• Ask students to explain each others' ideas |
| BSST1 |
| • Have a good idea of the time frame for the lesson |
| BSST3 |
| • Planning is really important to science lessons<br>• Have a firm grasp of the lesson's goals and time constraints<br>• I teach better if I am involved in making decisions about lesson goals |
| BSST2 |
| • Give students opportunities to work through something and see that they could actually figure it out and that they didn't have to just find the answer in a book<br>• I struggled with non-defined time constraints and incompletely formulated goals for the discussion portion |
| RT2 |
| • I learned a lot about myself as a science teacher:<br>o I will teach in a way that is reflective of my students' engagement<br>o I will need to find ways to assess students other than their engagement<br>o Sometimes I will need to continue despite a lack of engagement<br>o I will need to create lessons that are as engaging as possible |

As Table 4.18 reveals, Hannah tended to focus upon the time frame and learning goals in her BSST reflections. This was particularly salient for two reasons: Hannah admitted that she did not have advanced notice before teaching her BSSTs (i.e., she did not have enough lead time to plan what the lesson portion would entail) and she did not have a time-bounded or goal-oriented objective for each of her BSSTs. In effect, then, these medium-authentic approximations of practice served to highlight the importance of planning, time management, and learning goals in science lessons for Hannah. In her postRT2 interview, Hannah said that she had time to plan this lesson in advance, and had a better idea of the lesson's learning goals. Consequently, her lessons learned focused on another aspect of science teaching, namely, student engagement.

**Hannah's ideas about investigation lessons more generally.** Hannah's ideas about investigation lessons were informed by her teaching experiences and changed in subtle ways during her last year of teacher preparation. She maintained a year-long focus on student-directed science teaching and learning, but initially described a greater emphasis on free, naturally-engaging exploration:

> I think the teacher's role is just to kind of put it out there and then to facilitate, and then I think the student's role is to use the things the teacher has given them, and use them to explore their own questions … if it's really something that they don't know the answer to and are going to have to study to find out, then they'll be engaged, and then their job is to do that exploration and figure out something new that they didn't know before they answered the question. (Hannah, Initial F09 interview)

Hannah described investigations in elementary science as entailing students testing out something they are wondering about and the teacher in a facilitator role, consistent with inquiry science teaching orientations. At the end of the methods course semester, Hannah elaborated on the teacher's role in investigation lessons:

> I think it would involve a lot of classroom discussion…in your initial discussion you get the kids to come up with that question that you're going to already test so it's like they're designing their own experiment…during the investigation you can give helpful reminders or questions…when teachers kind of walk around and remind them, like, Why do you think this happened? What's going on right here?

I think that helps them… (Hannah, End F09 interview)

By the end of her student teaching semester, Hannah adopted a more extreme view of the division of labor in investigation lessons, and described the most effective investigation lessons as ones that are largely student-directed with minimal guidance from the teacher.

> … from the student's perspective, I think that investigations are a way for them to kind of like explore their own ideas and figure out their own sorts of questions and then test them… like "I wonder what would happen if…" and then getting to actually test it out. And then I think from a teacher's perspective, too, you can set experiments up and you can say that experiments are investigations but they aren't as much as just allowing the kids to have freer rein of the materials and really explore…Especially if you just give them some questions to guide them, I think was what worked best for me. (Hannah, End W10 interview)

Unlike other teachers in this study, Hannah's orientation toward learner-directed investigation lessons was consistent with her approximations of practice instructional approaches, particularly during her student teaching semester (see above). In other words, Hannah demonstrated consistency in her ideas and instructional approaches.

In describing a typical investigation lesson, Hannah reiterated her orientation toward student-directed learning:

> …I think a good investigation lesson starts with a recap…and then I think there would be some…question that they've been wondering or that you can help them think they've been wondering or that you want them to test…just introducing it as "your job today is to figure out what happens when this happens" and then I think the biggest chunk of the time is the actual experimentation, but I think there has to

> be some way for students to keep track of their work too…And then at the end, I think in the best investigation lessons, you have just as much time for students to come together and share what they discovered…and then you take all the things that they've shared and launch into questions from it and some sort of a discussion and then see if you can come up with an answer at the end, all together. (Hannah, End W10 interview)

As the above quote suggests, Hannah was mindful of the social aspects of learning and doing science. Fostering a productive social atmosphere, materials management, and space considerations also factored into Hannah's thinking about investigation lessons.

> Materials and space I think are the two showstoppers, like, if you don't have those it doesn't really matter what else happens because you can't do the lesson… I think a lot about my students and pairings and who would work well together and what sorts of discussions we should have…I want to really plan out the minimal beginnings with the guidelines for what we're going to do, and then time-wise, too, I always have to think about time so that we get enough time to talk about it afterwards. (Hannah, End W10 interview)

During investigation lesson enactment, Hannah attended to time, individual student engagement, and gauging student learning:

> I think time and each student, how engaged they are, what they're doing, what they're learning…and then trying to get a sense of what's being learned and what's not being learned, like, what's making sense and what's not…there's always one student I need to look past, like, "I know you get it, what about the rest of them?" so… (Hannah, End W10 interview)

Here, Hannah alluded to her need, as a teacher, to identify “bellwether” students, or those whose understandings could indicate whether the lesson was a useful learning experience for most students (in addition to those students who always seemed to “get it”).

To gain a more complete picture of Hannah’s views about investigation lessons, I asked her to describe a successful investigation lesson. She said,

> I think one of the things that helps me determine is, like, 3 weeks later, if somebody still brings it up in class, and then the rest of them go “Oh yeah! I remember!” I think that means it was a successful lesson…[I]n the moment, on the day of, I think listening to students talk to each other gives a really good idea, and then…I get an idea of what they’re learning is what they’re saying to each other. … And if they can tell me what’s going on, or they can tell me what they’ve learned then I know it was successful. (Hannah, End W10 interview)

Hannah’s ideas about successful investigation lessons involved two main components: retention of material learned over time, as well as an understanding of what is going on in the moment. Hannah made no mention of whether those understandings or scientific knowledge were or should be normative in nature.

**Summary of Hannah’s changing ideas about investigation lessons**

In total, Hannah’s ideas about elementary classroom investigation lessons underwent a shift from idealistic to practical to idealistic-grounded-in-experience. Initially, Hannah spoke about investigation lessons in general terms, in which students determined the course of their own learning and teachers facilitated this learning. During the methods course semester, Hannah incorporated more practical concerns into her discourse about science teaching, emphasizing the role of time- and materials-management, and ascribing more responsibility to the teacher in navigating student learning, consistent with a guided inquiry science teaching orientation. By the end of the academic year, Hannah returned to a more learner-directed stance on elementary science investigation lessons, which was informed and reinforced by her own approximations of practice. Hannah's changing ideas about science teaching and changing teaching practice also informed and were informed by changes in her confidence as a science teacher, which I explore in more detail in the next section.

**Hannah's confidence for teaching elementary science**

In interviews and methods course artifacts, Hannah revealed how her confidence for teaching elementary science changed throughout the year. I begin by describing Hannah's approximation of practice-specific reports of her confidence levels and transition to a more general picture of Hannah's confidence as an elementary science teacher.

**Hannah's confidence for teaching approximations of practice investigation lessons.** After each methods course semester approximation of practice, I spoke with Hannah about her feelings regarding her teaching of the lesson or lesson portion. Hannah's confidence in her science teaching did not appear to change from approximation of practice to approximation of practice. Table 4.19 displays excerpts of Hannah's responses to interview (I) and written assignment (W) questions pertaining to her confidence in her approximations of practice. A more complete set of Hannah's responses to these questions may be found in Appendix N.

Table 4.19

*Hannah's feelings during and after her methods semester approximations of practice*

| During enactment ("How did you feel while teaching?") | After enactment ("Did this experience impact how you feel about teaching science?") |
|---|---|
| PeerTch | |
| I was feeling pretty good, it was pretty exciting….I think it worked really well. (I) | NA |
| BSST1 | |
| Pretty good…sometimes I felt like the discussion was getting out of control…other times I felt like they were doing a really good job of talking to each other. I felt a little bit lost parts of the time… it was a really student-led discussion... (I) | No (I)<br>I was really happy with my work facilitating the discussion in this class …I was a little less happy with the discussion itself. I don't really think that leading students toward a desired answer is…helpful …I didn't really succeed in leading the students toward choosing the sun.... (W) |
| BSST3 | |
| Pretty good. I didn't have a plan, and I usually don't have a lesson plan, but I usually have at least an outline of at least 3 main points and I kind of had to just go with my instincts …I was really responding to what they were doing. (I) | No, I don't think so (I) |
| BSST2 | |
| I really liked this lesson. I actually, I sort of planned this lesson, I had an idea for it…I pitched it to my CT and he added another piece…I thought it was cool that it was different from what I had been doing and that he let me do that...I felt very proud. (I) | No (I)<br>… I felt especially proud of my work…My CT and I "invented" this lesson together…I felt like I had been in charge of the goals for the station, and as a result I had a very clear idea of what my comments and contributions should be…. (W) |
| RT2 | |
| I felt pretty good about this lesson, I had gone over it a couple times and…had written out the lesson plan…I kind of talked to my CT and…one of the other 3rd grade teachers too…so I kind of had some ideas about what might happen …the kids were really engaged…and they asked all the right questions to make it go where it needed to. (I) | No. I thought it was really interesting… the kids were so engaged and like I said it was recess that they were missing and I thought it was interesting how he [my CT] said we need to work more on our timing, and I was like "I don't think so, I think we need to work on having more science and less recess." (W) |

As Table 4.19 reveals, Hannah tended to derive her sense the lesson's success from her students' enthusiasm. Across approximations of practice, the degree of agency Hannah experienced in planning and enacting lessons contributed to her feelings as a teacher. For example, Hannah took pride in her contributions to her BSST2 design (see Table 4.19).

**Hannah's confidence for teaching investigation lessons more generally.** At the beginning of Fall 2009, Hannah expressed confidence in her science knowledge and a high level of confidence in her ability to effectively teach elementary science. She attributed the latter to her prior experiences with science teaching and the training she received at the museum.

> I feel like I've been doing it [teaching science] for a while now. … the museum is one of those places where you're kind of given...all the materials, everything you need, and then there's I teach, you watch; we teach together; you teach, I watch. …everything that I teach stems from one of the 3 people who trained me in it...I feel like that will actually be really hard for me when I do get into my own classroom where I don't have that, but I feel like too that I've done so much with it and I feel like I have put a lot of myself into the different topics that I teach that I think it will be OK. (Hannah, Initial F09 interview)

Much of Hannah's museum-based science teaching was highly scripted, and she expressed some initial doubt about a seamless transfer to elementary classroom science teaching. Despite differences between teaching in a museum and an elementary classroom, Hannah expressed confidence about science teaching, which she attributed to her museum teaching experience.

> I feel like if there's anything I've learned at the museum, it's that I have that rhythm for what a science lesson should feel like, I guess, and I can't explain that any more clearly than that but I feel like I know what needs to happen in order for it to make sense. (Hannah, Initial F09 interview)

In subsequent interviews, Hannah was able to articulate more precisely which elements of science lesson enactments felt as they should (see Table 4.19).

To get a richer picture of Hannah's confidence for teaching science investigation lessons, I asked her to respond to the following written items during three of our interviews. Unlike her post-approximation of practice interview responses, these data suggest some slight changes in Hannah's confidence.

Table 4.20

*Hannah's evolving confidence for science teaching investigation lessons*

| | Beginning Fall 2009 | End Fall 2009 | End Winter 2010 |
|---|---|---|---|
| I will not be very effective in teaching science investigations. | Disagree | Strongly Disagree | Strongly Disagree |
| I will find it difficult to explain to students why science investigations work. | Unsure | Disagree | Disagree |
| I will be able to evaluate and adapt existing science investigations for use in my classroom. | Agree | Strongly Agree | Strongly Agree |
| I will find it difficult to support students' sense-making using data they have gathered in science investigations. | Disagree | Disagree | Disagree |
| I will find it difficult to effectively introduce, monitor, and conclude a lesson that involves an investigation. | Disagree | Disagree | Disagree |

As Table 4.20 reveals, by the end of the methods course semester, Hannah's responses indicated a higher degree of confidence in three of the five survey items. She gave identical responses at the conclusion of her student teaching semester.

When asked to verbally reflect on her confidence in herself as a science teacher, Hannah revealed how her confidence changed alongside changes in her ideas of what constitutes “good” science teaching.

> I think I found out that there was a lot that I didn’t know … I was very confident at the beginning because the only teaching I’d done was kind of like canned teaching, it was like “here’s your lesson, go teach it” and it was like I’m supposed to teach it just like that, I don’t really have to make any decisions. …I think it was more a lot of, like, moving away from science just being fun and engaging toward how can it really be helpful and useful for kids? And so I don’t know…I’m not sure about that…I’m confident, just not *very* confident anymore. (Hannah, End F09 interview)

One aspect of science teaching Hannah cited as contributing to her self-confidence was her preparation for teaching investigation lessons:

> MN: How would you rate your comfort level with teaching a science lesson that involves an investigation? Do you feel this has/has not changed this semester? Why?
>
> Hannah: 5 [most confident]. I think they’re my favorite. They’re definitely the best kind of science lessons. I would just need to be really good at getting prepared ahead of time, which is generally something I struggle with, so that part, as long as I did the preparations ahead of time, the lesson is going to be great. (Hannah, End W10 interview)

In this excerpt, Hannah alluded to differences between preparing to teach science at the museum and preparing to teach a classroom-based elementary science lesson. As much of

Hannah's confidence in her science teaching at the outset of the methods course derived from her prior museum-based teaching experience, and preparation for museum teaching differs from classroom science teaching, it is not surprising that Hannah modified her initial confidence level in hindsight, armed with new insights into what elementary classroom science instruction entails.

**Summary of Hannah's changing confidence for teaching elementary science**

Overall, the data suggest that Hannah's confidence in her ability to teach elementary science in general and investigation lessons in particular did not undergo drastic changes during the course of her final year of teacher preparation. She began confident in her ability to teach science, and ended the year-long study confident in her science teaching ability, albeit from a somewhat more informed point of view. As Hannah became more aware of the differences between elementary classroom science teaching and the more informal science teaching that comprised her experience base prior to the methods course, she identified areas of need for her own improvement as a science teacher. In doing so, she realized that her initial self-confidence level was perhaps not appropriate to the demands of day-to-day classroom science teaching; however, as she gained experience teaching science in the classroom, she also gained confidence in her ability to adapt her science teaching practice to this new context.

Having described changes in Hannah's ideas about science teaching and self-confidence for science teaching, I focus now on Hannah's explanations for changes in her thinking and feeling about teaching elementary science.

**Hannah's description of her changing ideas about teaching elementary science**

Like Bridget, Hannah was very self-aware of her ideas about science teaching. At a gross level, most of Hannah's ideas about how science should be taught did not change, which she acknowledged. However, Hannah cited salient differences between her museum teaching experiences and her experiences teaching elementary science in a school setting as prompting important changes in her science teaching orientations.

> I think coming from the…museum to a classroom was really different because at the …museum, you teach the same thing, and 50 minutes later you teach it again, and then 50 minutes later you teach it again, so you get to hone in on the specific skills in *this* lesson, whereas in the classroom it was much more long-term and much bigger picture and there was a lot more touching back to see what you missed yesterday. And so that was just kind of different, I just had to approach things in a different way, but I think what it really did for me was it took that little section of lesson and it just added, you know, the recap here from yesterday and the discussion here at the end from today and then tying it all together, but I still kept that sacred 50 minutes of pure investigation… (Hannah, End W10 interview)

In short, Hannah saw her classroom science teaching as building upon and extending her museum science teaching experiences, with the added dimension of integrating student learning over time.

**Hannah's description of her changing confidence for teaching elementary science**

When asked to comment on the nature of changes in her self-confidence as a science teacher over the course of the study, Hannah offered the following:

> I think it's a cycle. Because I think that I am very confident in my ability to teach science, which I think makes me a better science teacher…It has a lot more to do with your knowledge than your teaching abilities, I guess, and I think that because I have done a lot of science teaching, I have confidence in my science teaching and because I have confidence in my science teaching, I'm able to teach science well, so it's like a cycle. (Hannah, End W10 interview)

Like Bridget, Hannah identified the self-reinforcing nature of teaching experience in supporting her growing confidence as a science teacher. In this manner, she indirectly associated her confidence in her science teaching with her approximations of practice.

**Summary and end of year model for Hannah**

In summary, Hannah was a self-confident beginning elementary science teacher with a solid science knowledge background who came into the methods course with some science teaching experience. In her approximations of practice, Hannah employed instructional approaches that were consistent with her ideas that elementary science should be learner-directed, and placed particular emphasis on connecting the science content to her students' knowledge, ideas, and experience. She valued social elements of doing science, and supported her students in engaging in productive, collaborative scientific work.

During the year-long study, Hannah came to recognize important differences between her previous museum-based science teaching experiences and elementary classroom science teaching. In particular, Hannah appreciated the needs for advanced planning, materials management, and achieving learning goals as part of classroom science instruction. She compared her approximations of practice science teaching experiences to her previous informal science teaching experiences, using the latter as a foundation for growth in her own science teaching. As she progressed through her approximations of practice, Hannah's ideas about and confidence for science teaching changed in subtle ways that reflected this new context for science teaching and the differences in its demands on her as a teacher. Hannah was metacognitive about changes in her ideas and confidence about teaching science, and readily identified drivers for the shifts in her thinking. Overall, Hannah began the year with a positive outlook on science teaching, and as she engaged in her approximations of practice, continued to revise and refine both her thinking and science teaching practice in ways that reflected an accommodation of ideas, confidence, and instruction to the classroom setting.

The models proposed in Chapter 2 did not appear to reflect Hannah's case. At the beginning of the study, Hannah differed from the typical prospective elementary science teacher depicted in Figure 2.1 in a number of ways. First, she demonstrated a great deal of confidence in her ability to teach investigation lessons, and science more generally. Second, she came into the methods course with strong knowledge about science teaching (particularly subject matter knowledge), and definite orientations toward science teaching, both derived in large part from her previous museum-based science teaching experience. Finally, Hannah began the study without demonstrating a strong reliance on her cooperating teacher or the classroom curriculum materials as factors shaping her science instruction. In these and other ways, Hannah differed markedly from the typical prospective teacher beginning the science methods course.

Figure 4.2 illustrates Hannah's end of year model with regard to the study constructs and the data presented in her case study description.

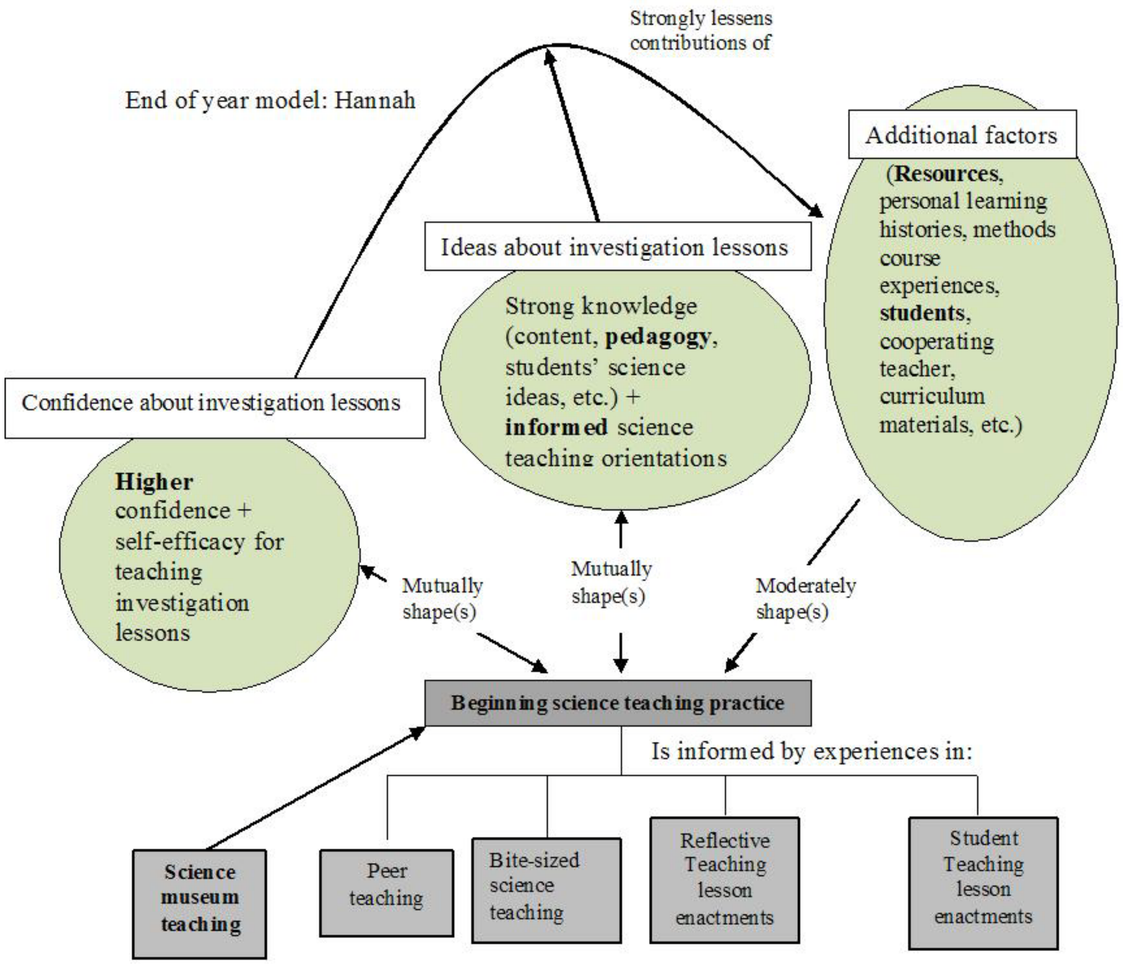



*Figure 4.2.* Hannah's end of year model

As Figure 4.2 indicates, Hannah completed the study with higher confidence and stronger ideas about science teaching, which informed her teaching practice, similar to the model in Figure 2.2. Unlike the typical prospective elementary teacher, however, Hannah's initially clear ideas about science teaching and investigation lessons were largely reinforced through her approximations of practice, although she did gain new appreciations for scientific modeling and lesson planning and preparation. A notable difference between Hannah's end of year model and the model in Figure 2.2 includes the role of Hannah's science museum teaching experience. At the beginning and end of the study, Hannah indicated that this was an important factor shaping how she thought about and carried out science instruction. Finally, contributions of additional factors in Hannah's end of year model appeared to be less influential than posited in the generic end of year model. In short, Hannah's data indicated that she was not the typical prospective elementary science teacher.

## Natalie

### Overview

Natalie majored in language arts and minored in math in the undergraduate elementary teacher education program. As an elementary science methods course student, Natalie was reserved and rarely participated in whole class discussions. Her written work and peer teaching in the course reflected a deep thoughtfulness about science teaching. During this study, Natalie was placed in a second grade classroom at Monarch Elementary in Ann Arbor. Natalie began the elementary science methods course without previous science teaching experience.

### Natalie's science background

Natalie's science background included four semesters of high school science and the minimum number of college-level science courses required for an education major. When asked, Natalie identified her science courses, textbooks, hands-on activities, and self-initiated research as the biggest sources of her science knowledge. She began the methods course with a positive attitude toward science and science teaching, stating:

> I really enjoy science, as long as it's not chemistry, so I think that that would reflect in my teaching. When I'm more excited about things I'm more confident. (Natalie, Initial F09 interview)

Natalie also expressed a positive attitude toward science and science teaching at the close of her student teaching semester. When I asked her to reflect on her knowledge of the science topics she had taught over the year, Natalie said:

> Well I definitely had to do some background research, because I didn't know a whole lot, I couldn't remember a whole lot … background research was important and it's neat in the Science Companion book they have a section for background research, background information to teach this lesson, and they also have topics on the internet too that would be good for me to know too in case questions come up... (Natalie, End W10 interview)

In this interview excerpt, Natalie alluded to her reliance on the classroom science curriculum, Science Companion, as an instrumental resource for her own science teaching preparation. As Natalie progressed through her approximations of practice, she maintained her positive attitude about science teaching, despite experiencing some challenges in her lesson enactments. In the following section, I explore in more detail Natalie's approximations of practice and the instructional approaches she used to teach investigation lessons.

**Natalie's approximations of practice trajectory**

Natalie conducted all her field-based approximations of practice with her entire second grade class. Due to scheduling conflicts, I was unable to observe all Natalie's approximations of practice. Natalie's BSST2 was not included in the data set because it entailed a text-based discussion rather than a firsthand or secondhand investigation as the learning activity (see Hannah's case study description for an explanation of text-based discussions and secondhand investigations). Table 4.21 displays the trajectory of

Natalie's approximations of practice and the science topics covered in these lessons and lesson portions.

Table 4.21

*Natalie's approximations of practice trajectory*

| | BSST1 | RT1 | PeerTch | RT2 | BSST3* | ST1 | ST2 |
|---|---|---|---|---|---|---|---|
| Date | 15 Oct. 2009 | 23 Oct. 2009 | 9 Nov. 2009 | 19 Nov. 2009 | 23 Nov. 2009 | 27 Jan. 2010 | 19 Mar. 2010 |
| Lesson or lesson portion | Intro: Rock types | Properties of minerals | Station: Weight of an ice pack over time | Mineral hardness and streak, scratch tests | Review: Mineral properties | Sound vibra-tions | Observe seeds |

*BSST3 was not observed

Natalie taught lessons and/or lesson portions from three second grade science units: rocks and minerals, sound, and life cycles. Similar to Bridget, Natalie had opportunities to teach additional science lessons that were not observed as part of this study. The lessons and lesson portions that constituted her approximations of practice all contained key features of investigation lessons, which are described in the next section.

**Key features of investigation lessons in Natalie's approximations of practice**

Typically, Natalie's approximations of practice included all anticipated and some unanticipated key features of investigation lessons. Lesson and lesson portion observation data were collected and analyzed as described in Chapter 3, and are presented in Table 4.22.

Table 4.22

*Key features of investigation lessons in Natalie's approximations of practice*

Anticipated = A, Observed = O

| Key feature of investigation lesson | BSST1 | RT1 | PeerTch | RT2 | ST1 | ST2 |
|---|---|---|---|---|---|---|
| Identifying the investigation purpose(s) | A, O | A, O | O | A* | A, O | A, O |
| Connecting investigation lesson and students' knowledge, ideas, and/or experiences | O | A, O | O | A, O | A, O | A, O |
| Establishing data collection | | A, O | A, O | A, O | A, O | A, O |
| Fostering sense-making with data | | A, O | A, O | A, O | A, O | A, O |
| Supporting claims with evidence | | A, O | O | A* | A, O | A, O |

*Observation did not include the very beginning and ending of this lesson, which is typically where these key features occurred.

There are several points to note in Natalie's approximations of practice. First, Natalie tried to make the science content relevant to her students' lives ("Connecting investigation lesson and students' knowledge, ideas, and/or experiences") in every lesson and lesson portion observed. This feature, which Natalie explicitly acknowledged as being important in her science teaching, is discussed in later sections of this case study. Additionally, in her BSST1 and peer teaching enactments, Natalie included key features of investigation lessons that had not been anticipated given the scope of the lesson portion in question. For example, in her peer teaching of an investigation station, Natalie included all key features of investigation lessons, rendering the station a "mini-lesson." Finally, Natalie included all key features of investigation lessons in the science lessons I observed during her student teaching semester. This was unusual among case study teachers, particularly considering the consistent presence of the claims/evidence feature.

To elaborate upon Natalie's approximation of practice enactment data, and to provide more insight into the instructional approaches Natalie used to achieve the key features of investigation lessons, I now turn to each of the key features in turn.

**Identifying the investigation purpose(s).** In her RT1, Natalie told her students, "Today you will be working as geologists to find properties of rocks and minerals." At the end of the lesson, she asked students why it would be important for geologists to know the properties of rocks and minerals. After taking a couple student responses, Natalie marked and repeated the desired answer. This example nicely illustrates Natalie's preferred instructional approach to identifying the investigation purpose: framing the lesson by introducing the investigation purpose and later eliciting students' ideas about the purpose of the work they just completed and underscoring the "correct" purpose. Table 4.23 presents a summary of the instructional approaches for identifying the investigation purpose(s) in Natalie's approximations of practice.

Table 4.23

*Natalie's instructional approaches to identifying the investigation purpose(s)*

| **Identifying the investigation purpose(s)** | BSST1 | RT1 | PeerTch | RT2* | ST1 | ST2 |
|---|---|---|---|---|---|---|
| Developing authentic process skills | | X | | | | |
| Answering a question or problem-solving | | | | | | |
| Scientific modeling | | | | | | |
| Teacher tells purpose | X | X | X | X | X | X |
| Other | X | X | | X | | X |
| **Mostly teacher-directed** | X | X | X | X | X | X |
| **Mostly student-directed** | | | | | | |
| **Intermediate** | | | | | | |
| **Not done or NA** | | | | | | |

*The very beginning of this lesson was not observed, so there may have been additional instructional approaches employed that are not indicated on this table.

Table 4.23 shows Natalie's instructional consistency in identifying the investigation purpose across her approximations of practice. In Natalie's case, the "other" code typically (but not always) indicated the teacher posing questions to elicit students' ideas about the investigation purpose. Such similarity in instructional approaches, regardless of the particulars of the approximation of practice, suggests that Science Companion lesson plans might have provided some guidance in enacting this key feature.

**Connecting investigation lessons and students' knowledge, ideas, and experiences.** One key feature of Natalie's science teaching that was easy to discern in her approximations of practice was how she made the science accessible and relatable for her students. For example, as part of her ST2 lesson about the functions of plant parts, a student likened a seed coat to the winter coats the students wore to keep them warm and protected outside. Natalie marked this contribution, expressed her enthusiasm for this analogy, and went on to compare the seed's stored food with students' lunch boxes. Later in the lesson, Natalie had students write in their science notebooks about one thing that surprised them in their investigation of seeds. In these ways, Natalie helped students consider what they already knew and had experienced, and how they could connect these experiences and knowledge to science content.

Table 4.24 displays the instructional methods Natalie used to support connections between the investigation lesson and students' knowledge, ideas, and experiences.

Table 4.24

*Natalie's instructional approaches to connecting the investigation lesson*

| **Connecting investigation lesson and students' knowledge, ideas, and experiences** | BSST1 | RT1 | PeerTch | RT2 | ST1 | ST2 |
|---|---|---|---|---|---|---|
| Connecting to previous lessons | X | X | X | X | X | X |
| Connecting to real world examples | | X | X | | X | X |
| Elicit student ideas | X | X | X | X | X | X |
| Relating to a scientific model | | | | | | |
| Other | | X | X | X | X | X |
| **Mostly teacher-directed** | X | X | | X | X | X |
| **Mostly student-directed** | | | | | | |
| **Intermediate** | | | X | | | |
| **Not done or NA** | | | | | | |

Although her instructional approaches were often very teacher-directed, Natalie's dedication to fostering and ensuring connections between investigation lessons and students' knowledge, ideas, and experiences was evident in many ways. In interviews, Natalie explicitly acknowledged this as a focus of hers; her ideas about students' thinking in science are described later in this case study. Natalie's stated beliefs and instructional approaches proved congruent, and the data do not reveal a connection between approximation of practice authenticity and this key feature.

**Establishing data collection procedures.** To establish data collection, Natalie employed highly structured, teacher-directed methods for describing and deploying investigation procedures. In her peer teaching lesson, for example, Natalie usually handled the ice pack, placed it on the electronic balance, and had her students take readings at time intervals determined by Natalie. Students were directed to record the electronic balance reading data on a data table contained in their "weight of an ice pack over time" station worksheet. Table 4.25 shows the instructional approaches Natalie used to establish data collection procedures in this and her other approximations of practice.

Table 4.25

*Natalie's instructional approaches to establishing data collection procedures*

| **Establishing data collection** | BSST1 | RT1 | PeerTch | RT2 | ST1 | ST2 |
|---|---|---|---|---|---|---|
| Teacher modeling | | | | X | X | X |
| Directions | | X | X | X | X | X |
| Discovery | | | | | | |
| Directed discovery | | X | | X | X | X |
| Supported data recording | | | X | X | | |
| Other | | X | X | X | X | X |
| **Mostly teacher-directed** | | X | X | X | X | X |
| **Mostly student-directed** | | | | | | |
| **Intermediate** | | | | | | |
| **Not Done or NA** | X | | | | | |

In Natalie's later approximations of practice, she demonstrated for students how to collect and record investigation data, instructional approaches consistent with a guided inquiry orientation to science teaching.

Throughout her approximations of practice, Natalie worked to determine the best ways to support her second graders in carrying out investigations. As her approximations of practice progressed, Natalie broke instructions down into smaller, more manageable chunks for second graders. She used visual cues (e.g., procedural steps recorded on an overhead projector) to aid her students in carrying out data collection and recording responsibilities. In her ST2, Natalie physically demonstrated how students should manipulate their seeds. She also structured this lesson so that students carried out a portion of the investigation, then regrouped as an entire class before moving on to the next portion of the investigation. Natalie circulated, prompted individual students to remain on-task and supported them in recording data properly. This combination of instructional approaches resulted in a more streamlined and effective investigation enactment. It contrasted with Natalie's RT1, in which she gave students all the investigation instructions upfront and then spent much of the investigation clarifying student confusions and managing off-task behavior. In essence, then, gaining more teaching experience in approximations of practice helped Natalie develop effective methods for establishing data collection procedures.

**Fostering sense-making with data.** In Natalie's approximations of practice, with the exception of her peer teaching experience, students gathered qualitative data. In some lessons this involved observing and recording physical characteristics of samples (rocks, seeds, etc.). In other approximations of practice this entailed manipulating a variable and recording the observed effect(s). Natalie's ST1 lesson was one example of the latter, in which students created "dance floors" for pepper particles using plastic wrap-covered disposable cups. By tapping pencils against the side of the cup, they made their pepper particles "dance." To help her students relate the pencil tapping noise to the vibrations visible in the dancing pepper, Natalie engaged her students in a variety of discourse formats. While the investigation was underway, she circulated and asked small groups of students what they thought was making the pepper move, and after the investigation she conducted a whole-class discussion to go over students' findings. She also posed questions to help students connect their observations to the concept of sound vibrations. In these ways, Natalie positioned her students as sense-makers. Table 4.26 summarizes Natalie's instructional approaches to foster her students' sense-making with their investigation data in her approximations of practice.

Table 4.26

*Natalie's instructional approaches to fostering sense-making with data*

| **Fostering sense-making with data** | BSST1 | RT1 | PeerTch | RT2* | ST1 | ST2 |
|---|---|---|---|---|---|---|
| Pattern-seeking | | | X | | X | |
| Relating findings to real world | | | X | | X | |
| Discourse-based | | X | X | X | X | X |
| Scientific model-based | | | | | | X |
| Telling | | X | | | X | X |
| Other | | X | X | X | X | X |
| **Mostly teacher-directed** | | X | | | | X |
| **Mostly student-directed** | | | | | | |
| **Intermediate** | | | X | X | X | |
| **Not done or NA** | X | | | | | |

*The very end of this lesson was not observed, so there may have been additional instructional approaches employed that are not indicated on this table.

As Table 4.26 shows, Natalie used a variety of methods to help students make meaningful conclusions from their investigation data. In some cases, Natalie told students outright what their data meant, consistent with more traditional, didactic science teaching. More often, though, she engaged students in conversations designed to help them arrive at understandings of their investigation outcomes, consistent with a guided inquiry orientation. These conversations usually positioned Natalie as the questioner and students as the suppliers of answers, thereby scaffolding students to arrive at normative scientific understandings of the data they gathered.

In evaluating these data, I found no clear trends relating instructional approaches to qualities of the approximation of practice, outside of the general trend involving discourse-based sense-making across approximations of practice. The lack of apparent patterns here suggests that Natalie's instructional approaches were highly dependent on the science content in question, and the subject and structure of the lesson itself, rather than the approximation of practice complexity or authenticity.

**Supporting claims with evidence.** Natalie was unique among case study teachers in her consistent work to support students in making evidence-based claims about the scientific phenomena they studied. Specific examples are presented following Table 4.27, which shows how Natalie and her students supported claims with evidence in each approximation of practice.

Table 4.27

*Natalie's instructional approaches to supporting claims with evidence*

| **Supporting claims with evidence** | BSST1 | RT1 | PeerTch | RT2* | ST1 | ST2 |
|---|---|---|---|---|---|---|
| Discursive | | X | X | X | X | X |
| Scientific model-based | | | X | | | |
| Using written supports | | | | X | X | X |
| Other | | X | X | X | X | X |
| **Mostly teacher-directed** | | X | X | | X | |
| **Mostly student-directed** | | | | | | X |
| **Intermediate** | | | | X | | |
| **Not done or NA** | X | | | | | |

*The very end of this lesson was not observed, so the instructional approaches indicated here are inferences based on triangulating among statements made by Natalie during earlier portions of the lesson, a post-enactment interview with Natalie, and information in Natalie's written RT2 assignment. Furthermore, there may have been additional instructional approaches employed that are not indicated on this table.

As stated earlier, Natalie supported students in making evidence-based claims whenever the approximation of practice contained the potential for this key feature. Table 4.27 shows that her instructional approaches were largely discursive in nature, for example, asking students what they concluded from the investigation and why. Table 4.27 also reveals that Natalie often combined instructional approaches to satisfy this key feature of investigation lessons. In her later approximations of practice (ST1 and ST2), Natalie introduced written supports as a support for her students' evidence-based claims. For example, in her ST1, Natalie had students record in their science notebooks "I think ______ because _____." Before releasing students to do this work, Natalie modeled for them how an acceptable answer would begin ("I think the pepper danced because …"). Additionally, she reminded students what constituted supporting evidence for the completion of this sentence, and assisted students in crafting evidence-based claims.

**Summary of Natalie's instructional approaches in her approximations of practice**

Natalie's instructional approaches to enacting key features of investigation lessons changed more noticeably for some key features (e.g., Supporting claims with evidence) than others (e.g., Connection investigation lessons and students' knowledge, ideas, and experiences). When changes in instructional approaches were noted, they appeared to relate more directly with learning-from-experience than with features of the approximations of practice. Thus, the biggest trend in Natalie's instructional approaches to teaching investigation lessons over her approximations of practice appears to be due to experience-based learning; having opportunities to implement lessons learned in subsequent approximations of practice. In the next section, I explore how Natalie's ideas and confidence played important roles in her recursive experiential learning. I also discuss Natalie's perceptions of changes in these two constructs.

**Natalie's changing ideas about and confidence for teaching elementary science**

Of the four prospective teachers in this study, Natalie appeared to make the greatest gains in her confidence for teaching elementary science. Despite these noticeable changes, Natalie's ideas about effective science teaching changed very little. As evidence for these claims, I present data from methods course assignments, post-approximation of practice interviews, and beginning- and end-of-semester interviews.

**Natalie's ideas about approximation of practice investigation lessons.** Natalie was truly a student of her own practice; she derived many key points from reflecting on her approximations of practice enactments. Table 4.28 provides a paraphrased summary of what Natalie stated as her biggest take-away lessons from each approximation of practice.

Table 4.28

*Natalie's lessons learned from her approximations of science teaching practice*

| Lessons learned |
|---|
| BSST1 |
| • What I could do differently in an introduction, what students could answer, and time management<br>• Improvisation allows teachers to follow students' questions and curiosities about science; teachers should be willing to stray from or supplement their lessons when appropriate<br>• Lessons might not go exactly as planned, but I should not worry as long as the students and I are learning the content and having meaningful discussions |
| RT1 |
| • Science teaching does not always appear to be structured because a lot of it deals with improvising and allowing students to investigate |
| BSST2 |
| • Science teaching includes a lot of improvising; OK not to stick word for word to a lesson plan<br>• Science teaching involves different methods (reading a text, showing pictures, and having students write/draw pictures of their predictions and what they learned)<br>• Integrate science into other subjects to increase students' exposure to scientific thinking |
| PeerTch |
| • How to improve more and stray from my lesson plan--it doesn't have to be so structured as long as we end up with the same concepts<br>• Experiments don't always go as planned. There are other ways students can learn content<br>• Stay calm. If the experiment doesn't work out there are other ways to present material<br>• Important to probe students' thinking, make sure they can explain their claim<br>• Make connections between students' ideas and promote inter-student discussion |
| RT2 |
| • More teaching = more practice = more confidence and the less frazzled I am. Once I feel more confident in the classroom, things will run more smoothly, this will reflect upon my students<br>• Science teaching does not always go as anticipated<br>• If students are really involved in their work and/or investigations, let them continue working as long as I make time for discussion and concluding the lesson another time<br>• Be flexible in adjusting my schedule to fit in an extra twenty or so minutes of science<br>• It is important for students to have a concluding discussion to evaluate their achievement of the learning goals and their understanding of the big idea |
| BSST3 |
| • A concluding discussion is essential to a lesson so that students understand the lesson's purpose and so that the teacher can evaluate how his/her instruction went and which students need further support with understanding the big idea |

As Table 4.28 reveals, Natalie reiterated several themes across her approximations of practice lessons learned. These commonly-revisited aspects of science teaching included maintaining instructional flexibility so that teaching might be responsive to students' needs and contributions, and keeping in mind that deviations from a lesson plan are not necessarily disastrous and often potentially beneficial to student learning. Natalie also reiterated the importance of checking in with students to assess their thinking and whether their ideas have changed as a result of the lesson. These interrelated, overarching themes resurfaced in other interviews with Natalie and in her methods course artifacts.

**Natalie's ideas about investigation lessons more generally.** Over her last year of teacher preparation, Natalie maintained an emphasis on the importance of investigations in science teaching and learning. Her approximation of practice experiences underscored her belief in the importance of working with students' ideas in science. Below, I present data that expand upon these two elements of Natalie's ideas about science teaching, and show how these ideas changed in subtle ways over the study.

When asked to describe elementary science investigations in general, Natalie stated that she envisioned investigations as predominantly cognitive work done by the students with the teacher serving in a facilitative/management capacity. Natalie believed that students should do the knowledge construction involved in investigation lessons, and her initial ideas about investigation lessons were rooted in classroom science lesson observations.

> MN: What do investigations in elementary science entail?
>
> Natalie: I noticed in my class they make predictions about what they think is going to happen and they have to explain why they predicted that, and then they

> make their observations and they share back what they saw and found out and they talk about that and then I guess make a conclusion.
>
> MN: How do you see the teacher's role in investigations?
>
> Natalie: Just maybe guiding, not telling, not telling students but letting them find out on their own. (Natalie, Initial F09 interview)

Though her orientations toward investigations did not change appreciably by the end of the methods course semester, Natalie did describe the teacher's role in investigation lessons in more detail, and made specific reference to her own teaching experiences.

> MN: Can you say more about what investigations involve from the teacher's perspective?
>
> Natalie: They involve lots of set-up, good classroom management skills, I thought it was difficult to manage several small groups and also keep the entire group on track. It's also hard as a teacher to know where the line is for what you want your students to get by themselves and what you can give them, especially if there's a time crunch, and when you're at the end of the investigation time and a lot of students haven't gotten the idea you wanted them to get, I'm not sure when to be just like "well OK, you're supposed to get this." (Natalie, End F09 interview)

Following her student teaching semester, Natalie answered the interview question ("What do investigations in elementary science entail?") by relating an anecdote from her own teaching experience:

> I think investigations entail actually investigating. One of my students actually made the comment that she really liked how she could ask me a question in science and I'll explain a little bit, like maybe give her a little guidance but I don't

> give out the answer, so I think that's really central in investigating, let them figure it out for themselves, that's what really makes them excited. (Natalie, End W10 interview)

Looking across Natalie's answers to this interview question, it is particularly striking how Natalie's responses reflect the degree to which she has increasingly assumed the identity and authority of an elementary science teacher.

When asked to describe a typical investigation lesson in the abstract, Natalie identified distinct elements to the lesson and made several references to her own developing science teaching practice.

> I'd say there's definitely a mini-lesson in the beginning…it acts like an introductory discussion, like maybe to assess what they know so far about a subject, I usually like to do a KWL or list on chart paper the questions that we have…and then we have the investigation, the students have a set of procedures to follow…they're given time to, free time, just to like look at whatever they're investigating and come up with any thoughts or questions and then after that a lot of times I give them the assignment, so like the pages with the questions that they have to answer…some free observation time, and then some more structured guidance, and then end with a group discussion of everyone reporting what they found. (Natalie, End W10 interview)

Natalie also described her own preferred approach to handling the student-directedness versus teacher-directedness tension in teaching investigation lessons. Natalie's approach represents the "best of both worlds": giving students time to engage in self-directed exploration followed by more structured, teacher-directed inquiry. In other words, Natalie espoused inquiry and guided inquiry science teaching orientations.

When planning investigation lessons, Natalie revealed that she attended to her students' ideas and tried to anticipate what to do to facilitate their learning.

> I pay attention to what students might, like, alternative ideas they might have, and then I'll practice the experiment and I'll know what they might have trouble doing and so I can anticipate that and I can give them more support, more time, more thorough directions, I think that's important. (Natalie, End W10 interview)

And when teaching an investigation lesson, Natalie stated that she attended to her students' observations, the ease with which they carried out the investigation, and what the students were learning. Part of her work in teaching an investigation lesson involved tailoring her supports to her students' emergent needs.

> I pay attention to what kinds of observations students are making, what connections they're making, and if anybody's struggling with anything… I think it's really important to be so involved with the students' work that I can just adapt my lesson on the fly, and I call them "a-ha moments" like when I notice a student doing something that other students would benefit from seeing I'll announce it to the whole class and point it out, or when someone brings up a really interesting question, I'll announce that to the whole class, if somebody finds something challenging I'll re-explain that or give them more support. (Natalie, End W10 interview)

Natalie's descriptions of what she thought about during investigation lesson planning and enactment were grounded in the realistic notion that science lessons may not always progress as planned, an idea that surfaced numerous times in her approximations of practice. Regardless of whether the lesson played out as expected, Natalie gauged the efficacy of an investigation lesson

> …by what my students present in their concluding discussion, what their last thoughts and ideas about the lesson are, gives me insight into what knowledge they've gained and what I need to cover again, and what I possibly could skip over. (Natalie, End W10 interview)

Here, Natalie made reference to another overarching theme in her ideas about science teaching: the importance of considering students' ideas.

Throughout the year, Natalie maintained a focus on students' ideas and student thinking. At the beginning of Fall 2009, Natalie attended to students' ideas and the relevance of science to their lives.

> STEBI-B survey item: I do not know what to do to turn students on to science.
>
> Natalie: Strongly disagree. I think I have some pretty good ideas, I know it's important to engage students' prior knowledge and make everything relevant to their experiences whenever possible. (Natalie, Initial F09 interview)

In the same vein, Natalie made specific mention of attending to students' alternative ideas. When I asked her what she would advise a colleague to consider when teaching a science lesson conclusion, she stated:

> Look out for alternative ideas… I would want my students to all come to the same conclusion at some point, but I'm not sure how I would do that by guiding them and not telling them, so I guess I would have them watch out for balancing that, the guiding and telling, because you wouldn't want them to keep alternative ideas

> and form alternative ideas. (Natalie, Initial F09 interview)

Natalie offered some reasons why considering students' alternative ideas were particularly salient to her as a beginning science teacher:

> …if you were to correct a student right off the bat then they wouldn't, they would just give up, there would be no reason for them to investigate. And so by not correcting them you're giving them that opportunity to find out for themselves whether or not it's true. (Natalie, Initial F09 interview)

Natalie's initial interview responses suggest that she had already developed several logical and meaningful rationales for teaching investigation-based science. Strong beliefs in evidence-based scientific knowledge and student agency in developing that knowledge were recurrent themes among Natalie's science teaching orientations. In addition, eliciting students' ideas to inform instruction and gauge her teaching efficacy emerged as prominent ideas. As Natalie stated following her student teaching semester,

> I think [relationships between] my science instruction and students' prior knowledge are important…for example, we started a lesson about fruit with a KWL and I think that was really helpful because we had, then I could assess what they already knew about fruit and what I should say or shouldn't say…we had guiding questions that we came up with as a class that we wanted to investigate on top of what Science Companion wanted them to fill out in their journals, which was really neat. So I think that the students' prior knowledge and then evaluating their work afterward helps me, helps my instruction and lets me see how effective my teaching is. (Natalie, End W10 interview)

In word and in action, Natalie concerned herself a great deal with whether and what her students were learning in her science lessons. Evidence of such atypical focus on student learning at the preservice level is explored in more depth in Chapter 6.

**Summary of Natalie's changing ideas about science teaching**

While there were many other ideas that Natalie espoused about science teaching, two ideas that informed and were informed by her approximations of practice focused on the nature of investigations in elementary science education and the paramount importance of eliciting and working with students' ideas. Natalie began the methods course semester with well-articulated orientations toward science investigation lessons and the centrality of student ideas to investigation-based learning. While the core tenets of these ideas did not change appreciably during the year, what did change was that Natalie was able to more assertively state her ideas and provide evidence from her own teaching experience to support and validate her orientations toward investigation lessons and students' ideas in elementary science.

**Natalie's confidence for teaching elementary science**

Although Natalie felt comfortable in her knowledge of science, and her general ideas about how it should be taught, this did not translate into confidence in her science teaching skills in her early approximations of practice. In our interviews, Natalie was very forthcoming in talking about her confidence as a science teacher. Data from these interviews show how Natalie's confidence for teaching elementary science, and teaching investigation lessons in particular, increased during the year.

**Natalie's confidence for teaching approximation of practice investigation lessons.** Shortly after completing each approximation of practice, Natalie and I discussed her feelings about how the lesson went. Specifically, I asked Natalie how she felt during the teaching of the lesson and whether this experience influenced her overall feelings about teaching science. Natalie proved to be highly-self critical, focusing on her perceived shortcomings and how she could improve her teaching practice. Table 4.29 summarizes Natalie’s responses to two interview questions across her approximations of practice. A more complete set of Natalie’s responses may be found in Appendix O.

Table 4.29

*Natalie's feelings during and after her methods semester approximations of practice*

| During enactment<br>("How did you feel while teaching?") | After enactment<br>("Did this experience impact how you feel about teaching science?") |
|---|---|
| BSST1 | |
| Natalie did not answer this question | NA |
| RT1 | |
| At the beginning… [I felt] pretty confident…I sort of lost confidence when my CT had to step in more…[I] started questioning myself and started feeling really flustered. (I)<br>I felt flustered when students could not finish their work in the allotted time … I wanted them to leave with a certain answer, but I did not think that I should just tell them something.(W) | It's a bit scary… I like structured things and following a specific plan… to step back from it and let them [go], that's harder for me. (I)<br>I felt really confident about my ability to teach science prior to this lesson and after this lesson I felt like there was a lot to improve on. (W) |
| PeerTch | |
| In the beginning when the experiment was going well, I was a little bit nervous … the last two groups the experiment didn't work at all and I could feel myself getting a little flustered … (I) | I'm feeling maybe a little bit more confident but I don't know if a room full of second graders is more intimidating than a group of five college students.(I) |
| RT2 | |
| A little bit frazzled, there was a lot of people in here watching…during the investigation was when I actually started sweating, because there's a lot of groups and there was a lot of questions and I wanted to make sure everything was running well and I don't miss anybody…but before that I felt really confident... (I) | The more lessons I do, the more practice, the more confidence I have and this time I was a little less frazzled, a *lot* less frazzled than I was the first time. (I)<br>I definitely felt more confident teaching this lesson than I had during my first RT. I felt better prepared for the lesson and I knew what was expected of me and what I expected from my students. (W) |
| BSST3 | |
| Rushed. Very rushed. We were running out of time… my CT was just in the back of the room giving me the "hurry up, move it along" sign… but other than that, I felt ok about it. I would have liked to…talk more about it. (I)<br>I felt extremely rushed during my BSST because we were running out of time for the science lesson. (W) | I think that the conclusion is important for students to know why they're doing something, I still feel the need for that as a student. (I) |

In many of her post-approximation of practice reflections, Natalie expressed some discomfort when the lesson enactment took unexpected deviations from her plan. In the field, Natalie's confidence in her teaching tended to waver when she was faced with behavior, time, and materials management challenges while teaching. In her peer teaching, Natalie led an investigation station with small groups of her colleagues, who did not present behavior management issues. However, the investigation sometimes yielded errant data, which Natalie had to figure out how to manage in the moment of peer teaching. In her later approximations of practice (RT2 and BSST3), Natalie's stress derived from having adult observers in the classroom and time constraints, respectively. Taken together, Natalie's comments about her approximations of practice teaching experiences suggest that she continued to struggle with issues relating to self-confidence as a science teacher. In contrast, the retrospective view Natalie presented offered a more optimistic picture of her evolving science teaching confidence.

**Natalie's confidence for teaching investigation lessons more generally.** In our interviews that took place at the beginning and end of Fall 2009 and end of Winter 2010 semesters, Natalie spoke of her science teaching confidence in a more holistic way that reflected integration of her science teaching experiences. At the beginning of Fall 2009, when she had not yet taught any science, Natalie stated that she was confident in both her knowledge of science and her ability to effectively teach elementary science. She added that her confidence stemmed from an enjoyment of science, with the expectation and that this enjoyment would be conveyed in her science teaching (see quote in "Natalie's science background" section). Natalie stated that her confidence in her science teaching ability began to increase after watching her cooperating teacher (CT) teach science lessons.

> I think it [my confidence in my science teaching ability] changed once I started observing lessons in the classroom, and seeing what my CT does and thinking "oh I can do that" and thinking what else I might do, so I became more confident. (Natalie, Initial F09 interview)

Once she began her approximations of practice, however, Natalie experienced a downward shift in her self-confidence as a science teacher. As the post-approximation of practice reflections above suggest, and as was previously noted, Natalie was highly self-critical of her science teaching practice, and tended to focus on problems or areas for improvement rather than progress made. By the end of the methods course semester, Natalie admitted to having gained confidence in her ability to teach investigation lessons, however, she remained characteristically self-critical:

> I feel more confident…I still see where I can improve but I'm excited to have the opportunities for some student teaching to work on it [teaching investigation lessons]. (Natalie, End F09 interview)

And at the end of her student teaching semester, she expressed a similar sentiment:

> MN: Using a scale from "not very confident" (1) to "very confident" (5), how would you rate your comfort level with teaching a science lesson that involves an investigation?
>
> Natalie: I feel really confident about it so I would want to give myself a 5 but I always want to leave room for growth, so 4.5? (Natalie, End W10 interview)

These interview data tended to be highly-revealing indicators of Natalie's overall confidence level, as well as indicators of Natalie's humility and self-scrutiny.

In her approximations of practice, Natalie demonstrated an almost palpable shift in her demeanor. In her early approximations of practice, Natalie's instructional approaches bespoke a cautious, intimidated quality, and her cooperating teacher often interjected to assist during lessons, particularly with respect to behavior management. In her later approximations of practice, Natalie appeared to have internalized a teacher identity, and asserted herself as an authoritative, self-assured teacher figure in her science lessons.

In our interviews, I asked Natalie to complete STEBI-B type survey items to indicate her current comfort level with aspects of teaching investigation lessons. Table 4.30 summarizes Natalie's responses.

Table 4.30

*Natalie's evolving confidence for teaching science investigation lessons*

| | Beginning Fall 2009 | End Fall 2009 | End Winter 2010 |
|---|---|---|---|
| I will not be very effective in teaching science investigations. | Strongly Disagree | Strongly Disagree | Strongly Disagree |
| I will find it difficult to explain to students why science investigations work. | Strongly Disagree | Strongly Disagree | Strongly Disagree |
| I will be able to evaluate and adapt existing science investigations for use in my classroom. | Strongly Agree | Strongly Agree | Strongly Agree |
| I will find it difficult to support students' sense-making using data they have gathered in science investigations. | Disagree | Strongly Disagree | Strongly Disagree |
| I will find it difficult to effectively introduce, monitor, and conclude a lesson that involves an investigation. | Strongly Disagree | Disagree | Strongly Disagree |

These data do not appear to indicate much change in terms of Natalie's confidence for teaching investigation lessons. There are several possible explanations for this finding, which is highly incongruent with Natalie's interview data. For example, Natalie may not have considered student behavior management as an element of teaching investigation lessons, and may have focused more keenly on the science content aspect of science lessons. As these items are worded, much room for user interpretation remains. To wit, some teachers in this study chose to focus on their general communication skills when responding to the item "I will find it difficult to explain to students why science investigations work," rather than focusing on their knowledge of the science content underlying the investigation. For this reason, I am inclined to place less emphasis on these data and rely more strongly upon open-ended self-reports relating to confidence as a science teacher, which more clearly captured nuanced changes in this construct.

**Summary of Natalie's changing confidence as a science teacher**

In summary, Natalie reported increases in her confidence for teaching science, particularly investigations, as she progressed through her approximations of practice. Much of Natalie's increased confidence appeared to be associated with learning how to effectively manage time, materials, and student behavior—especially when any or all of these resulted in departures from Natalie's lesson plan. I now explore what Natalie viewed as the reasons for changes in her ideas about and confidence for teaching elementary science investigation lessons. In addition to reflecting on these aspects of her teaching metacognitively, Natalie offered further evidence in support of my claims about her ideas and confidence throughout the study.

**Natalie's description of her changing ideas about teaching elementary science**

In our final interview, I asked Natalie to offer some insight into her changing ideas about science teaching. The following excerpt captures part of our conversation:

> I want the students to know that they are more than capable of coming up with the knowledge on their own, that they can come up with those ideas…like the sound unit, Edwin figured out sound vibrations and moving air molecules by himself, no one told him that, he came up with sound waves, he's 7 years old, I was amazed! And that's what gets me really excited is to see them excited too, about learning and I want them to know that what they have to say is important to me and it's important to everyone else and that they can all benefit from hearing from each other. (Natalie, End W10 interview)

Here, Natalie described her underlying orientation toward prioritizing students' ideas in her science teaching. She spoke of empowering her students to create their own knowledge, and made specific reference to one of her student's "a-ha!" moments in science to illustrate the excitement this generated for her as a teacher. She also talked about how she valued creation of a class-wide dialog, rather than a student-teacher dialog, in her science lessons.

When I asked her to comment about her changing ideas about science teaching and what likely prompted those changes, Natalie revealed:

> At first I thought it [science teaching] was just going to suck for lack of a better word, because it was so crazy the first time I taught it, but I think gaining confidence and actually being excited about teaching science and knowing the

> students were able to come up with those great ideas on their own and watching them do that was definitely a big driver. (Natalie, End W10 interview)

Here, Natalie made explicit the connection between her changing ideas about science teaching and her evolving confidence as a science teacher. She attributed successful experiences in effecting student learning as generative for both her ideas (largely attitudinal) and confidence for science teaching.

**Natalie's description of her changing confidence for teaching elementary science**

Following her reflections on her changing ideas about science teaching, I asked Natalie to comment on how her self-confidence as a science teacher changed over the year. Natalie explained how her confidence increased and, in hindsight, she downgraded her initial level of confidence about her science teaching. Natalie attributed this increase in confidence to her various experiences having taught science, both in the methods course and during her student teaching semester. She added that witnessing her own improvement as a science teacher helped bolster her confidence in her science teaching.

> MN: Do you feel like your feelings about science teaching have changed at all?
>
> Natalie: I think in the beginning I shouldn't have marked "confident." [laughing] I probably marked "confident" because I thought it was going to be like no big deal, that it would be really easy because the curriculum is already all written out for you, all you have to do is read from it. I was greatly mistaken [laughing]. But after doing the assignments for ED421 [science methods course] I think I can say that I'm confident now. Now I understand the work that goes into it and all of the different aspects and why everything's important. (Natalie, End F09 interview)

Natalie proposed that her initial self-confidence was largely naïve, lacking in experience-based knowledge of the realities of elementary science teaching. Natalie attributed an increase in her confidence to her approximations of practice *in toto*, and went on to identify specific elements of approximations of practice that were particularly helpful in boosting her confidence.

> Being able to practice in the classroom, having all those opportunities to teach science. Even in our peer teaching, I thought that was really helpful, I felt like I was exposed to a lot of different aspects of science teaching. And I really liked the bite-sized [science teaching assignments], because it gave me a way to really get my feet wet before having to do a whole lesson, which was really helpful. And I never taught a lesson with an investigation before, even with students working in small groups, at all, so that was really a different experience. I think I improved in my teaching, which helped me gain more confidence. (Natalie, End F09 interview)

At the end of her student teaching semester, I again asked Natalie to comment about her self-confidence in her science teaching. She reflected:

> Well in the beginning, when I taught the rocks lesson, I thought I was confident and then when I got in the classroom I was just not very confident at all with the science, and it was so chaotic at first because there were so many things going on. Definitely as I got more experience I gained a lot of confidence and teacher presence in the classroom and instruction just came more naturally. (Natalie, End W10 interview)

Here, Natalie made references to specific elements of her approximations of practice that affected her confidence as a science teacher. Again, I asked Natalie if she thought her confidence as a science teacher had changed during her student teaching semester, and she stated:

> Oh definitely, I feel like in the beginning, lessons with investigations can be really overwhelming, especially for someone who was as inexperienced as I was at first, but now I feel like I got the hang of it, and now that I understand, once I got to really understand why we need each part of the lesson, it came more naturally and just kind of flowed together. (Natalie, End W10 interview)

Natalie alluded to her approximations of practice—specifically, the BSSTs--as factors that contributed to her increased confidence for teaching investigation lessons.

**Summary and end of year model for Natalie**

In summary, Natalie began her approximations of practice with no previous science teaching experience but confident in her science knowledge and ability to teach elementary science. In her approximations of practice, she typically employed teacher-directed instructional approaches to satisfy key features of investigation lessons. Natalie's approximations of practice were particularly notable for her consistent efforts to elicit and work with students' ideas, and to support her students in making evidence-based claims about the topics they investigated.

Natalie held strong orientations toward science teaching in general and investigation lessons specifically. Particularly salient for Natalie were the notions of attending to students' ideas and supporting them in doing the cognitive work in science investigation lessons. Her dedication to students' ideas was consistent throughout the year-long study, and was evident in her words and actions. Natalie was aware that her ideas about science teaching were supported and strengthened by her approximation of practice experiences, and that her growing confidence as a beginning science teacher was an important component of her thinking about science teaching.

Finally, Natalie's confidence as a science teacher increased remarkably throughout the year. As she gained experience teaching investigation lessons, Natalie was very self-critical and aware of her areas for continued improvement. Natalie's confidence as a science teacher was tied to her abilities to manage science lessons in terms of time, materials, and student behavior, and to empower students in the construction of their own scientific knowledge. She often cited examples from her own approximation of practice experiences to support her ideas and confidence as a science teacher, and acknowledged that this confidence had grown appreciably.

When compared with the typical prospective elementary teacher illustrated in Figure 2.1, Natalie demonstrated very few differences. Natalie indicated a higher degree of initial confidence in her abilities to teach investigation lessons—a view she later described as naïve. Natalie's end of year model illustrating the evidence-based relationships between study constructs is presented in Figure 4.3.

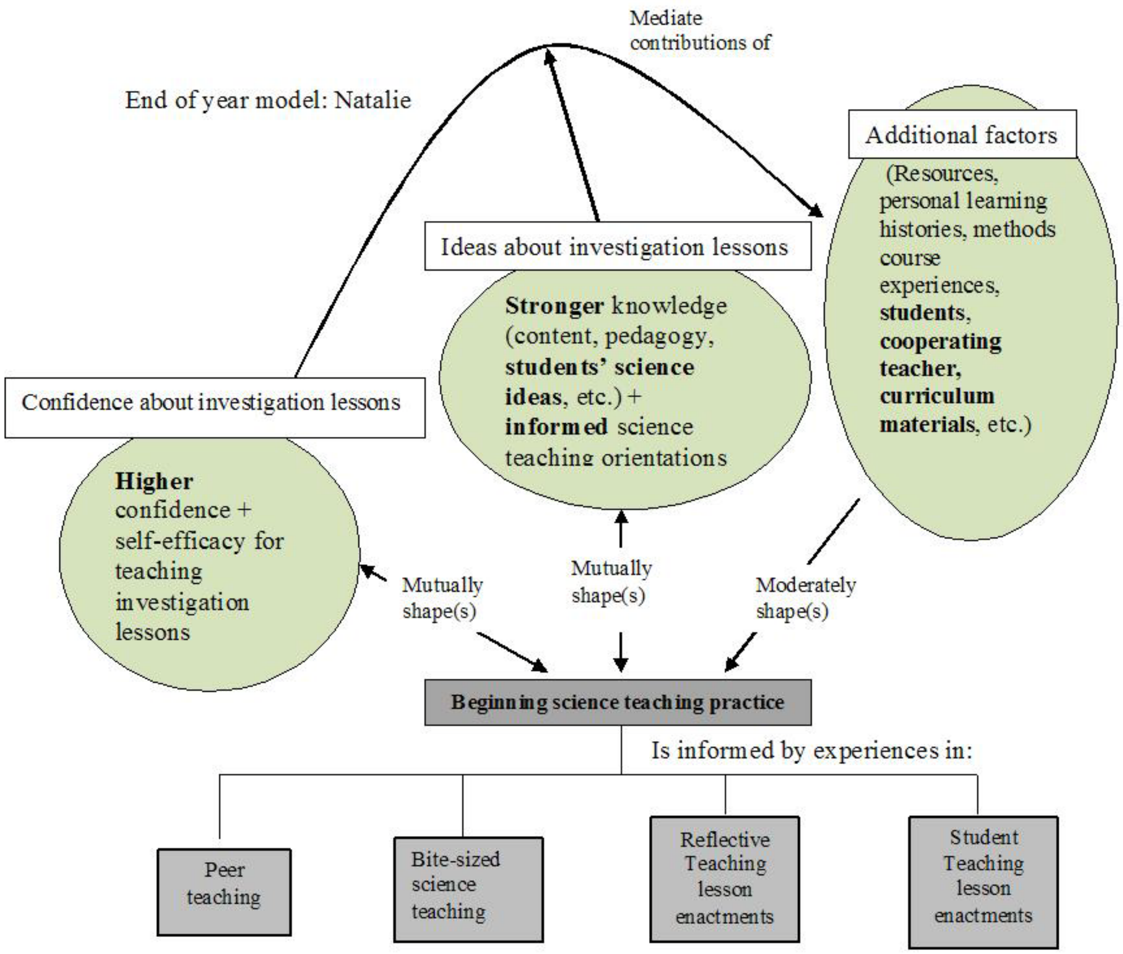



*Figure 4.3.* Natalie's end of year model

As Figure 4.3 reveals, Natalie's end of year model did not differ drastically from the generic model proposed in Figure 2.2. Similar to Bridget, Natalie demonstrated greater reliance on her cooperating teacher and classroom curriculum materials as factors shaping her science teaching than originally anticipated in the end of year model in Figure 2.2. Specific to Natalie, and reflected in Figure 4.3 in bold text, is the degree to which Natalie's initial ideas about learner-focused science instruction remained strong influences on her science teaching throughout the study.

## Polly

### Overview

Polly was a language arts major and social studies minor in the undergraduate elementary teacher education program. In the elementary science methods course, Polly participated thoughtfully in whole-class discussions. She was placed in a third grade classroom at Landings Elementary in Ann Arbor, with a cooperating teacher who was very enthusiastic about teaching science. Polly began the methods course without science teaching experience and was not initially excited about teaching science, a sentiment that seemed to change over the year.

### Polly's science background

Polly did not have an extensive background in science. She had taken the minimum number of college-level requirements in science (physics for elementary teachers, biology, general science, and one elective) and had two years of science in high school, also a minimum school requirement.

Polly attributed her knowledge of science to what she learned in elementary and middle school science classes but stated that while she remembered "doing things" she didn't necessarily remember the outcomes of experiments. She stated that later on in high school and college, learning science entailed a lot of reading and memorization, especially in biology, whereas in geological science her learning involved a more diverse set of activities. Polly admitted that she probably did not remember a lot of the science she learned.

Polly stated that she had to relearn the science content before teaching it to elementary students. She noted that planning was important to her science teaching.

> It was almost like I had to kind of re-teach myself…Understand it at my level, and, but understanding how are third graders going to perceive it, what are they going to need to learn, how can I best teach it so that they understand it versus telling them how I understand it. But some of it, it obviously was like "oh yeah" but some of it was I had to kind of refresh and go back and I couldn't just say "I'm teaching light, let me tell you" I had to plan and prepare. (Polly, End W10 interview)

Overall, Polly was aware of her limited science background, and openly admitted to needing to review and relearn the material before trying to teach it to others.

**Polly's approximations of practice trajectory**

Polly was placed with a cooperating teacher who enjoyed teaching science. Unlike other case study teachers, Polly's science teaching experiences in the field were limited to the approximations of practice observed as part of this study. The order in which Polly enacted her approximations of practice is depicted in Table 4.31.

Table 4.31

*Polly's approximations of practice trajectory*

| | RT1 | BSST1 | PeerTch | RT2 | BSSTs 2 & 3* | ST1 | ST2 |
|---|---|---|---|---|---|---|---|
| Date | 28 Oct. 2009 | 11 Nov. 2009 | 16 Nov. 2009 | 20 Nov. 2009 | 9 Dec. 2009 | 26 Mar. 2010 | 14 Apr. 2010 |
| Lesson or lesson portion | Opaque, trans-lucent, and trans-parent materials | Intro to opaque materials and shadows | Sense-making discussion using investiga-tion data | Trans-parent materials and refraction | Magnetic objects scavenger hunt | Model of Earth and its moon | Scale model of planets |

*Polly taught the entire lesson to satisfy BSST2 and BSST3 requirements.

Approximation of practice lessons and lesson portions Polly taught in her field placement were part of elementary science units about light, magnetism, and the solar system. Lesson plans for light and magnetism lessons were taken from the Science Companion curriculum, whereas lesson plans for solar system lessons were part of Polly's cooperating teacher's own solar system unit materials.

**Key features of investigation lessons in Polly's approximations of practice**

Table 4.32 displays an overview of the key features of investigation lessons observed in Polly's approximations of practice lesson enactments.

Table 4.32

*Key features of investigation lessons in Polly's approximations of practice*

Anticipated = A, Observed = O

| Element of investigation | RT1 | BSST1 | PeerTch | RT2 | BSSTs 2 & 3 | ST1 | ST2 |
|---|---|---|---|---|---|---|---|
| Identifying the investigation purpose(s) | A, O | A, O | O | A, O | O | A, O | A, O |
| Connecting investigation lesson and students' knowledge, ideas, and/or experiences | A, O | A, O | A, O | A, O | O | A, O | A, O |
| Establishing data collection | A, O | | | A, O | A, O | A, O | A, O |
| Fostering sense-making with data | A, O | | A, O | A, O | A, O | A, O | A, O |
| Supporting claims with evidence | A | | A, O | A | A | A | A |

While most of Polly's approximations of practice contained the expected key features of investigation lessons, this was not always the case. In all but one of her approximations of practice in which supporting claims with evidence was anticipated, she did not incorporate instructional approaches to satisfy this key feature. Below, I present detailed descriptions of the instructional approaches Polly used in her approximations of practice.

**Identifying the investigation purpose(s).** Whenever relevant to the approximation of practice lesson content, Polly informed her students of the purpose(s) of their scientific investigations, as Table 4.33 reveals.

Table 4.33

*Polly's instructional approaches to identifying the investigation purpose(s)*

| **Identifying the investigation purpose(s)** | RT1 | BSST1 | PeerTch | RT2 | BSSTs 2 & 3 | ST1 | ST2 |
|---|---|---|---|---|---|---|---|
| Developing authentic process skills | | | | | | | |
| Answering a question or problem-solving | | | | | | | |
| Scientific modeling | | | X | | | | |
| Teacher tells purpose | X | X | | X | X | X | X |
| Other | X | | | X | | | |
| **Mostly teacher-directed** | X | X | X | X | X | X | X |
| **Mostly student-directed** | | | | | | | |
| **Intermediate** | | | | | | | |
| **Not done or NA** | | | | | | | |

Polly was consistent in her instructional approach for this key feature across approximations of practice. Typically, Polly informed her students of at least one investigation purpose prior to releasing students to carry out the investigation. For example, in her RT1, Polly initiated the lesson by telling students "Today we'll explore different materials and see how much light they allow to pass through them." Even Polly's phrasing was remarkably consistent across her approximations of practice ("Today we/you are going to…"). Thus, approximation of practice authenticity had little to do with the instructional approaches Polly used to identify the investigation lesson purpose(s).

**Connecting investigation lessons and students' knowledge, ideas, and experiences.** Polly's approximations of practice revealed much more instructional variety with regard to the second key feature of investigation lessons, connecting the investigation lesson with students' knowledge, ideas, and experiences. For example, in her RT2, Polly engaged her students in a review of terminology, asked for examples of each type of material (opaque, translucent, and transparent), made explicit references to previous lessons by drawing and discussing a diagrammatic model of light passing through and reflecting off an object, and asked students to explain the concepts represented in the model. Table 4.34 presents the instructional methods Polly employed in each of her approximations of practice.

Table 4.34

*Polly's instructional approaches to connecting the investigation lesson*

| **Connecting investigation lesson and students' knowledge, ideas, and experiences** | RT1 | BSST1 | PeerTch | RT2 | BSSTs 2 & 3 | ST1 | ST2 |
|---|---|---|---|---|---|---|---|
| Connecting to previous lessons | X | X | X | X | | X | X |
| Connecting to real world examples | | | | X | X | | |
| Elicit student ideas | X | X | X | X | X | X | X |
| Relating to a scientific model | | | | X | | X | |
| Other | X | | | | X | X | X |
| **Mostly teacher-directed** | X | X | | X | | X | X |
| **Mostly student-directed** | | | | | | | |
| **Intermediate** | | | X | | X | | |
| **Not done or NA** | | | | | | | |

Polly made efforts to relate the science to her students' knowledge, ideas, and life experiences in all her approximations of practice. One method Polly used to do this was establishing coherence between lessons in a unit. For example, in her BSST1, Polly engaged her students in a question-and-answer review of the material she covered in the previous lesson, her RT1. This review served to activate students' knowledge of terminology ("opaque," "translucent," and "transparent") and also to remind them of what they had done in the previous investigation. Also, this set the stage for the rest of the lesson, in which Polly's cooperating teacher engaged students in a further investigation of opaque materials.

Polly's instructional approaches with regard to this key feature were typically teacher-directed, regardless of the authenticity or complexity of the approximation of practice. In her peer teaching, however, Polly permitted her students a greater role in determining the direction of this element of the lesson. This was likely a byproduct of engaging in peer role play, as Polly admitted to feeling awkward "teaching" her peers.

**Establishing data collection procedures.** Like her colleagues, Polly favored teacher-directed and curriculum materials-directed procedures for establishing what constituted data and how those data were to be recorded. Polly's RT and BSST lesson plans were taken directly from Science Companion, which contained prescribed, highly-structured protocols for investigations. By contrast, the lessons Polly taught during her student teaching semester came from her cooperating teacher's other science teaching resources. Despite the source of the lesson plans, Polly gave very scripted, step-wise directions for the proper execution of these investigations, as Table 4.35 reveals.

Table 4.35

*Polly's instructional approaches to establishing data collection procedures*

| **Establishing data collection procedures** | RT1 | BSST1 | PeerTch | RT2 | BSSTs 2 & 3 | ST1 | ST2 |
|---|---|---|---|---|---|---|---|
| Teacher modeling | X | | | X | X | X | X |
| Directions | X | | | X | X | X | X |
| Discovery | | | | | X | | |
| Directed discovery | X | | | | | X | X |
| Supported data recording | X | | | | X | | |
| Other | | | | X | | X | X |
| **Mostly teacher-directed** | X | | | X | | X | X |
| **Mostly student-directed** | | | | | | | |
| **Intermediate** | | | | | X | | |
| **Not Done or NA** | | X | X | | | | |

In general, Polly's students followed highly-prescribed investigation protocols, which were often accompanied by tables to support students in collecting and recording data. A notable exception to this trend was observed in the magnetism lesson (BSSTs 2 and 3) in which Polly's students were instructed to record their data using a preset data table, but were allowed to determine which items they would test (and therefore, what would constitute their data) in their classroom magnetic objects scavenger hunt. This was the only example of an approximation of practice in which students were encouraged to engage in this type of open exploration, perhaps because the science content and structure of the lesson plan allowed for this type of investigation.

**Fostering sense-making with data.** Unique to Polly's approximations of practice were the ways in which she combined a variety of instructional approaches and discussion formats to support her students in making sense of their investigation data. The presence of so many instructional approaches and discussion formats was consistent with Polly's belief in her learners' multiple learning styles, which is discussed in a later section. Table 4.36 displays the instructional approaches observed in Polly's approximations of practice with regard to this key feature.

Table 4.36

*Polly's instructional approaches to fostering sense-making with data*

| **Fostering sense-making with data** | RT1 | BSST1 | PeerTch | RT2 | BSSTs 2 & 3 | ST1 | ST2 |
|---|---|---|---|---|---|---|---|
| Pattern-seeking | | | X | | X | | |
| Relating findings to real world | | | | | X | X | X |
| Discourse-based | X | | X | X | X | X | X |
| Scientific model-based | | | X | X | | X | X |
| Telling | X | | | X | | X | X |
| Other | X | | X | X | X | X | X |
| **Mostly teacher-directed** | X | | | X | | | |
| **Mostly student-directed** | | | | | | | |
| **Intermediate** | | | X | | X | X | X |
| **Not done or NA** | | X | | | | | |

As she progressed through her approximations of practice, Polly became more familiar with her students' particular needs in carrying out and making sense of investigations. In her later approximations of practice, Polly spent more time during the investigation engaging with small groups and individual students directly to support their sense-making efforts. For example, in her ST2 lesson, Polly fostered sense-making while interactively circulating among her students as they created scale-model representations of the solar system. Polly tailored her questions to students on the basis of their investigation progress; in some cases she asked questions that prompted them to think about what their data signified in terms of relative distances between planets and the Sun. In other cases, Polly scaffolded student thinking about how to use the instructions, materials, and their math skills to determine the next planet's location on their solar system models. In this manner, Polly differentiated her sense-making supports responsively to indicators of her students' understandings. Interestingly, this element of

Polly's science teaching became more prominent after her RT2 lesson, in which students were unable to discern any visual differences between a pencil in a jar of oil and a pencil in a jar of water (illustrating refraction). This was a particularly eye-opening experience for Polly, and is explored more in the data relating to her ideas about and confidence for teaching investigation lessons.

**Supporting claims with evidence.** Due to time and other constraints, Polly's approximations of practice often did not include helping students develop evidence-supported claims or conclusions. Table 4.37 displays the data from her lesson and lesson portion enactments with respect to this key feature of investigation lessons.

Table 4.37

*Polly's instructional approaches to supporting claims with evidence*

| **Supporting claims with evidence** | RT1 | BSST1 | PeerTch | RT2 | BSSTs 2 & 3 | ST1 | ST2 |
|---|---|---|---|---|---|---|---|
| Discursive | | | X | | | | |
| Scientific model-based | | | X | | | | |
| Using written supports | | | | | | | |
| Other | X | | | | | | |
| **Mostly teacher-directed** | X | | | | | | |
| **Mostly student-directed** | | | | | | | |
| **Intermediate** | | | X | | | | |
| **Not done or NA** | | X | | X | X | X | X |

Particularly in her later approximations of practice, Polly omitted this key feature of investigation lessons due to a "hard stop" (e.g., a "special" or instruction in a different subject). Basically, Polly ran out of time for the lesson conclusion, which she acknowledged in our post-approximation of practice interviews. In most cases, this resulted in an unresolved lesson in which students did not formalize their sense-making as evidence-based claims. This trend emerged among her full-length, field-based lessons, and appeared to be a consequence of Polly's time (mis)management, unanticipated interruptions, and other constraints of real elementary classrooms--aspects of more highly-authentic and complex approximations of practice.

**Summary of Polly's instructional approaches in her approximations of practice**

In general, Polly tended to exhibit more traditional, teacher-directed instructional approaches to achieving the key features of investigation lessons in her approximations of practice. This did not indicate a strictly didactic orientation toward science teaching, however, as Polly demonstrated instructional elements consistent with multiple science teaching orientations. She frequently told students the purpose(s) of their investigations, and tended to give very structured, scripted directions for carrying out investigations. However, in connecting the investigation lesson with students' knowledge, ideas, and experiences, and fostering sense-making with data, Polly exhibited more flexibility, relying much more upon student contributions in determining her instructional approaches. Finally, Polly's later and more-authentic approximations of practice demonstrated a typical casualty of elementary science teaching: running out of time for a substantive lesson conclusion. Changes in Polly's approximations of practice were most notable with regard to the ways in which she supported students in making sense of data; however, trends may be explained by increasing familiarity with her students and identifying preferred instructional approaches.

**Polly's changing ideas about and confidence for teaching elementary science**

I now shift to a consideration of Polly's data relevant to my second research question. First, I explore Polly's ideas about science teaching as they relate to her approximations of practice. I then describe Polly's changing ideas about investigation lessons from a more general perspective. First-hand accounts from interviews and methods course assignments were primary data sources for these portions of the study.

**Polly's ideas about teaching approximation of practice investigation lessons.** Polly's ideas about investigation lessons reflected the details of her approximations of practice experiences. Of the four case study teachers, Polly experienced the most variability in her investigation lesson enactments: some worked well while successful execution of other investigation lessons proved more challenging. In all cases, however, Polly maintained a positive outlook and viewed these experiences as valuable learning opportunities, as Table 4.38 summarizes.

Table 4.38

*Polly's lessons learned from her approximations of science teaching practice*

| Lessons learned |
| --- |
| RT1 |
| • Groups of students will work at different paces; always need to have more planned<br>• Circulating among students is valuable (versus observing from a seated position)<br>• Students can be really enthusiastic about science |
| BSST1 |
| • Having taught the previous lesson allowed me to assess my students' learning and how well I taught the lesson<br>• A simple introductory lesson can be very important for future lessons.<br>• Students might know more than I think [they do], and might not. Be prepared for both situations |
| PeerTch |
| • Sometimes lessons are not going to be very engaging or fun, but still need to be effective<br>• Creating a chart helped to organize student thoughts/ideas<br>• When students get off topic, have a way to bring them back into the discussion<br>• Really know the science content, and be prepared to have a way to tie students' ideas together |
| RT2 |
| • Refraction (the content) is hard…I could tell that they weren't getting it…and I learned that that investigation really wasn't the greatest either… I know what not to do next time<br>• I am glad I got to be a part of a science lesson gone wrong... I think of ways in which I could have done things differently. This was a great opportunity for me, especially to reflect upon |
| BSSTs 2 and 3 |
| • BSST2: A scavenger hunt is a great idea for a science investigation. It was fun and students were engaged and curious about magnets.<br>• BSST3: The way in which I ask or phrase my question can be really beneficial for a discussion. Also, discussions are important for a science lesson: they give me opportunities to informally assess student knowledge, review what should have been learned, and clear up any misunderstandings that might cause a student to be confused |

In Table 4.38, Polly identified a variety of lessons she learned from her science teaching experiences. Similar to the other teachers in this study, Polly typically abstracted these experienced-derived ideas to the much broader context of elementary science teaching (in general). Unlike other case study teachers, Polly experienced investigation lesson failures. For example, Polly's RT2 investigation did not yield desired, convincing data in the form of observations of a pencil appearing to "bend" due to refraction. In an effort to compensate for this unforeseen glitch, Polly told her students what they should have observed and why this was the case, only to realize that her own subject matter knowledge on the topic of refraction was inadequate to offer a satisfactory explanation. Polly acknowledged these shortcomings in our post-enactment interview, and expressed genuine intentions to use this experience to enhance future lesson preparation measures.

**Polly's ideas about teaching investigation lessons more generally.** Polly's ideas about investigation lessons became more informed by her own experiences and teaching preferences during her final year of teacher preparation. At the beginning of Fall 2009, Polly emphasized the "fun and engagement" factors of investigation lessons consistent with activity-driven science teaching, coupled with a belief in with student-directed discovery learning. She asserted that actually doing and seeing investigations firsthand is helpful for developing knowledge, and described the teacher's role in investigation lessons as cognitive support-giver rather than "provider of answers."

> Polly: I think the number one thing is fun and engaging if you look at it from a broader sense, but hands-on definitely…
>
> MN: What do you see as being the teacher's role in the investigation?
>
> Polly: …letting the students investigate themselves. Not just telling them right or wrong …letting the students discover for themselves and find out the right…you want to also understand what they're thinking and investigating, and I think that can be done through just questioning and inquiry and really observing like if the students are working, well "why do you think that is?" or "Can you tell me more

> about that?" and from that you can also assess what the students are doing and if, what they're getting and how you can adjust your teaching. (Polly, Initial F09 interview)

By the end of Fall 2009, Polly had broadened her idea of what constitutes an investigation (e.g., she included scavenger hunts) and emphasized the teacher's role as catering to individual students and their needs during the investigation.

> …[the teacher's role is] seeing what they [the students] know and what they don't know, that can help guide the rest of your lessons, …I almost feel like investigations come before teaching a lot of the material…the teacher goes around and evaluates and assesses students, that can really shape how the discussion goes... I also think the investigations can just be an opportunity for the teacher to not necessarily have to teach in front of the whole class but to go around and do little teaching lessons to each group and going around and doing that kind of stuff. (Polly, End F09 interview)

This emphasis on differentiated science instruction was evident in Polly's approximations of practice, particularly those at the end of Fall 2009 and Winter 2010.

At the end of Winter 2010, Polly reiterated her belief that investigations should be largely student-directed learning facilitated by the teacher. Polly also discussed what she viewed as prerequisite measures to insuring successful, student-directed investigation lessons:

> … letting students explore, and as a teacher …talking to them, more as like when you're walking around, as you're circulating, talking to different groups and things like that …letting them kind of be the scientists and discovering for

> themselves…that would take a lot of, at the beginning, you know, how we're going to do this, how you're supposed to act, what you're supposed to be looking for, but that to me would be just kind of open-ended for the kids, when they're doing these investigations. (Polly, End W10 interview)

In this excerpt, Polly revealed that providing student-specific supports during the investigation, and allowing students to direct the course of their investigative learning, remained strong elements of her science teaching orientations.

Building on these descriptions of classroom science investigations, Polly described her idea of a typical investigation lesson.

> Once maybe you've done a little bit of talking to the kids about what you're going to learn about, maybe introducing a few key concepts, and then letting them go and...work together and kind of just talking amongst each other and maybe they have questions to follow or something or exact outlines of how to do different investigations or what they're supposed to figure out...once they've done that, bringing them back together and having that discussion about well, what did you find? What did you find interesting? What's something you learned, you know, well why is that? And really questioning them. (Polly, End W10 interview)

Polly viewed proper planning as central to teaching science investigation lessons. When planning investigation lessons, Polly attended to materials and management concerns, as well as her students' needs and her instructional responses to facilitate their understanding. Polly also identified time management considerations, learning outcomes, and student engagement as factors in her planning.

> [I attend to] what materials I need to have, preparation ahead of time, how is this going to work management-wise, what am I going to do to best suit the needs of my students, you know, what do I need to do ahead of time that's going to help them get to the end of the stage of understanding …are the students going to get anything from this investigation, is it more that I should demonstrate one, or is it too time-consuming that we're going to have to break it up and then it's going to be a lost cause because they're not going to remember, more logistical stuff... (Polly, End W10 interview)

Polly went on to state that while teaching an investigation lesson, she attended to social interactions and student involvement, and whether the activity was resulting in productive learning for the students. Polly framed these considerations as "questions to self."

> Are they doing what I wanted? Are the results kind of happening in the way I wanted them to, happening in a way that they get something from it? Are they working together…to try to solve the problem? Are there some students who are doing all the work? How can I pull in those other kids? Are they questioning each other? Are they talking about the investigation or are they totally off-topic? Different things like that. (Polly, End W10 interview)

Successful investigation lessons, in Polly's view, involved student enjoyment, which necessitated appealing to a variety of learning styles; reaching desired learning goals; and applying knowledge gained from the investigation to other situations. Polly mentioned student recall as a determinant in whether an investigation was successful.

> It [an investigation lesson] would be successful in the sense that it was enjoyed, but whether or not it be that day, or assessment would be a big way, if they were

> supposed to get something from it, or what we did in that investigation, did they take it and use it somewhere else?…maybe not necessarily that they can recall right then and there, but maybe later on on a test or in an assignment or a field trip, things like that. (Polly, End W10 interview)

Here, Polly also alluded to the importance of students making connections between science they learn in school and their experiences outside of the classroom.

**Summary of Polly's ideas about science teaching and investigation lessons**

Polly's ideas about science teaching, in general, emphasized hands-on learning. In her approximations of practice, she listed a number of take-home lessons that, although generic, derived from the particulars of her experiences teaching science lessons and lesson portions. As she progressed through her approximations of practice, Polly increasingly provided differentiated supports for students' sense-making, particularly while the investigation was underway. Such instructional approaches were consistent with guided inquiry orientations toward science teaching promoted in the methods course. While her broader ideas about science teaching and hands-on science learning did not change appreciably over the year, Polly offered more detailed examples and explanations to support her thinking about investigations in elementary science.

**Polly's confidence for teaching elementary science**

Confidence in herself as a science teacher was another important and variable aspect of Polly's approximations of practice. Responses to interview questions revealed a great deal about how Polly's confidence in her science teaching abilities evolved over the year. Approximation of practice reflections, coupled with general statements about her confidence as a science teacher, provide a textured picture of Polly's changing self-confidence over the course of this study.

**Polly's confidence for teaching approximation of practice investigation lessons.** Despite having had some less-than-successful science teaching experiences, Polly maintained a positive outlook on herself as a science teacher, and her confidence in her science teaching increased as the approximations of practice progressed. Table 4.39 displays snippets of Polly's reflections about her feelings during and after lesson enactment, collected from interviews (I) and written assignments (W) and paraphrased for clarity, when necessary. A more complete set of Polly's responses may be found in Appendix P.

Table 4.39

*Polly's feelings during and after her methods semester approximations of practice*

| During enactment<br>("How did you feel while teaching?") | After enactment<br>("Did this experience impact how you feel about teaching science?") |
|---|---|
| RT1 | |
| I wasn't nervous at all … I literally was studying [the content]…but I knew all the answers when they were asking things, and I really surprised myself.… (I)<br>I look forward to future lessons and feel I am on my way to becoming a confident and experienced teacher of science. (W) | I'm excited to do the next few, and I really like that I used the lessons. (I)<br>I was worried I would not be confident or able to answer student questions…I found myself both confident and able to answer questions…I also enjoyed the lesson and had fun teaching it. (W) |
| BSST1 | |
| Fine…I really enjoyed doing it … I was comfortable going up there so I could just focus on…making sure my wording was right … so that… students got it, understood it. (I) | It just reassured [me] that I know I can do it... they were getting the material, and that's kind of reassuring for me to know OK I did it last and something must have worked. (I) |
| PeerTch | |
| I wasn't nervous, then when I started doing it I kind of was because … I felt like I really had to push the students to talk … (I) | It really was important to pay close attention to details and really make sure to think about all the possible students' ideas and what could come up... (I) |
| RT2 | |
| The beginning was great and then I felt overwhelmed because it wasn't working like it should have… I was frustrated … the investigation part kind of failed…but I thought the beginning and obviously doing the review again really helped (I) | No…I was more nervous this time, but I'm still excited to teach more science lessons …they are so engaged and although they didn't get it, they still were sticking with me and trying to understand what I was saying, that made me feel important... (I)<br>Even though my immediate reaction…was discouraging…I learned a great deal… (W) |
| BSSTs 2 and 3 | |
| Good! I thought it was fun, I mean it was definitely a cool science lesson… it's so interesting how different the classroom setting is when there's only 16 [students], and I had fun with it... (I) | … the students in this class are very engaged and it makes the whole science learning process more enjoyable… even if I'm not confident in myself, they really look up to me…they'll let me know if they don't get it…it helps me know I didn't clarify that enough.(I)<br>It did not go as well as I would have liked but it gave me an opportunity and something I can work on next time. (W) |

As Table 4.39 shows, Polly's early approximations of practice were characterized by an unanticipated sense of comfort and confidence that appeared to grow with each teaching experience. Then, in her RT2, Polly encountered some instructional hurdles (previously discussed) that appeared to momentarily shake her self-confidence somewhat. Polly maintained a positive outlook on science teaching, however, and stated that she was excited to continue to gain experience and confidence in her teaching. In her BSSTs 2 and 3 lesson, Polly hinted that her confidence was largely dependent on her students: their willingness to view her as an authority in the classroom, their ability to pick up on and reflect Polly's enthusiasm for science, and their honest efforts to learn and understand the material.

**Polly's confidence for teaching investigation lessons more generally.** Over the year-long study, Polly's confidence in her science teaching abilities increased. Prior to her approximations of practice, Polly expressed uncertainty about her knowledge of science and her ability to effectively teach elementary science, due in part to a dislike of science.

> I have not had lots of science background, because I never liked it, but what I did learn I still remember a lot of it, I just need to review and recall a lot of it. (Polly, pretest)

Despite a lack of confidence, Polly felt that if she could convey enthusiasm about teaching science, her students would embrace science learning. Polly related this idea to her cooperating teacher's (Mrs. C's) enthusiasm for science lessons, and having observed her third graders' response to Mrs. C's spirited instructional style.

> I've learned from Mrs. C that no matter the topic, you have to be excited about it,

> and that's something that I'm really trying…even if I don't always know exactly what I'm talking about, if I'm excited about it and I'm interested then they will feel that and be the same way…Mrs. C, you know, she just gets so excited and I think that's something I really hope to grow in and…so I've learned that even if I'm not confident in the subject, I'm confident in my teaching and I can present it in a way that I can make it exciting, but as for the content, no, I'm not as confident… (Polly, Initial F09 interview)

Polly also indicated a need to feel confident in her content knowledge, which required advanced preparation for her lessons.

> I definitely would have to…know that what I'm teaching the students is the right thing, really make sure I read the lessons ahead of time. With time I'm sure that I will become confident … I feel that with Mrs. C it was a perfect match because I'm not confident in science and she takes her lessons beyond what the textbook, what the directions say…I hope that, especially by the end of the semester with all the science lessons that I could quickly read over what it says and feel confident to wing it in a sense and go up there and find out what are their ideas and then go from there. (Polly, Initial F09 interview)

For Polly, confidence (real or faked) was an instrumental element of science teaching. Table 4.40 shows Polly's responses to STEBI-B type survey items about teaching investigation lessons.

Table 4.40

*Polly's evolving confidence for teaching investigation lessons*

| | Beginning Fall 2009 | End Fall 2009 | End Winter 2010 |
|---|---|---|---|
| I will not be very effective in teaching science investigations. | Disagree | Disagree | Disagree |
| I will find it difficult to explain to students why science investigations work. | Unsure | Disagree | Disagree |
| I will be able to evaluate and adapt existing science investigations for use in my classroom. | Agree | Unsure | Unsure |
| I will find it difficult to support students' sense-making using data they have gathered in science investigations. | Disagree | Disagree | Disagree |
| I will find it difficult to effectively introduce, monitor, and conclude a lesson that involves an investigation. | Disagree | Disagree | Disagree |

Similar to other case study teachers, Polly's confidence for different elements of teaching investigation lessons, as indicated by the STEBI-B type instrument, either remained constant or increased slightly. At the end of the methods course semester, she expressed some hesitation regarding her ability to evaluate and adapt curriculum materials for her own use. I asked her to elaborate on this answer, and she stated:

> … that's something that I'm kind of still working on, in terms of the adapting portion, I've kind of just taken what I've been given and used… but I need to be able to have that option of changing lessons and adapting them and I really haven't done any type of really, aside from looking at a few students' work, I really haven't done any type of real evaluation in terms of their science investigation.... (Polly, End F09 interview)

Although evaluating and modifying science curriculum materials was an overarching focus of the methods course and prospective teachers were asked to do exactly this in three lesson plan analysis assignments, they often did not have the same freedom to modify their approximation of practice lessons plans. In the above quote, Polly revealed that most of her teaching experiences followed closely the lesson plans she was given, and that her uncertainty with regard to this survey item was due, largely, to a lack of experience evaluating and adapting science lessons that she then proceeded to teach.

After the methods course semester, I asked Polly to comment more generally on how she felt about teaching an investigation lesson. She said she felt:

> …fine. I think that, depending on the content, you know, I would need to do my own research to understand, which I think every teacher does, and after year and year of doing you don't have to because you know it, but I think that I'm excited to teach some more and change some different things and kind of work on my own personal goals of what I can do differently and things like that, so yeah, I'd say that I look forward to teaching some and I really appreciate the feedback from the people that do watch and help me to grow as a teacher and do different things and so… (Polly, End F09 interview)

Again, Polly expressed her enthusiasm to continue teach science and to grow and learn from those teaching experiences. By the end of her student teaching semester, when asked about her comfort level for teaching in investigation lesson, Polly said:

> … I think, you know, if I was given proper curriculum or if I did my own research and figured out what I wanted to do and knew what I wanted to do and planned it, then hopefully it would go successfully and if not, then, you know, you learn next time. (Polly, End W10 interview)

Polly reiterated her expectation that her science teaching would not always go as planned, but that she would recognize those less-than-successful lessons as opportunities for continued growth as a teacher.

**Summary of Polly's changing confidence about science teaching**

As a whole, the data suggest that many of the confidence-related changes Polly experienced were rooted in her approximations of practice. Polly had lessons that went well and reinforced her self-confidence as a science teacher, and lessons that turned out differently than anticipated, which prompted her to re-evaluate elements of her developing science teaching practice. While she professed the belief that maintaining enthusiasm and excitement when teaching science was an important factor in student engagement and science learning, her own enthusiasm and excitement were not always genuine. Overall, though, Polly's confidence for science teaching grew, and this growth was characterized by some confidence-challenging incidents in specific approximations of practice. Despite these challenges, Polly maintained a positive attitude and embraced her own capacity for continued growth in teaching science.

**Polly's description of her changing ideas about teaching elementary science**

In our final interview, Polly talked about how and why her ideas about science teaching changed. She credited the variety of instructional experiences explored in the methods course as one factor that helped her improve her attitude about science teaching.

> I kind of never liked science because in high school and some of the college, I wasn't engaged… there was a lot of talking to me, and I think I would have benefited from hands-on … and now having had the opportunity in our methods class and doing a variety of different things, and the class was approached in so

> many different ways for learners, and the variety of kind of assignments we had to do and different things like that helped me see OK there is some positive in science, I can do this, I can be a good science teacher. … I know what I have to do as a teacher to improve my teaching of science but I'm glad I know that now, because if I had not had this class and tried to start teaching it might have been different, I might not have been so excited… (Polly, End W10 interview)

Here, Polly hinted that a big step in adopting a positive attitude toward elementary science teaching was overcoming her own negative feelings as a science learner. She cited the influence of science learning experiences in the methods course, and indicated an awareness of progress toward her vision of a good science teacher.

In our final interview, Polly acknowledged that she valued her individualized supports for students thinking during investigations, and elaborated on why this was of particular importance to her.

> I think right now as a beginning teacher I might not necessarily make all the instructions right away as clear as I would like them to be and I kind of have picked up on where are some kids confused, how can I benefit them…I think that's important for me too because I am constantly assessing these kids to make sure what I'm teaching them or what they're doing, are they understanding it, can we continue, can we go on from here, so being able to do that, and yeah, I definitely agree with pulling in some of those kids that might not necessarily understand or like you said, tailoring it so that they understand… really questioning them—well why do you think that is? And trying to pull and make sure I get everyone included. (Polly, End W10 interview)

Polly revealed that her approximations of practice allowed her to become better-acquainted with her learners' needs by assessing them on an individual basis. Additionally, Polly's approximations of practice enabled her to develop a solution to a problem of practice: How to teach investigation lessons in a way that minimizes confusion and involves students in doing the work. By developing an approach that focused on tailoring supports during investigations, Polly reinforced for herself the importance of this aspect of science instruction. She also began to develop an instructional style that was both effective and comfortable for her.

**Polly's description of her changing confidence for teaching elementary science**

Along the same lines, I asked Polly to describe her sense of how and why her confidence as a science teacher had changed over the year. In our first interview, Polly identified an awareness of her need to develop confidence for teaching science:

> I now know from her [Polly's cooperating teacher] and already what I need to do for myself for science, I need to forget what I don't know and that's happened and I need to take everything that comes and learn it and if I don't remember magnets or decomposition, go back and understand it and from there…I would say that I would definitely think that I'm more confident in science teaching but of teaching of science, I'm not, I'm still, I know how to approach it now and I think that will help. (Polly, Initial F09 interview)

After conducting her approximations of practice, Polly acknowledged that her confidence in herself as a science teacher had increased. She attributed changes in her confidence to the supported experiences she had teaching science in her field placement classroom.

Polly recognized the value in having taught a lesson that did not go well. When I asked her why her confidence increased, she said:

> Because of the experiences I've had this semester. And being able to teach science with … you [referring to MN] there and having my CT there… I did have a really well [sic] lesson and had a not-so-great lesson and I got to see…both were great teaching opportunities for me …I was introduced to so many things that I knew about but just didn't even think about in science… I think just too, having the experience, being able to do the lessons…I had never taught science before, and I think, so I think it's different to teach science and learn science...I definitely had to research my content in what I was teaching …and going into my semester I think I was thinking like "oh no, I hated learning science, I'm not going to want to teach science"…well not that I hated learning science, I wasn't good at it, I couldn't obtain things that I should have, and now that I know ways to teach it, it's been more interesting and fun. So that's why my confidence has changed. (Polly, End F09 interview)

In the above quote, Polly reflected on how she felt about teaching science at the beginning of the semester and talked about overcoming her own negative science learning experiences during the methods course semester. Providing a positive science learning experience for her students—one that differed from her own experiences as a science learner—seemed important to Polly's vision of herself as a science teacher.

At the end of her student teaching semester, I asked Polly to comment on how she perceived her confidence had changed over the academic year. She replied:

> At first I was probably a little shaky, but I think my confidence has grown, definitely. I think that I'm aware of what I need to do to prepare myself to teach these lessons, and I think that's something that is really important. I don't know necessarily if I would say…I think for now, as a first time teaching science, I did an adequate job, I think like everything else there's room for improvement… (Polly, End W10 interview)

Polly ended her final year of teacher preparation much as she began: with an eye toward continuing to improve her science teaching practice.

**Summary and end of year model for Polly**

A study of Polly's science teaching over the last year of her teacher preparation revealed several significant changes. Polly entered the elementary science methods course feeling unsteady in her background knowledge of science and her ability to effectively teach science to elementary students. As she engaged in her approximations of practice, Polly made efforts to appear enthusiastic about science teaching and learning, which, in turn, fueled her own growing enthusiasm for teaching science. While many of Polly's instructional approaches with respect to the key features of investigation lessons were characterized by a high degree of teacher-directedness (e.g., identifying the investigation purpose(s)), other instructional approaches revealed Polly's efforts to make science relevant to her students' lives and her dedication to providing highly-tailored supports to engage and encourage her students in carrying out investigations and understanding the work they were doing.

Over the course of the year, Polly maintained orientations toward science teaching that featured hands-on learning, and underscored the importance of investigations to positive student learning experiences. The most striking area of growth regarding Polly's ideas about teaching science in general and investigations in particular involved the role of the teacher during investigations. Polly developed a more-detailed picture of how an elementary teacher could facilitate her students' learning in science, and her ideas were informed by, and also informed, her approximations of practice. Polly acknowledged the centrality of her focus on differentiating instructional supports during investigation lessons, and hinted that her own background as a science learner was influential in this thinking.

Finally, Polly grew in her confidence as a science teacher. Given that not every approximation of practice went smoothly, it was especially remarkable that Polly only allowed her confidence to be shaken by enactment challenges for a short time before adopting the attitude that such experiences afforded her invaluable learning opportunities. Polly's newfound confidence for science teaching appeared to be a work in progress, and at the end of the study, Polly expressed an expectation of continued growth in this area.

Polly resembled closely the model of the typical prospective elementary teacher depicted in Figure 2.1. Few, if any, differences were noted between this generic model and Polly's data at the beginning of the study. Figure 4.4 illustrates a model specific to Polly at the end of the study.

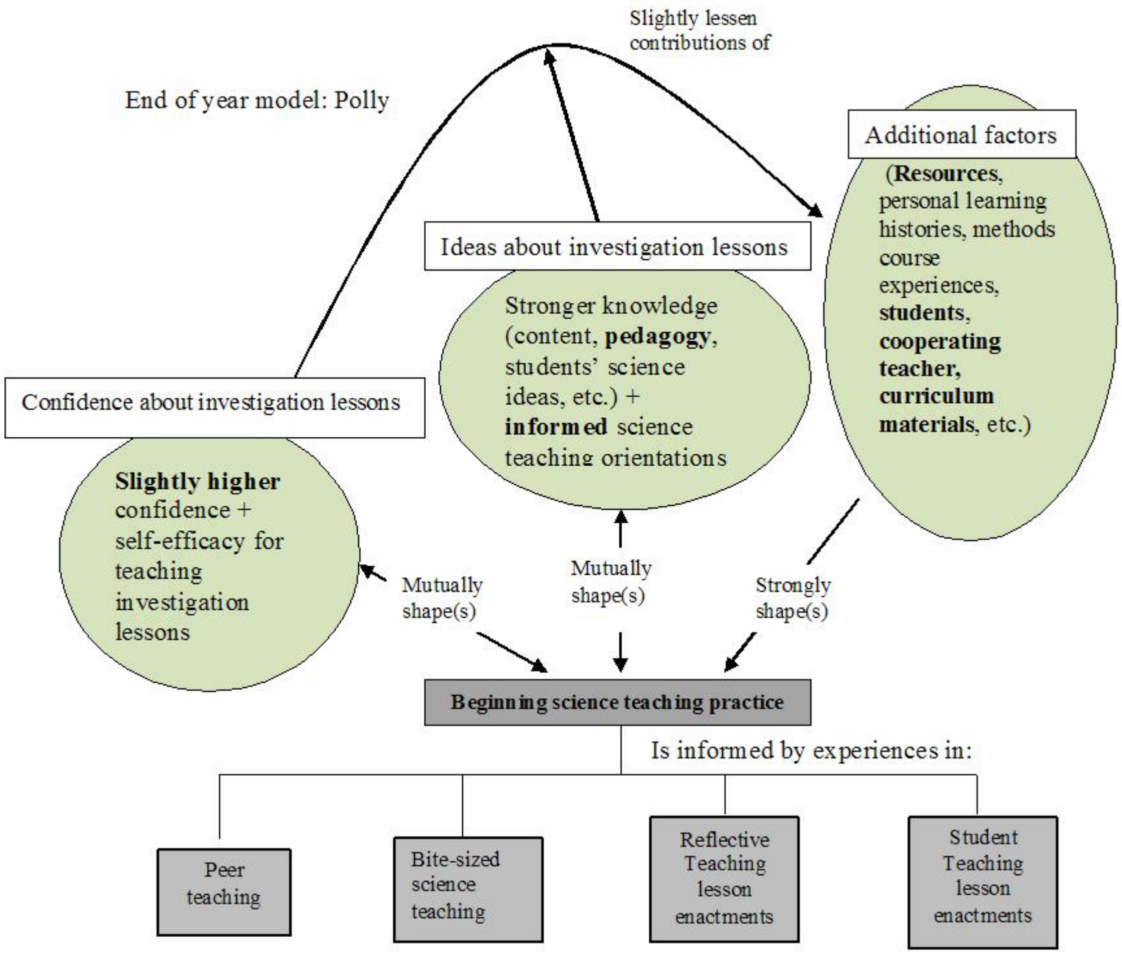



*Figure 4.4.* Polly's end of year model

Polly's end of year model demonstrated several minor differences from the generic end of year model presented in Chapter 2. Unlike the generic model, Polly's confidence increased only slightly, and her ideas about investigation lessons seemed to be more impacted by experience-derived changes in knowledge of pedagogy rather than other types of knowledge. Finally, additional factors in the form of guidance from the cooperating teacher and curriculum materials' recommendations appeared to shape Polly's science teaching practice more strongly than anticipated by the generic end of year model.

## Cross-case study comparisons

Having presented case studies and models for Bridget, Hannah, Natalie, and Polly, I now explore some of the similarities and differences among case study teachers' approximations of practice. Specifically, I address research question 3: How do prospective elementary teachers' instructional approaches, ideas, and confidence levels compare across their approximations of practice? In addressing this research question, I identify and highlight relevant case study teachers' approximation of practice data.

### Cross-model comparisons

To begin, I offer a brief comparison of the end of year models for each case study teacher. This cross-model comparison frames the ensuing data comparisons that constitute the remainder of this chapter.

Examination of the models in Figures 4.1, 4.2, 4.3, and 4.4 reveals construct-level similarities and differences among case study teachers' end of year models. In all cases, prospective teachers' final confidence levels were higher than their initial confidence levels, a finding predicted by the generic model in Figure 2.2. Additionally, case study teachers' models reflected stronger, experience-derived ideas about investigation lessons and science teaching, also an anticipated finding. On the surface, this appears to indicate similar outcomes among case study teachers; however, closer analyses of the findings reveal nuanced differences between case study teachers. These specific differences are elaborated upon in the sections that follow.

One difference among individual case study teachers' end of year models and the generic end of year model concerns the role of additional factors in shaping science teaching practice. Models describing Bridget, Natalie, and Polly all revealed the continuing influence of cooperating teachers and curriculum materials as factors shaping their instruction later in the study. While the same was not true for Hannah, she least resembled the typical prospective elementary teacher described in Chapter 2. This comparison illuminates two important cross-case findings: that the generic models do not fit any case study teacher in all respects, and that approximations of practice in this study—while important factors in prospective teachers' developing science teaching practice--were not sufficient to ameliorate beginning teachers' needs for curricular and mentor supports by the end of the study. These ideas are revisited in Chapter 6.

While the end of year models presented here and in Chapter 2 portray the interrelated nature of prospective teachers' science teaching practice, ideas, and confidence, they do not adequately describe the data underlying case study teachers' instructional approaches, ideas, and confidence in teaching science lessons involving investigations. A closer examination of data concerning these particulars and rationales is the focus of the remainder of this chapter. For analytical purposes, I have introduced an arbitrary division among these constructs solely to organize the analyses that follow.

**Instructional approaches**

In this section, I explore similarities and differences among prospective teachers' approximation of practice instructional approaches. Three themes are discussed and supported by pertinent data. First, I focus on fidelity to lesson plans in case study teachers' approximations of practice instructional approaches. Second, I identify similarities and differences among case study teachers' areas of instructional focus in their approximations of practice. Finally, I consider self-reported influences on case study teachers' instructional approaches in their approximations of practice, and the similarities and differences among their perspectives.

**Fidelity to lesson plans.** Research shows that beginning teachers often follow curriculum materials with high degrees of fidelity (e.g., Grossman & Thompson, 2008). In this study, all prospective teachers' cooperating teachers used Science Companion as the main elementary science curriculum. Units and lessons in Science Companion are aligned with state science education standards and generally promote inquiry-oriented science teaching and learning. High fidelity to Science Companion, or any science curriculum, however, is not promoted as part of the methods course. Rather, methods course instructors emphasized critical analysis and modification of science curriculum materials, thereby promoting the development of principle-driven professional judgment among prospective elementary science teachers, with the intention of further improving these already inquiry-oriented, fairly coherent, curriculum materials (Beyer, 2009; Davis, 2006b; Davis & Smithey, 2009).

Prospective teachers in this study fell into two categories with respect to their reported fidelity to approximations of practice lesson plans. Bridget, Natalie, and Polly comprised the "higher fidelity" category; they followed curriculum materials and lesson plans very closely in their enacted lessons. Hannah, meanwhile, was the sole representative of a "lower fidelity" group; she used curriculum materials and lesson plans to inform her sense of what lessons should entail, but often deviated in form and in substance from what was specified in those lesson plans.

Recall that when the methods course began, Bridget, Natalie, and Polly lacked any science teaching experience. Each case study teacher was given lesson plans for her approximations of practice, and across approximations of practice, these three case study teachers taught in ways indicated by lesson plan instructions and recommendations. By contrast, Hannah began the methods course having taught stand-alone science lessons in a local museum. Hannah also used Science Companion lessons for her field-based approximations of practice, but tended not to enact these lesson plans as written.

To assess case study teachers' perceptions of whether and how they modified lesson plans in their approximations of practice, I asked them to comment on this topic in our post-enactment interviews. Table 4.41 contains responses from each case study teacher, from each type of approximation of practice. Recall that lessons taught during the student teaching semester did not have post-enactment interviews because case study teachers moved directly into teaching the next subject area.

Table 4.41

*Case study teachers' answers: Did you make any changes to the lesson plan?*

| | Peer teaching | BSST | RT2 |
|---|---|---|---|
| Bridget | "Not really…I don't think I changed too much." | "I didn't really make any changes…" (BSST3) | "I put their names on it [the materials] ahead of time and passed it out, just to save a couple seconds…" |
| Hannah | "A lot. I think we took the main ideas …and we kind of just tried to make that as interesting as we could." | Did not have formal lesson plans for any of her BSSTs | "Yes... the original lesson plan was just very long and overly scripted…I don't know if I really changed that much from it, I just didn't use everything from it." |
| Natalie | "I just made a worksheet because… it was a little more straightforward." | "Honestly, I didn't really use the lesson plan, she [my CT] just said to make sure I ask the kids about why did they think they did this today, basically, so that's what I did." (BSST3) | "I don't think I changed very much of it, if anything I added more questions to the reflection…" |
| Polly | "…no I didn't make any changes." | "I really didn't change anything because the lessons that they provide are very thorough." (BSST1) | "No, I didn't make any changes to the lesson plan itself aside from a few little logistical things." |

Bridget, Natalie, and Polly often did not make significant changes to the lesson plans provided to them. As several of their quotes suggest, these case study teachers sometimes made minor changes to the lesson plans in their approximations of practice. Minor changes include the addition of a worksheet for recording data, or changing how investigation materials were distributed, as Natalie's peer teaching and Bridget's RT2 quotes indicate. Such changes did not alter the substance of the lesson, but did alter the enactment logistics such that the form and intent of the lesson were maintained.

Hannah, on the other hand, took more liberties with lesson enactments in her approximations of practice. Even in her peer teaching, where she was given a lesson plan, Hannah made changes that resulted in a different experience for learners than that intended by the curriculum designers. For example, Hannah's peer teaching lesson focused on eliciting students' initial ideas about condensation and supporting them in creating models of those initial ideas. In her approximation of practice, Hannah asked students to create a single artwork project-cum-consensus model of condensation that could be used to explain the range of alternative ideas assigned to students by the teacher educator. Hannah's original lesson plan outlined how the teacher would prompt students to each draw their own initial models of condensation (again, on the basis of the specific alternative idea assigned by the teacher educator), which they would revise in subsequent lessons and ultimately use to create an evidence-based group consensus model. Thus, Hannah's changes to the lesson plan resulted in unforeseen emphases on 1) using art supplies to create three-dimensional scientific models, and 2) social bargaining, or compromise, in the creation of a common representation of initial, disparate ideas about condensation. These were neither indicated nor intended goals of the lesson plan, and represented major deviations from the original lesson plan.

At the end of their student teaching semester, I asked each case study teacher to comment on the relationship between the field classroom curriculum materials and her own science instruction across the year of the study. Bridget said:

> I feel like my science instruction was very heavily based on Science Companion. I tweaked it, but never really actually changed it. In the beginning, because I wasn't comfortable enough taking ownership in the classroom, I didn't make that decision, they weren't my students, they were her students and I was just helping, so, but then towards the end because I had *so* much other stuff going on I was creating my own reading lessons from no curriculum, I was creating my own writing lessons from no curriculum, so where I had the curriculum I pretty much just stuck to it because it was a piece I didn't have to create. (Bridget, End W10 interview)

Bridget's response reveals that her initial apprehension and lack of teacher identity factored into her decision to stick closely to lesson plans. She indicated that her fidelity to science lessons plans as a student teacher was motivated by different factors entirely.

In speaking about the relationship between classroom science curriculum materials and her instructional approaches, Natalie stated:

> Science Companion is … really, really structured, it tells you *exactly* what to say for the discussion, *exactly* what to do for the whole investigation, and it just keeps going on. …what I would do when I first started, like during the methods class, when I was teaching those science lessons, I did like word for word, basically exactly what Science Companion said to do, everything step by step. But as I moved through my student teaching I would be like "Ok I'll look at Science Companion, OK this is the objective, this is what they want me to get through," and then I kinda just went with it. I thought about what would be important to bring up with my students and I had those conversations with other second grade

> teachers, it was a lot easier to cater to my class' needs and Science Companion was more like a…starting point for the lessons, but not so much an exact plan. (Natalie, End W10 interview)

Natalie's relationship with the curriculum materials was very similar to Bridget's initially, but as she gained experience, confidence, and spoke with other teachers about lessons, Natalie became more comfortable with introducing conservative lesson plan deviations. Observations of Natalie's student teaching semester lessons did not indicate that she had made wholesale changes to the lesson plans; rather, her alterations affected some of the discussion formats, and added short, supplemental video segments.

Polly, meanwhile, followed lesson plans closely when enacting them. Unlike other case study teachers, Polly taught lessons that were not from Science Companion:

> In the beginning of the year I used it [Science Companion] and when I taught my lessons I really enjoyed it, I think that it's really beneficial. This past, student teaching, I didn't use the curriculum …my CT had kind of given me alternative lessons, she provided me with them, and it wasn't as useful... (Polly, End W10 interview)

Polly expressed a preference for the Science Companion curriculum, largely due to the supports it provided teachers (see previous quotes in this chapter). Although her student teaching semester lesson plans did not come from Science Companion, Polly maintained consistency across approximations of practice, using many of the same instructional approaches in enacting lessons from other curricular resources. In both Science Companion and non-Science companion lessons, Polly's teaching indicated a high degree of fidelity to the lesson plan itself and/or her cooperating teacher's suggestions. Recall, too, that Polly stated that her cooperating teacher did not encourage lesson plan modifications, and thus Polly lacked practical experience and confidence in this area at the end of her student teaching semester (data presented earlier in this chapter).

Hannah, again, provided a counterpoint in terms of the relationship between her science instruction and the classroom curriculum materials. On this topic, she said:

> I think that for me, Science Companion was like the outline of what needed to happen. For me it was like a big picture and it was like a go-to, but … I wasn't always teaching their lessons necessarily the way they wanted me to, but if I wanted to know the general sequence of lessons and the big picture of what the kids were supposed to get, that was what I used to get that, and I think for a lot of their lessons, I looked at the title and was like "Ok, lemme see what I can do with this" it was more, a lot like, much bigger picture. (Hannah, End W10 interview)

Lesson observations were consistent with Hannah's contention. Unlike her peers, Hannah regularly deviated in substantive ways from supplied lesson plans. In two of her three BSSTs, she lacked a formal lesson plan for the lesson portions she taught. In these respects, Hannah differed greatly from other case study teachers.

In summary, an analysis of the study data that considered fidelity to curriculum materials across approximations of practice revealed a natural division among the four case study teachers in this study. In the "higher fidelity" group, Bridget, Natalie, and Polly carried out their approximations of practice largely as indicated in the lesson plans they were provided. The sole "lower fidelity" representative, Hannah, took many more liberties with enactment in her approximations of practice, and stated that she used lesson plans as a guide rather than a script for her science teaching.

**Areas of instructional focus.** As case study teachers progressed through their approximations of practice, they demonstrated areas of special focus within their science teaching practices. However, no two case study teachers zeroed in on the same aspects of science teaching in exactly the same way in their approximations of practice. In this section, I briefly identify and describe each case study teacher's area(s) of instructional focus and her perceptions of this aspect of her science teaching.

In addition to focusing on improving her delivery of investigation instructions (described earlier), another area of focus in Bridget's science instruction was introducing the investigation lesson's purpose. Instructional approach data showed that this key feature of investigation lessons was often very teacher-directed in nature. Per Science Companion lesson plans, the purpose was typically part of the closing discussion. Reflecting on her BSST3, Bridget stated:

> The students were not able to come up with the "big idea" on their own… The above-mentioned part of the BSST that went not-so-well was a surprise for me. I handled this by listening intently to the possible reasons that they did offer, and then offered the "big idea" as an additional possibility. (Bridget, postBSST3 written reflection)

Bridget also identified the role of identifying the investigation lesson purpose immediately after teaching her BSST3, when she stated:

> …I'm kind of in this mode of backward design lately, and telling them upfront what it is that we're talking about and this curriculum isn't designed that way, it's kind of do the thing and then tell them what it is that they learned, so that's part of the conclusion and that's maybe something I would take out of the conclusion, or

> maybe keep in the conclusion but also have in the beginning as well. (Bridget, postBSST3 interview)

In subsequent lessons, Bridget made efforts to include some discussion of the investigation purpose in the lesson introduction.

In our final interview, I asked Bridget to comment on her thinking about students' recognition of the investigation lesson purpose:

> I feel like that's something that's come from every methods class I've taken at the university is you want to make sure, at the very least you want to make sure that *you* know what the purpose of the lesson is and you want to make sure that your students are getting that, and I think the best way to do that is to be upfront with them and to say "This is the thing that you're going to need to remember…" (Bridget, End W10 interview)

In this excerpt, Bridget reiterated what was consistently observed in her approximations of practice: that her preferred approach to identifying the investigation purpose typically involved telling the students the point of the lesson.

Hannah demonstrated a different focus across her approximations of practice: ensuring that her students were working together harmoniously and respectfully as they carried out investigation lessons. Hannah acknowledged this several times in her post-approximation of practice interviews and reflections (see Hannah's case study earlier in this chapter), including the following excerpt from her post-RT2 interview:

> …I had really high expectations for my students and I knew that they would be respectful and kind and helpful to each other… in the beginning I was in the front or involved in their presentations and by the end I was in the back and kind of

> watching them present to each other and really do it. That was really cool. They far exceeded my expectations about working together as a class... (Hannah, postRT2 interview)

In our final interview, I asked Hannah to speak to this aspect of her science teaching:

> I think that my school upbringing has a lot to do with it, I went to a K-12 school, I was with the same 24 people my entire life, so by the time I was a senior, we knew how to learn together because we had been doing it for so long…looking back, I think everybody should grow up in that same atmosphere because you end up so comfortable with learning and so comfortable with knowing how to work with somebody, and I think that's probably why. I see that in all my college science classes, I always made friends with the people next to me, and we always worked together on the things we were doing 'cause that's just how I was brought up. (Hannah, End W10 interview)

Hannah revealed that her experiences as a science learner motivated this focus on the social aspects of elementary science lessons, and implied that one of her missions as a teacher was to provide her own students with similar collaborative learning experiences.

Eliciting and working with students' ideas in science was a year-long focus for Natalie, as described previously. One component of working with students' ideas that was particularly salient to Natalie's approximations of practice was the closing, or sense-making, discussion that follows an investigation. On this topic, Natalie reflected:

> I learned that a concluding discussion is essential to a lesson. I felt extremely rushed during my BSST because we were running out of time for the science lesson. In the future I think I would just push the discussion until the next day so

> that the students would have enough time to talk. I think it is important to have a closing discussion so that students understand the purpose of the lesson and so that the teacher can evaluate how his/her instruction went and which students need further support with understanding the big idea. (Natalie, postBSST3 written reflection)

Natalie expressed similar views of the importance of the closing discussion in other interviews and reflections (provided earlier in this chapter). In particular, Natalie shared an anecdote from one of her own teaching experiences that illustrated her attention to one student's changing ideas in a science lesson. Natalie's emphasis on student empowerment in learning science, coupled with her enthusiasm in witnessing student excitement and learning in science, were powerful influences on this area of instructional focus.

In addition to teaching science enthusiastically, Polly focused on differentiating the supports she provided students during investigation lessons. As described previously, Polly's approximations of practice were characterized by the development of approaches to supporting students' work during investigation lessons in ways that were consistent with Polly's ideas about science teaching. Polly's focus on supporting learners individually derived from her experiences as a science learner, as she revealed:

> …tailoring it so that they understand and that to me, I was probably one of those kids who would kind of just stand back and say "yeah, we're going great." You know, really questioning them—well, why do you think that is? And trying to pull and make sure I get everyone included. (Polly, End W10 interview)

In this manner, Polly sought to provide her students with more stimulating science learning experiences than she had had.

Both Bridget and Polly encountered tensions associated with positioning students to successfully conduct investigations. However, they adopted different approaches to this problem of practice. Bridget emphasized breaking an investigation protocol into smaller sets of instructions, and delivering those instructions more clearly to the entire group of students intermittently throughout the investigation. Polly's approach focused on clarifying the investigation procedures and outcomes in manners responsive to individual students' needs, largely while the investigation was underway. In this regard, Polly and Bridget provided interesting counterexamples to one another, as they developed approaches to a common problem of teaching investigation lessons.

In summary, each case study teacher developed a unique area of instructional focus as she progressed through her approximations of practice. Bridget focused on methods to support students in reaching normative understandings of investigation lesson purposes. Natalie demonstrated an instructional focus on students' ideas, including supporting and empowering students' sense-making following an investigation. Hannah emphasized the social aspects of doing and learning science by encouraging her students to work together respectfully. And Polly developed her own instructional approaches to supporting a range of learners in conducting investigations. Despite differences in instructional focus, each case study teacher worked mindfully throughout her approximations of practice to develop her own approach to addressing what she viewed as an important aspect of science teaching practice.

**Influences on instruction.** The third enactment-related theme among case study teachers in this study relates to perceptions of the major factors influencing their science instruction. In our closing interviews, I asked each case study teacher the following question: What are the biggest influences on how you have taught science lessons this semester? Bridget said:

> …my own experience with science, and things I remember from elementary school and the things I remember excited me about science, having teachers what were enthusiastic about what they were doing, and getting to actually do stuff, I never liked reading, I hated science until I got to high school because all it was was reading. I liked elementary school science because it was playing with stuff. (Bridget, End W10 interview)

As her response revealed, Bridget identified her own experiences as a science learner as the some of the biggest influences on her science instruction. She also cited methods course elements, including students' alternative ideas, investigations, and scientific modeling, as having made an impact on her science teaching:

> …things we talked about in 421 [the methods course] about students having alternative ideas and that that's OK but you have to kind of figure out…their alternative ideas are based on something and finding out what they're based on and being able to find what the grain of truth is there in their ideas and setting them up from that and then pointing out the pieces that they're missing… And then the investigations and the modeling, I had no idea what those were when I started 421 and now they are very integral parts of what I believe about science teaching, so that. (Bridget, End W10 interview)

Finally, Bridget cited her cooperating teacher as a factor shaping her science instruction, particularly as a source of knowledge and experience teaching the science curriculum:

> And then my cooperating teacher as well. She's taught the curriculum many times before, so when it comes to teaching a lesson I'll talk to her "Oh we're teaching this lesson this week, what can you tell me about, how does this usually go, is there anything that I need to change, from your experience, that doesn't work, or should I use these other materials or …" so those kinds of things, having somebody there who's dealt with this particular curriculum was really helpful. (Bridget, End W10 interview)

In response to this question, Bridget failed to note the influence of the curriculum itself, which she had already identified as a major determinant of her instructional approaches.

Hannah's response to the same question highlighted her previous museum science teaching experience:

> Probably the…museum is a really big one. I stole a lot of things from there when I was teaching light, I was like "oh we do this in the museum, I'll do this it's more fun." And honestly that probably had the biggest influence of everything, just because my most extensive experience teaching science is from there. (Hannah, End W10 interview)

Although elsewhere, Hannah noted the salient differences between teaching science in the museum and teaching science in an elementary classroom, the quote above is consistent with Hannah's bigger-picture view of science teaching and the role of investigations, which was described earlier in this chapter.

According to Natalie, her approximations of practice instructional approaches were influenced by several factors, including methods course elements, the curriculum materials, and advice from her cooperating teacher and other second grade teachers:

> I think definitely what I learned in science methods class helped me out, especially having that little experience with the bite-sized teaching and the other, the lesson beforehand helped. And then I used the Science Companion curriculum, so that was helpful, and not only was that helpful but I was able to talk with my cooperating teacher and then I also talked with other second grade teachers about how they presented lessons, and I felt like just getting that feedback from all the different teachers of how because everyone presents information in a different way, you know, has different styles or things that they want to cover, really helped me tailor the lessons for our class. (Natalie, End W10 interview)

Here, Natalie alluded to how she integrated information from these various sources in making instructional decisions. Presumably, relative contributions from each of these sources changed, particularly as Natalie progressed through the methods course. Earlier in the same interview, Natalie noted that talking with other second grade teachers about science lessons was something she had not done before her student teaching semester.

Polly identified her cooperating teacher's enthusiasm for science teaching as a major factor in her own approximations of practice science teaching experiences.

> Definitely my CT's enthusiasm for it, that was something I don't think I had much of, and just her passion for science, OK—I see how engaged and how much these kids love science, I need to find that. And I think that might not be my strongest subject area that I teach, but…I see now that OK look at all of these cool things that she does and how much she's learned about it and…watching her teach some of her lessons, I mean, even for me, I'm a 23 year old sitting there and

> I'm totally engaged in her lessons and I'm listening like I was a 3rd grader, so having that is really important. (Polly, End W10 interview)

Similar to Bridget, Polly neglected to mention curriculum materials and enactment suggestions from her cooperating teacher as factors in her instructional approaches.

Table 4.42 summarizes the factors each case study teacher described as important to the instructional approaches in her approximations of practice.

Table 4.42

*Influences on case study teachers' science instruction in 2009-2010*

| Case study teacher | Self-reported influences | Additional factors |
|---|---|---|
| Bridget | • Personal science learning experiences<br>• Methods course elements (e.g., students' ideas, investigations, scientific modeling)<br>• Cooperating teacher and her experience with the curriculum | • Curriculum materials/lesson plans<br>• Ideas about investigation lessons<br>• Self-confidence |
| Hannah | • Prior museum science teaching experience | • Personal science learning experiences<br>• Ideas about science teaching and learning<br>• Subject matter knowledge |
| Natalie | • Methods course elements (e.g., BSST)<br>• Curriculum materials<br>• Cooperating teacher<br>• Other second grade teachers | • Curriculum materials/lesson plans<br>• Self-confidence<br>• Ideas about investigation lessons (e.g., students' ideas) |
| Polly | • Cooperating teacher's enthusiasm for science teaching | • Curriculum materials/lesson plans and cooperating teacher's suggestions<br>• Personal science learning experiences<br>• Students' needs during investigations |

Many factors that influenced how case study teachers carried out their approximations of practice were not explicitly addressed in response to the interview question "What are the biggest influences on how you have taught science lessons this semester/year?" These other factors are supported by interview data presented in case study profiles, and are listed in the rightmost column of Table 4.42. For example, Bridget stated that her enactments followed closely the Science Companion lesson plans, yet she did not highlight the influence of these curriculum materials in response to this particular interview question. Similarly, Natalie's increased confidence for teaching science was acknowledged repeatedly in our interviews, but was not named as one of the biggest influences on her teaching practice.

### Ideas about teaching investigation lessons

In this section, I consider similarities and differences among case study teachers' ideas about teaching investigation lessons and how their ideas changed throughout their approximations of practice. Two major themes are evident in these data. One theme considers what case study teachers identified as lessons learned from their approximations of practice. The other theme relates to the perceived drivers of change in case study teachers' ideas about science teaching and investigation lessons.

**Lessons learned from approximations of practice.** As described previously, all case study teachers identified lessons learned from their approximations of practice. Case study teachers expressed these lessons learned as ideas that could be applied to other, future science teaching opportunities. Table 4.43 summarizes the topics of lessons learned by each case study teacher as indicated in post-enactment interviews and written reflections.

Table 4.43

*Topics of lessons learned by case study teachers in their approximations of practice*

| PeerTch | BSSTs | RT2 |
|---|---|---|
| | Bridget | |
| • Materials planning<br>• Student participation and engagement<br>• Filling extra time productively | • Clarity and comprehensibility of directions<br>• Delivery of instructions<br>• Supporting students' articulation of the "big idea" | • Planning and time management |
| | Hannah | |
| • Creative expression of scientific ideas<br>• Teamwork<br>• Students' understanding one others' ideas | • Time: planning and management<br>• Supporting student reasoning<br>• Lesson goals and time constraints | • Assessing students<br>• Student engagement |
| | Natalie | |
| • Improvisation<br>• Experimental uncertainty and alternative instruction<br>• Staying calm<br>• Probing student thinking<br>• Promoting inter-student interaction | • Improvisation<br>• Integrating science into other subjects<br>• Importance of concluding discussion | • Unanticipated outcomes<br>• Responsive time management<br>• Importance of concluding discussion |
| | Polly | |
| • Making lessons effective<br>• Organizing student thoughts/ideas with charts<br>• Guiding discussions<br>• Content knowledge<br>• Connecting students' ideas | • Preparing for range of students knowledge<br>• Language<br>• Discussions as informal assessment tools | • Content knowledge<br>• Testing investigations before teaching<br>• Learning opportunities from lessons gone wrong |

As Table 4.43 shows, case study teachers' lessons learned covered a range of topics. Certain ideas about science teaching were expressed by two or more case study teachers. For example, Bridget (PeerTch and RT2), Hannah (BSSTs), and Natalie (RT2) alluded to aspects of time management in their approximations of practice lessons learned. Similarly, in their peer teaching approximations of practice, both Polly and Natalie cited the role of the teacher in facilitating science conversation between students, which Hannah identified as students understanding their peers' ideas.

Other ideas expressed as lessons learned from approximations of practice appeared to be teacher-specific. For example, Polly alone cited the importance of thoroughly understanding the science content of the lesson in advance of teaching. Natalie indicated that going "off-script" (improvisation) was a particularly salient aspect of science teaching for her. Bridget underscored her focus on effective delivery of investigation instructions, and Hannah mentioned her attention to helping students solve problems and answer scientific questions by relying on their reasoning skills. Many of these lessons learned were highly relevant to that case study teacher's instructional focus described in the previous section.

In summary, case study teachers' ideas about science teaching, derived from their approximations of practice, exhibited some common and some unique elements. Implications of this finding are discussed further in Chapter 6.

**Sources of change in ideas about science teaching.** In our interviews, prospective elementary teachers all supported orientations that featured hands-on, investigative learning in elementary science. Despite sharing these orientations, case study teachers contributed a range of unique backgrounds and experiences as science learners. While the general notion that investigations are important in elementary science teaching and learning did not change dramatically throughout this study, all case study teachers demonstrated nuanced and personal changes in their knowledge about and orientations toward investigation lessons. Table 4.44 displays data relevant to case study teachers' backgrounds at the beginning of this study, and summarizes data presented earlier in this chapter pertaining to case study teachers' self-reported changes in ideas about investigation lessons.

Table 4.44

*Case study teachers' changing ideas about investigation lessons*

| | Science teaching experience prior to methods course | Initial attitude toward science based on own learning experiences | Changes in ideas about investigation lessons: Major foci | Biggest influences on changing ideas |
|---|---|---|---|---|
| Bridget | None | Mixed | Task management, time management | Science learning history, methods course, seeing science with younger students, teaching experiences |
| Hannah | Extensive, informal | Positive | Planning, time management, goals | Differences between classroom and museum science teaching, long-term planning, coherence between lessons |
| Natalie | None | Positive | Student ideas and empowering learners | Gaining confidence and excitement for teaching science, witnessing student learning |
| Polly | None | Negative | Enthusiasm for teaching, individualized supports | Science learning history, variety of approaches in methods course, course assignments, teaching lessons, self-awareness of planning needs |

Case study teachers focused on different aspects of investigation lessons when talking about their ideas and sources of change in those ideas. The column entitled “Changes in ideas about investigation lessons: Major foci” highlights examples of aspects of investigation lessons discussed by case study teachers in our interviews. Moreover, case study teachers’ ideas about these (and other) aspects of investigation lessons changed in some way over the duration of the study. For example, Natalie initially held strong ideas about eliciting and working with students’ ideas in science, and these ideas were supported and refined as she progressed through her approximations of practice. The final column of Table 4.44 shows what case study teachers perceived as the sources for change in their ideas about investigation lessons. For example, Natalie attributed changes in her ideas about investigation lessons largely to her own gains in confidence and excitement for teaching science and by witnessing student learning taking place.

Inspection of Table 4.44 reveals areas of commonality and areas of difference among case study teachers. For example, both Bridget and Hannah identified time management as an aspect of science teaching where they had experienced changes in their ideas in the form of lessons learned in their approximations of practice. By contrast, only Polly talked about the importance of conveying enthusiasm while teaching science. Similarities and differences are also observed in terms of case study teachers’ perceived drivers of change in their ideas about teaching investigation lessons. Both Bridget and Polly cited the influence of teaching investigation lessons on their ideas about investigation lessons. Bridget and Polly also cited their own negative experiences as science learners as factors impacting their changing ideas about teaching investigation lessons. Hannah, who was the sole case study teacher with prior science teaching experience, talked about the role this teaching experience played in her own changing ideas about teaching science. And Natalie alone acknowledged the influence that gaining self-confidence had on her thinking about teaching investigation lessons.

In summary, case study teachers exhibited areas of similarity and difference in terms of their changing ideas about science teaching. Furthermore, certain factors appeared to prompt change in more than one case study teacher's ideas about science teaching (e.g., personal science learning history) while other change-prompting factors appeared to be teacher-specific (e.g., prior science teaching experience).

**Confidence for science teaching and teaching investigation lessons**

Finally, I consider case study teacher data in terms of the confidence they expressed for teaching investigation lessons, and confidence as science teachers more generally. These data support two themes. The first theme relates to case study teachers' confidence levels during each approximation of practice, and areas of similarity and difference in these data. The second theme focuses on case study teachers' gains in confidence after completing approximations of practice, which indicated differences in the relationships between teaching experience and confidence.

**Confidence levels during approximations of practice.** Earlier in this chapter, I presented data from each case study teacher's descriptions of how she felt during and after each of her approximations of practice (see Tables 4.9, 4.19, 4.29, and 4.39). For comparison purposes, I compiled these data in chronological order of the approximations of practice, and assigned generic labels (e.g., a case study teacher's first approximation of practice was labeled AP1) in Table 4.45. I also reduced the data to a minimal description of how the case study teacher felt while teaching the particular lesson or lesson portion, preserving the language used by the case study teachers.

Table 4.45

*Case study teachers' feelings during approximations of practice*

| | AP1 | AP2 | AP3 | AP4 | AP5 |
|---|---|---|---|---|---|
| Bridget | Pretty much confident | Non-scary | Felt natural | Nervous* | Began chaotic, finished calm |
| Hannah | Pretty good* | Pretty good | Pretty good | Really happy | Pretty good |
| Natalie | NA | Confident then flustered | Nervous and flustered* | Confident then flustered | Rushed |
| Polly | Not nervous at all | Fine, comfortable | Kind of nervous* | Overwhelmed | Good, fun |

*Peer teaching approximation of practice

One important factor to bear in mind when interpreting data such as these is that each case study teacher had a different threshold for feeling confident, or nervous or flustered. Also, some case study teachers were more self-critical than others. Rather than comment on these aspects of the data, I focus instead on two similarities. First, all case study teachers except Hannah expressed nervousness about their peer teaching approximation of practice, largely because it entailed role-playing with their peers in a teaching capacity. Often, this nervousness was due to discomfort with the idea of being critiqued by their peers, as Bridget articulated in her post-peer teaching interview:

> …[I was] definitely more nervous than I am with second graders just because they're in the same spot that I am so they can kind of see "oh well you didn't do that right" (Bridget, post peer teaching interview)

In cases of field-based approximations of practice, a second similarity is evident. Again, with the exception of Hannah, case study teachers expressed feelings of being nervous or flustered relating to unforeseen issues with the investigation lesson enactment. For example, Polly became "overwhelmed" when the investigation in her second RT2 did not work as planned and students were unable to observe refraction. Bridget stated that the first day of her two-day RT2 was "chaotic" largely because the dough for students' fossil models was unexpectedly goopy, also a materials-related issue. Natalie expressed that she felt "confident then flustered" when teaching her RT1 because her introduction went smoothly, but then students were unable to finish their work in the allotted time. Even Hannah, who did not admit to feeling flustered or nervous while teaching, expressed that she struggled with managing the direction of her introductory discussion:

> …sometimes I felt like the discussion was getting out of control and…other times I felt like they were doing a really good job of talking to each other. I felt a little bit lost parts of the time, like "where are we going to go from here?" but I think that was because it was a really student-led discussion... (Hannah, postBSST1 interview)

Across these examples, case study teachers expressed a common sentiment: that unplanned enactment changes affected their self-confidence as science teachers.

Hannah differed from her peers in the area of self-confidence. In all of our post-approximation of practice interviews, she expressed a consistently high degree of confidence. This was perhaps not surprising, since Hannah had taught science lessons prior to taking the methods course. When she did identify aspects of her teaching that presented challenges for her, these challenges were discussed in terms of how they related to her ideas about science teaching, rather than how they affected Hannah's confidence. For example, in her post BSST1 reflection, Hannah wrote:

> I was really happy with my work facilitating the discussion in this class …I was a little less happy with the discussion itself. I don't really think that leading students toward a desired answer is something that is helpful in a discussion, and I think that because of this belief, I didn't really succeed in leading the students toward choosing the sun as the most important of the three components. (Hannah, postBSST1 reflection)

Additional examples that illustrate Hannah's confident, intellectually critical appraisal of her approximations of practice are provided in Table 4.19.

In summary, approximations of practice data focused on case study teachers' self-reported confidence during teaching suggest that peer teaching resulted in case study teachers' nervousness due to perceived scrutiny by their peers. Similarly, field-based approximations of practice presented challenges to case study teachers' confidence levels when aspects of investigation lessons—such as time and materials management—did not go as planned. Hannah was the lone exception, as she maintained self-confidence during peer teaching and when her field-based enactments strayed from her initial plan.

**Confidence for teaching investigation lessons: Beginning versus end of study.** Examination of case study teachers' confidence data from a holistic viewpoint reveals that all made gains in their confidence for teaching investigation lessons over the course of the year. Table 4.46 summarizes data presented earlier in this chapter pertaining to big-picture changes in case study teachers' confidence for teaching investigation lessons.

Table 4.46

*Case study teachers' self-reported confidence levels and confidence change factors*

| | Science teaching experience prior to methods course | Confidence level for science teaching--pretest | Confidence level for science teaching--posttest | Pretest confidence level described as naive? | Attributed increased confidence over academic year to… |
|---|---|---|---|---|---|
| Bridget | None | Confident | Very confident | No | Cyclical reinforcement of experience and practice |
| Hannah | Extensive, informal | Very confident | Confident | Yes | Cyclical reinforcement of experience and practice |
| Natalie | None | Confident | Confident | Yes | Gaining experience |
| Polly | None | Unsure | Confident | No | Awareness of preparation needs |

Here, it appears that Natalie's confidence level did not change and Hannah's confidence level regressed. However, both of these case study teachers offered further insight that indicated their initial confidence levels had perhaps been overrated. Natalie explained:

> I think in the beginning I shouldn't have marked "confident." [laughing] I probably marked confidence because I thought it was going to be like no big deal, that it would be really easy because the curriculum is already all written out for you, all you have to do is read from it. I was greatly mistaken [laughing]. But after doing the assignments for ED421 [science methods course] I think I can say that I'm confident now. Now I understand the work that goes into it and all of the different aspects and why everything's important. (Natalie, End F09 interview)

Similarly, Hannah reasoned:

> I think I found out that there was a lot that I didn't know… I was very confident at the beginning because the only teaching I'd done was kind of like canned teaching, it was like "here's your lesson, go teach it" and it was like I'm supposed to teach it just like that, I don't really have to make any decisions…I think it was more a lot of, like, moving away from science just being fun and engaging toward how can it really be helpful and useful for kids? And so I don't know…I'm not sure about that…I'm confident, just not *very* confident anymore. (Hannah, End F09 interview)

Polly and Bridget also elaborated on their increases in confidence for teaching investigation lessons, and these data may be found in their respective case study descriptions. Accounting for these additional data, all case study teachers, then, made gains in their confidence over the year.

Case study teachers' explanations for their increased confidence demonstrated some similarities as well as some differences. When asked what contributed to her increased confidence as a science teacher, Hannah stated:

> I think it's a cycle…I think that because I have done a lot of science teaching, I have confidence in my science teaching and because I have confidence in my science teaching, I'm able to teach science well, so it's like a cycle. (Hannah, End W10 interview)

Similarly, Bridget stated:

> I felt confident in my abilities, and I would teach a lesson and see that my students learned it, which would kind of boost my confidence even more, so it was just kind of a cycle that kept on going. (Bridget, End W10 interview)

Here, both Bridget and Hannah described a cyclical nature of experience and confidence, and how these two constructs mutually reinforced one another. Bridget also revealed that witnessing evidence of student learning was responsible for boosting her confidence as a science teacher. Natalie indicated student learning in conjunction with her increased confidence when describing changes in her ideas about science teaching:

> … I think gaining confidence and actually being excited about teaching science and knowing the students were able to come up with those great ideas on their own and watching them do that was definitely a big driver. (Natalie, End W10 interview)

In this quote, Natalie alluded to the highly interrelated nature of teaching experience, ideas about effective science teaching, and self-confidence as a science teacher.

Polly focused on different aspects of science teaching as integral to her improved confidence. She stated:

> At first I was probably a little shaky, but I think my confidence has grown, definitely. I think that I'm aware of what I need to do to prepare myself to teach these lessons, and I think that's something that is really important… (Polly, End W10 interview)

Polly's quote suggests that gaining an awareness of her own needs in order to teach science effectively was most central to her increased confidence as an elementary science teacher. She also implied that this awareness derived from teaching experience, which all case study teachers cited as influential to their confidence levels.

In summary, all case study teachers expressed gains in their self-confidence as elementary science teachers. Bridget and Hannah described a direct relationship between their teaching experience and their confidence increases, while Natalie and Polly identified factors in addition to teaching experience that influenced their senses of self-confidence as elementary science teachers.

## Chapter summary

In this chapter, I have presented data from case study teachers' approximations of practice, interviews, and reflections that first focus on the individual as the unit of analysis. Bridget, Hannah, Natalie, and Polly were characterized in terms of their instructional approaches, ideas about investigation lessons, and confidence for teaching investigation lessons. Changes were observed for each case study teacher, and data pertinent to case study teachers' perceptions of what prompted those changes were also presented. Models illustrating the interactions between study constructs at the end of the study were presented for each case study teacher.

In the second part of this chapter, I have presented comparisons of case study teacher approximation of practice data first at the model level and then in more detail along three separate, yet interrelated, dimensions. Cross-case study analyses of instructional approach data revealed differences and similarities in case study teachers' fidelities to lesson plans, instructional foci, and self-identified factors that influenced their science instruction. Second, case study teachers exhibited similar big-picture notions about the importance of hands-on learning, but differed in terms of the specific lessons learned in each of their approximations of practice. Case study teachers also demonstrated unique areas of focus in describing their ideas about investigation lessons, and offered a range of factors that prompted change in their thinking about investigation lessons. Finally, case study teachers' confidence levels varied on an individual basis with their approximations of practice, however, nervousness when teaching their peers emerged as a common theme. All case study teachers' confidence levels for teaching investigation lessons increased, and there were similarities and differences in how case study teachers related their teaching experience to their confidence levels.

In the next chapter, I continue to examine case study teachers' impressions of changes in their science teaching by focusing on what they perceived as the benefits and drawbacks of approximations of practice in their learning to teach science.

# CHAPTER 5

# UTILITY OF APPROXIMATIONS OF PRACTICE

## Chapter overview

In this chapter, I present data that address my fourth, and final, research question: What do prospective teachers perceive as the benefits and limitations of approximations of practice for learning to teach science investigation lessons? In asking this question, I sought to discover what prospective teachers viewed as the utility of their approximations of practice. As in the previous chapter, I consider data from two perspectives. The first perspective captures case study teachers' impressions of the utility (as benefits and drawbacks) of approximations of practice shortly after those experiences. The second perspective examines case study teachers' impressions of approximations of practice contributions to their science teaching practice, from a holistic, retrospective viewpoint.

## Approximations of practice utility: Immediate reactions

After each approximation of practice during the methods course semester, I asked case study teachers to comment on the benefits and the drawbacks of that particular approximation of practice. To streamline the data, I have paraphrased and summarized their responses in Tables 5.1-5.3.

Table 5.1

*Prospective teachers' immediate perceptions of peer teaching utility*

| Benefits of peer teaching (teacher role only) | Drawbacks of peer teaching (teacher role only) |
|---|---|
| Bridget | |
| • Gained experience with an unfamiliar pedagogy (scientific modeling)<br>• Received feedback from teacher educators and peers | • Groups of students were small; this work does not always transfer to whole class situations |
| Hannah | |
| • Group was a good representation of well-acquainted "students" working together<br>• Planned a lesson that I knew they could do | • Hard to envision authentic classroom management<br>• Peer students changed to normative ideas too easily |
| Natalie | |
| • Learned from challenging and unexpected student ideas<br>• Received peer commentary and feedback | • None |
| Polly | |
| • Learned importance of understanding the content | • Was challenged by peers' content knowledge |

Table 5.2

*Prospective teachers' immediate perceptions of bite-sized science teaching utility*

| Benefits of BSSTs | Drawbacks of BSSTs |
|---|---|
| Bridget | |
| • Focused on each part of the lesson and saw what the important elements were (BSSTs 1 & 3)<br>• Practiced management aspects of lesson (BSST2) | • Confused about role during rest of lesson (BSST3)<br>• Coordinating other lesson portions with cooperating teacher (BSST2) |
| Hannah | |
| • Experienced having a beginning-of-unit, unpredictable discussion with students' initial ideas (BSST1)<br>• Lesson conclusion was scientifically authentic (BSST3)<br>• Experienced stations in a science lesson (BSST2) | • None (BSST1)<br>• None, only learning opportunities (BSST3)<br>• Did not get to work with the entire class since format was small groups (BSST2) |
| Natalie | |
| • Gained a sense of how science lessons go (BSST1)<br>• Gained confidence as a teacher (BSST1)<br>• Realized importance of concluding discussion (BSST3)<br>• Recognized own teaching preferences (BSST3) | • Wanted to teach the rest of the lesson (BSST1)<br>• None (BSST3) |
| Polly | |
| • Focusing on one part of the lesson allowed concentration on that task and its presentation (BSST1)<br>• Taught a beginning-of-unit lesson (BSSTs 2,3)<br>• Exposed to a lesson format (scavenger hunt) that could be useful in other science lessons (BSSTs 2,3) | • Wanted to keep teaching the rest of the lesson (BSST1)<br>• Unable to see the next lessons in the unit due to Winter Break (BSSTs 2,3) |

Table 5.3

*Prospective teachers' immediate perceptions of reflective teaching utility*

| Benefits of RTs | Drawbacks of RTs |
|---|---|
| Bridget | |
| • Learning from RT1 was useful for RT2 (RT2)<br>• Enjoyed thinking and planning RT2 (RT2) | • Scheduling lessons during busy end of semester was difficult (RT2) |
| Hannah | |
| • Had more time to plan this lesson (RT2)<br>• Assumed greater agency over learning goals (RT2) | • None (RT2) |
| Natalie | |
| • Allowed self-evaluation of teaching (RT1)<br>• Lessened anxiety/nervousness for next RT (RT1)<br>• Allowed self-evaluation of teaching (RT2)<br>• Added to confidence for science teaching (RT2)<br>• Allowed students to view me as a teacher figure (RT2) | • None (RT1)<br>• None (RT2) |
| Polly | |
| • Pulled in all aspects of teaching an entire class (e.g., management, preparation, delivery, etc.) (RT1)<br>• Lesson didn't go well, which revealed areas for improvement (RT2)<br>• Was able to see what was difficult for students to understand (RT2) | • None (RT1)<br>• Lesson didn't go as well as RT1 but this prompted thinking about future improvements (RT2) |

As these data reveal, case study teachers identified a variety of benefits and drawbacks associated with the various approximations of practice. In the following sections, I explore in more depth similarities and differences among their interview responses.

**Immediate impressions of peer teaching utility.** Case study teachers' post-enactment reactions to peer teaching are indicated in Table 5.1. When asked about the benefits of teaching their peers as a means of learning to teach elementary science, Natalie and Bridget highlighted the opportunity for feedback from their peers and teacher educators in this approximation of practice. This feature was unique to the peer teaching approximation of practice. Another unique benefit of peer teaching was described by Polly, who said

> …I was challenged to a higher level in terms of like some of the content and with the older student, with the college peers, you really have to know your content... (Polly, post peer teaching interview)

In this quote, Polly reiterated her emphasis on solid content knowledge, something she cited as important after other approximations of practice. However, in this snippet, Polly alluded to a different reason for really knowing the science content: peer "students" also know the content, but pretend not to for role-playing purposes. In essence, Polly's statement reveals a desire to not be embarrassed in front of her peers. In this same vein, Natalie cited as a benefit of peer teaching her own sense of having been challenged by her peer students' ideas about the science content.

Hannah expressed an altogether different benefit of peer teaching that was well-aligned with her instructional focus on social interactions during science. Hannah pointed out that her peers, who were well-acquainted at this point in their teacher education program, functioned as a proxy for well-acquainted elementary students who had already learned how to work together toward a common goal. In essence, Hannah illustrated one advantage of the inauthentic nature of teaching her peers: it permitted her to ignore behavior management and concentrate on other aspects of science teaching.

With the exception of Natalie, case study teachers viewed the inauthentic elements of the peer teaching approximation of practice as drawbacks to learning to teach science. Specifically, Bridget noted the improbability of teaching small groups of students rather than an entire class. Hannah commented on the lack of classroom management considerations as a peer teacher, and Polly acknowledged the awkwardness of role-playing with one's peers. Hannah also expressed the opinion that her peers were too easily swayed from their assigned alternative ideas to normative ideas about the science content. This comment was especially interesting, given that changing students' ideas was *not* a learning goal or desired outcome for Hannah's peer teaching lesson.

**Immediate impressions of bite-sized science teaching utility.** As Table 5.2 reveals, case study teachers appeared to value their BSSTs as opportunities to focus on teaching discrete portions of science lessons. Bridget, for example, stated that her BSST1 was useful because

> …it made me pull it apart a little bit more and really delve into detail that, if I were doing the whole lesson and not focusing on the introduction… I might be tempted to just say the introduction would just be forgotten about, it's just the beginning, it's not the real lesson, but I think that focusing on it and having an assignment on it really makes you get into the mindset that this is an important part of what you're doing and you need to be able to do that effectively. (Bridget, postBSST1 interview)

Polly echoed this sentiment in her post BSST1 comments, adding that this approximation of practice allowed her to focus on how she presented the introductory material to her students.

Natalie and Hannah volunteered other benefits of the BSSTs for learning to teach science. Natalie stated that her BSST1 allowed her to gain a sense of how a science lesson would unfold in a classroom, in addition to providing her an opportunity to gain some confidence being in front of the classroom teaching science. Natalie also added that her BSST3 was useful because it was rushed (see Chapter 4 data), which helped underscore her own belief that leaving time for a concluding discussion in a science lesson was extremely important. Hannah added that her BSST1 afforded her an opportunity to hold what she viewed as a highly unpredictable beginning discussion, in which she elicited students' initial ideas about the science content.

While the perceived benefits of the BSSTs varied across case study teachers, the perceived drawbacks were strikingly similar. Natalie and Polly stated that they wanted to continue teaching the lesson after their BSST1s. Bridget expressed a similar sentiment in her comment about not knowing how she should involve herself during other portions of her BSST lessons. Finally, Hannah expressed some dismay at not having had the opportunity to work with all members of her classroom during her BSST2, which entailed working with small groups of students. The common thread, then, among these expressed drawbacks was an underlying dissatisfaction with the bounded nature of the BSST experience, and a desire to do more instructionally during these lessons.

**Immediate impressions of reflective teaching utility.** The most authentic approximation of practice during the methods course semester appeared to be the most useful in the eyes of case study teachers, as Table 5.3 reveals. Natalie and Hannah thought that this approximation did not have any drawbacks, as they indicated in our post-RT interviews. Polly's RT2 response stemmed from an enactment that did not go as well as she had hoped; however, Polly ultimately viewed this as a learning opportunity rather than a drawback inherent to the approximation of practice. Similarly, Bridget expressed that scheduling her RT2 was challenging. Again, this perceived drawback was not substantive to the approximation of practice.

Advantages to the RT assignments were identified by all case study teachers. Bridget indicated that her RT2 was especially useful because she could apply what she had learned in her RT1. Hannah stated that she was afforded more planning time and increased responsibility for determining the lesson goals in her RT2, which rendered the experience more enjoyable for her. After both her RTs, Natalie highlighted the contributions to her self-confidence as a science teacher in addition to providing her opportunities to critically evaluate her own science teaching practice. And Polly cited that her RT2 allowed her to gain insight into what was particularly difficult for students to understand in the lesson she taught. While case study teachers did not explicitly state that the more authentic nature of the reflective teaching experiences accounted for these benefits, the benefits cited all derive from having taught entire science investigation lessons in an elementary classroom.

**Summary of immediate perceptions of approximation of practice utility**

In summary, case study teachers' perceptions of the benefits and drawbacks of these three approximations of practice were measured immediately following their deployments and the data are presented in Tables 5.1-5.3. Overall, these data suggest that case study teachers viewed all approximations of practice as having benefits, and viewed more highly-authentic approximations of practice as more beneficial with fewer drawbacks in helping them learn to teach elementary science investigation lessons. In the next section, I consider case study teachers' retrospective reflections on approximations of practice utility after completing this set of experiences.

**Approximations of practice utility: Case study teachers' later reflections**

As previously stated, case study teachers were interviewed at the ends of the methods course and student teaching semesters. Also, on the methods course final exam (or posttest), all prospective teachers provided written reflections on the approximations of practice. This final exam took place shortly after case study teachers completed their final approximations of practice in the field, and yielded open-ended comments about the utility of each type of approximation of practice. Case study teachers' responses to final exam prompts are paraphrased and summarized in Tables 5.4-5.6.

Table 5.4

*Prospective teachers' end-of-methods-semester perceptions of peer teaching utility*

| What did this help me learn or improve? | What were the limitations or challenges of this experience? |
|---|---|
| Bridget | |
| • Getting students to work together to create an idea<br>• Adjusting lesson for timing | • Working with elementary students or working with a whole class would be different |
| Hannah | |
| • Co-planning and my view of co-planning<br>• Thoughts about working with students in centers or groups | • Difficult to imagine how important management would be with actual elementary students |
| Natalie | |
| • Experiments do not always go as planned ; always be prepared with a backup plan<br>• Importance of making connections between students responses and scientific content in discussions<br>• Unanticipated student questions provide interesting connections, insights, or opportunities to probe student thinking | • No limitations of the experience<br>• Working with my students toward forming new models or revising their initial models to match the true phenomenon |
| Polly | |
| • To really understand the content<br>• To address unexpected questions | • It was hard to actually get feedback from my peers, because everyone is nice and doesn't want to upset anyone |

Table 5.5

*Prospective teachers' end-of-methods-semester perceptions of peer student utility*

| What did this help me learn or improve? | What were the limitations or challenges of this experience? |
|---|---|
| Bridget | |
| • The process of teaching a unit; seeing how information is built from one lesson to the next | • To know how much/what we should know in the student role |
| Hannah | |
| • Seeing the ways in which teachers can do things effectively or ineffectively, depending a lot upon their attitude towards what they are doing | • Not moving forward rapidly enough; the material was not difficult enough to warrant this many lessons |
| Natalie | |
| • Get in the mind set of students and learn how they might think about scientific content<br>• Improve my perspective about students' alternative ideas and how to help them work towards reforming those ideas | • To think like an elementary student |
| Polly | |
| • To really stick with an alternative idea<br>• How important alternative ideas can be to students<br>• How hard it can be to change one's mind | • Since I knew about condensation it was hard to have an alternative idea and stick with it, and support my reasoning behind it |

Table 5.6

*Prospective teachers' end-of-methods-semester perceptions of bite-sized science teaching utility*

| What did this help me learn or improve? | What were the limitations or challenges of this experience? |
|---|---|
| **Bridget** | |
| • To focus in on each part and really see the importance of the introduction and conclusion | • Not knowing how involved I should be in the other segments<br>• Adapting my plan to fit other part(s) of the lesson |
| **Hannah** | |
| • Becoming a member of my classroom<br>• Discussion facilitation techniques | • Frustrating to have the pieces be so small but yet so important<br>• BSSTs weren't taken as seriously in the classroom as they needed to be for the methods class |
| **Natalie** | |
| • Learned the importance of each chunk of the science lesson<br>• Improve my science teaching<br>• Gained confidence in the classroom | • Trying to make it fit in with a lesson that my c.t. was teaching. |
| **Polly** | |
| • Concentrate on that just that task and how to present it in a way that was beneficial for students | • No assessment of student retention of BSST material |

Table 5.7

*Prospective teachers' end-of-methods-semester perceptions of reflective teaching utility*

| What did this help me learn or improve? | What were the limitations or challenges of this experience? |
|---|---|
| | Bridget |
| • Lesson pacing<br>• How to develop student thinking throughout a lesson | • Teaching in someone else's classroom<br>• Little input into which lessons I taught |
| | Hannah |
| • Planning<br>• Thinking about how to use methods course assignments as a member of the classroom and really have to make them relevant | • Over-planning the lesson it in order to make it fit into the required lesson plan format (for the assignment) |
| | Natalie |
| • Science planning and teaching<br>• Helped me learn what science teaching involves | • No limitations. I think this was a great assignment |
| | Polly |
| • Helped me to see that teaching a science lesson is not so scary or overwhelming<br>• Students took me seriously as a teacher | • No assessment of student retention of RT material |

Before examining differences between these and previous reflections on approximation of practice utility, note that the final exam also prompted prospective teachers to comment on the benefits and limitations associated with the peer student role. Table 5.5 reveals case study teachers' perceptions of how acting as an elementary student who held an alternative idea about condensation impacted their thinking and learning about science teaching. As Bridget and Hannah's responses to the "What did this help me learn or improve" prompt imply, inhabiting the student role allowed them to witness a variety of instructional approaches in science teaching, in the form of their peers enacting the peer teacher role. This was a unique benefit of this activity that rendered the peer teacher role a representation of practice from the peer students' perspective. Also in

Table 5.5, all case study teachers stated that the peer student role was challenging because they were unsure how to accurately represent the knowledge and thinking of elementary students. The meanings and implications of these findings are explored more fully in Chapter 6.

Returning to prospective teachers' perceptions of approximations of practice in which they assumed the teacher role, Tables 5.4, 5.6, and 5.7 indicate that at the end of the methods course semester, case study teachers identified new benefits for some of the approximations of practice. For example, Bridget stated that her peer teaching and RT experiences helped her learn about science lesson pacing, an aspect of teaching that she had not previously mentioned in connection with her approximations of practice. Similarly, Hannah noted the value of co-planning to her peer teaching experience, and also stated that her BSSTs and RTs served as vehicles to help her gain more classroom teaching experience in the field. Natalie's comments about the learning opportunities afforded by her RTs illustrate how her evaluation of these approximations of practice took on a retrospective quality in which she synthesized what she learned:

> I feel like I improved greatly between my two reflective teachings. This helped me learn what science teaching involves, for example, it involves possibly improvising when an experiment isn't running correctly, managing various small groups while at the same time making sure the large group meets the learning goal, and having discussions in which students can present and explain their scientific thinking. (Natalie, final exam)

As this quote suggests, Natalie's perspective shifted to a more holistic picture of the affordances of her RTs. Relative to her initial impressions in Table 5.3, Natalie downplayed the role her RTs had in increasing her self-confidence for teaching science. Polly, meanwhile, reiterated that her approximations of practice underscored for her the importance of science content knowledge, and also stated that her RTs had the added benefit of positioning her as a teacher in the classroom, which resulted in students' recognition of this authority and identity.

Hindsight also appeared to unearth some consistent and some new perceptions of approximation of practice limitations. For example, Bridget reiterated the challenge of integrating her BSST instruction with her cooperating teacher's instruction of the other portions of those science lessons. While this was something Bridget had previously expressed as a limitation of the experience, it was the first mention of this BSST limitation from other case study teachers. Natalie articulated her impression of this BSST-specific struggle in the following quote:

> It was difficult to make our teaching cohesive so that there was not an obvious choppiness between her teaching and then mine. (Natalie, final exam)

In reference to the peer teaching approximation of practice, Hannah and Natalie again indicated the lack of authentic management considerations as a limitation of this learning opportunity. Polly identified another limitation of the peer teaching approximation of practice:

> It was hard to actually get feedback from my peers, because everyone is nice and doesn't want to upset anyone… (Polly, final exam)

Here, Polly pointed out an important shortcoming of the peer teaching experience—that prospective teachers were reluctant to provide critical feedback on each others' performances. This relates closely to the limitation Polly identified in her immediate post-peer teaching interview, that role-playing peer teacher-student interactions were often awkward to negotiate.

Finally, on their final exams, case study teachers revealed several previously unidentified limitations of the reflective teaching assignments. While Natalie alone continued to maintain that this assignment lacked any shortcomings, Bridget stated that one limitation of this approximation of practice, from her experience, was her inability to choose which lessons to teach. On her final exam, Polly indicated that one drawback of the RTs (and the BSSTs) was that her experiences lacked an assessment component that would indicate how well students retained the material they learned in those prospective teacher-led lessons. Hannah, on the other hand, identified a limitation of the experience that was not inherent to the approximation of practice enactment: she noted that the written requirements for the RT assignments were inauthentic.

Taken together, these data suggest that time elapsed and additional experiences gained between teaching and reflecting upon these approximations of practice were perhaps important for prospective teachers to gain new understandings of the benefits and drawbacks of these opportunities for learning to teach elementary science. While there are many commonalities between the immediate-response and later-reflection table data, the novel advantages and disadvantages expressed by case study teachers at the end of their methods course semester suggest that in continuing to develop their science teaching practices, they were still assimilating approximation of practice experiences into their schema and instructional repertoire for elementary science investigation lessons.

After their student teaching semester, I again asked case study teachers to comment on the utility of their methods course approximations of practice. In these interviews, case study teachers' comments revealed an increasing emphasis on "practice" and "experience" that was less differentiated in terms of specific approximations of practice. For example, I asked case study teachers: "Have your science teaching experiences from the methods course—the BSSTs, peer teaching, and reflective teachings--been relevant and/or irrelevant to your science teaching as a student teacher, and how so?" Natalie responded,

> I think they've been totally relevant, I really liked how it was set up, how we had just a little like "snapshot" of each part of a lesson, because that really scaffolded us to teach an entire science lesson…after each lesson I just kept seeing different ways that I can improve and grow upon, and hopefully that will continue, I don't ever expect my teaching to be perfect but hopefully I will always be a reflective teacher, but I think it's all been relevant. (Natalie, End W10 interview)

Similarly, Polly stated:

> I thought the reflective teaching was very helpful, it was nice to have a lesson provided to me but really take it, write up a lesson plan, and then teach it and being able to reflect on it, I think reflecting is so important. … And then as for the bite-sized…they were helpful but it was hard to almost jump in, … but being able to ahead of time kind of write about those and focus on those, *that* was important…, I think teaching science and writing about it in any way benefited me just because it was practice, experience, things like that. (Polly, End W10 interview)

Natalie and Polly revealed that their thinking about the methods course teaching experiences emphasized the field-based approximations of practice experiences.

Experience, in general, was often cited as a benefit of the approximations of practice *en suite*, as the following end-of-methods-semester quote from Natalie illustrates:

> MN: If you had to pick one thing from this semester, anything at all, that has helped you learn to teach science the most, what would you say that one thing would be and why?
>
> Natalie: Actually teaching science…because I'm one of those people who can't learn just from reading about it, I have to learn by actually doing it, so I thought it was really helpful. Also I get really bad anxiety before teaching, so it helps cut down on that. I learned the most from the actual practice. (Natalie, End F09 interview)

Not every case study teacher tended to consider the approximations of practice *en suite*, however:

> I feel like the bite-sized really have helped, being able to see the three parts of the lesson, the introduction, the conclusion, and the meat of the lesson, and that kind of helps me to frame the lesson in my mind...so that's been really helpful. And then the experiences we did with…the ones where we did a full lesson…those were very helpful because it was actually teaching full lessons and it was from the same curriculum that I used during student teaching and that got me familiar with science... (Bridget, End W10 interview)

As the above interview responses from Bridget, Polly, and Natalie show, there appeared to be a "privileging" of the field-based approximations of practice in case study teachers' thinking about the utility of approximations of practice in learning to teach science. In the very least, none of these case study teachers explicitly credited the peer teaching approximation of practice as a valuable learning opportunity. Hannah, however, provided a different perspective, citing only the peer teaching experiences in her response:

> MN: Have your science teaching experiences from the methods course—the BSSTs, peer teaching, and reflective teaching--been relevant and/or irrelevant to your science teaching as a student teacher, and how so?
>
> Hannah: I think that the [peer teaching], getting to teach one and getting to see the different ones, especially in the beginning, like setting up a discussion, became really relevant because just some of the people I was with did a really good job and some of the people did a really bad job and so I kind of knew what to avoid and I knew what phrases would kind of felt like were shutting you down and I knew what to stay away from, and then I knew what worked really well, too. And we did a lot of that kind of discussion, that was something that my classroom was very focused on, was like a whole group discussion about what's going to happen, so I feel like it really prepared me for that… (Hannah, End W10 interview)

Again, taken together, these post-student teaching semester data suggest that case study teachers continued to integrate their ideas, confidence, and teaching practices to reflect what they had learned in their approximation of practice experiences. Overall, case study teachers tended to highlight the more authentic approximations of practice—BSSTs and RTs--as valuable contributors to their developing science teaching practices.

## Chapter summary

In Chapter 5 I have presented data from case study teachers' perceptions of the utility of approximations of practice in their learning to teach elementary science investigation lessons. These data were presented in three segments, each centered on a different relative timing between approximation of practice lesson enactment and subsequent reflection. Teacher-to-teacher and within-teacher/across-time similarities and differences in approximation of practice benefits and limitations were noted and briefly described in this chapter. Data suggest that case study teachers' impressions of the utility of approximations of practice in learning to teach elementary science investigation lessons continue to change and develop in concert with their increasing science teaching experience. In the next chapter, I discuss the meaning and implications of the data presented in Chapters 4 and 5 in terms of larger themes relating to prospective teacher preparation, both in elementary science and more generally.

CHAPTER 6

# DISCUSSION AND CONCLUSIONS

## Chapter overview

In this chapter, I consider the data presented in Chapters 4 and 5 in terms of what they mean for the preparation of these case study teachers, specifically, and prospective teachers more generally. Using the evidence generated in this study, I offer answers to the following questions:

- What functions do approximations of practice serve in the preparation of elementary science teachers?
- What is the value added by incorporating approximations of practice into prospective elementary science teacher preparation?
- What are the larger contributions and implications of this study's findings with respect to prospective teacher education in elementary science and other subject areas?

In discussing the meaning of study data as they apply to the three questions above, I situate this work within the larger landscapes of science education and teacher education literature. I also shed light on the contributions of this work to the growing body of knowledge and evidence-based practices in the preparation of effective beginning teachers. Most notably, approximations of practice allowed beginning elementary science teachers to develop instructional approaches, ideas, and confidence for teaching investigation lessons *prior to* their student teaching semester.

**Limitations of this study: caveats and considerations**

This study offers new insights into prospective teacher learning and the role of approximations of practice in the learning and development of four case study teachers. As with any research study, decisions relating to the design and execution of the research necessitate trade-offs in terms of what can and cannot be learned from the data collected. Accordingly, I briefly present three limitations of this study, and suggest ways in which future studies might improve upon this one.

In order to obtain data that were deep, rich, and highly internally-consistent, I chose to pursue a case study format for this research. While studying four case study teachers in-depth did indeed afford deep, rich, and highly internally-consistent data, these data are necessarily unique to the case study teachers as individuals, and do not describe the full range of approximations of practice experiences experienced by other prospective teachers in the methods course. This study, then, suffers from a lack of generalizability inherent to a case study research design. Despite this limitation, however, this study's findings contribute to theoretical understandings of how prospective teachers learn and develop, particularly in the area of teaching elementary science investigation lessons. Future work that examines a greater number of prospective teachers' experiences will be helpful in determining whether and how approximations of practice are more generally useful for a wider range of prospective teachers, as well as provide a broader empirical basis for theories of teacher learning and development.

I also conducted this study as both researcher and teacher educator. This necessarily meant that I was not a neutral party in the research process. Undoubtedly, my input as a teacher educator influenced the course of prospective teachers' learning and outcomes measured in this study, although I tried as much as possible to limit any undue influence on the latter. As their instructor, I formed relationships with each of the case study teachers that differ in substantial ways from the prototypical relationship between researcher and researched. It is possible that many of their responses to interview questions and assignment prompts reflected the teacher/student nature of our relationship, in addition to any personal feelings they may have had toward me. I sincerely believe that the affordances of my relationships with case study teachers outweighed the constraints, as these personal relationships permitted me to establish a rapport with the research subjects by relating to them more frequently and supportively than would have been possible had I functioned solely as a researcher for the purposes of this study. Future studies, however, may benefit from being conducted by those operating solely in a research capacity, as these studies may yield more objective data.

A third limitation of this study owes to its novelty as a design-based study. Approximations of practice, to my knowledge, had not been incorporated into elementary science methods courses as such prior to this work. Accordingly, I had no model upon which to base this work. However, I had the benefit of working with knowledgeable colleagues in the design and execution of methods course approximations of practice. I also benefited greatly from conversations about approximations of practice with my colleague whose dissertation research used the same cross-professional learning framework as an analytical lens to evaluate Winter 2010 master's level elementary science teaching methods course opportunities to learn science teaching practice (Shah, 2011).

As we, the undergraduate methods course planning team, discovered throughout the semester, there were elements of this work that fell short of our vision. For example, prospective teachers were neither comfortable nor skilled in offering constructive criticism to their peers, which Polly alluded to on her posttest as a limitation of the peer teaching experience. Also, as a teacher educator, I was inconsistent in my provision of feedback during peer teaching enactments. Cooperating teachers and prospective teachers alike expressed confusion and frustration over the BSST requirements. While these limitations were recognized and steps were taken to address them during the methods course and in the subsequent year, these limitations were unforeseen and rendered the approximations of practice less effective than they could have been.

Despite these and other limitations, this work offers valuable insights into prospective elementary science teacher learning and development, which I now discuss in more detail.

## Functions served by approximations of practice in elementary science teacher preparation

This study was designed with the idea and intent that approximations of practice would serve several functions in preparing prospective elementary science teachers. In the following subsections, I explore how the data presented in earlier chapters support the claim that approximations of practice helped prepare prospective elementary teachers in three interrelated areas of their developing science teaching practice: instructional approaches, ideas about, and confidence for teaching science investigation lessons.

**Instructional approaches**

One assumption underlying this work was that early science teaching experiences would foster the development of prospective teachers' instructional approaches in teaching investigation lessons. Particularly for those who had not yet taught science, approximations of practice provided a mechanism by which to gain initial science teaching experiences. Furthermore, the reflective teaching assignment parameters and the nature of the bite-sized science teaching assignments (BSSTs) helped to insure that prospective teachers would experience teaching lesson introductions, investigations, and conclusions. For Bridget, Natalie, and Polly, approximations of practice served this important purpose: they provided these case study teachers with their first tastes of what teaching science entails. And for Hannah, approximations of practice provided a new context in which she learned to adapt her previous science teaching skills.

In addition to affording *any* science teaching experience, approximations of practice allowed prospective teachers to work on aspects of instruction that were most relevant to their own developmental needs. For example, Natalie repeatedly mentioned her science teaching experiences allowed her to work on teaching in ways that were responsive to her learners in the moment, and that involved departures from her lesson plan. Natalie acknowledged that her initial science teaching experiences rendered her "frazzled" when aspects of the lessons did not go according to her plan; consequently, Natalie was able to hone in on this aspect of her science teaching and work to develop skills in this area. By contrast, Hannah, the experienced science teacher who was less concerned with management aspects of investigation lessons, focused more on her own discussion moves and ways to support students' productive social interaction during science lessons.

Approximations of practice also permitted case study teachers to "test-drive" perhaps unfamiliar instructional approaches in several different contexts. All case study teachers taught peer teaching lessons that involved scientific modeling, which was a new pedagogy for all of them. In this low-stakes setting, prospective teachers received feedback and additional support on their modeling-based instructional approaches. Bridget, in particular, explicitly acknowledged that she had never used a modeling-based approach prior to doing her peer teaching. After this approximation of practice, Bridget worked to infuse aspects of scientific modeling into her second reflective teaching lesson, gaining additional experience with scientific modeling in a more authentic teaching context. Similarly, Hannah opted to have her students create and use their own scientific models to explain day and night in her second reflective teaching assignment.

**Ideas about investigation lessons**

Approximations of practice gave case study teachers opportunities to put their ideas about teaching investigation lessons into action. This was especially true for Hannah, who expressed strong ideas about student-directed learning in science. In her approximations of practice, Hannah structured her lessons such that students were provided opportunities to explore and discover with the materials, in addition to being asked to conduct a particular investigation or solve a specific problem. In this manner, Hannah was able to apply her science teaching orientations in the enactment of her approximation of practice lessons.

Hannah provided an extreme case of ideas-in-action for several reasons. The other three case study teachers acknowledged that they tended to follow the curriculum materials provided to them rather closely, whereas Hannah tended to use lesson plans as a starting point for her lesson enactments. As the case study teachers revealed in this study, other external factors influenced their instructional decisions and limited their ability to introduce their own ideas about how a particular lesson could or should be taught. Most often, cooperating teachers' preferences, established classroom culture, and prospective teacher/cooperating teacher relationships constrained case study teachers' freedom to modify or overhaul entirely highly-structured lesson plans they were given to teach. Given these constraints and tendencies to follow the curriculum, prospective teachers still tested out their ideas about science instruction in a perhaps more limited way. For example, Polly noted that she lacked experience modifying and enacting modified lesson plans in her field placement classroom because her cooperating teacher did not encourage her to make changes to lesson plans. Despite this constraint, Polly had many opportunities to alter her instructional approaches in the moment of teaching to better respond to her students' emergent needs. In this manner, Polly had unscripted and perhaps unanticipated opportunities to implement her ideas about what would be most effective instructionally.

Perhaps more importantly, approximations of practice provided impetuses for prospective teachers to develop, revise, and refine their ideas about science teaching. Natalie's self-described "rushed" BSST3 underscored for her the importance of dedicating time to concluding discussions in science, and prompted her to think of ways to fit in those all-important sense-making discussions. Bridget and Polly, meanwhile, provided examples of how two case study teachers' ideas about how to best support students in carrying out stepwise investigations developed in different directions across their approximations of practice. Finally, Hannah came to understand that her previous museum-based science teaching experience was not directly transferable to elementary classroom science teaching, and that she needed to accommodate her practice to incorporate new ideas about lesson-to-lesson coherence and advanced lesson planning. In each of these cases, prospective teachers' knowledge of and orientations toward science teaching underwent changes that were grounded in approximation of practice experiences.

**Confidence for teaching investigation lessons**

Case study teachers developed confidence in themselves for teaching investigation lessons as they progressed through their approximations of practice. Carefully-designed approximations of practice contributed to growths in confidence in different ways, however. As case study teachers noted, peer teaching afforded feedback on their science instruction, which provided some reinforcement in terms of what was being done well or needed improvement (and how instruction might be improved). Self-study became more important in field-based approximations of practice, an aspect of these approximations of practice to which Natalie was especially attuned. BSSTs allowed prospective teachers to focus and gain a sense of competency with a portion of science instruction without being overwhelmed by the task of teaching an entire lesson. And full-length lessons—particularly the second reflective teaching and student teaching semester lessons--permitted case study teachers to build on their growing confidence by challenging themselves to succeed in new ways. While case study teachers' approximations of practice trajectories did not follow the logical, scaffolded progression from peer teaching to BSST to reflective teaching, their unique approximations of practice trajectories, nonetheless, did allow them to develop confidence in their abilities to effectively teach science in a piecemeal fashion. This relates closely to the previous point about approximations of practice providing prospective teachers opportunities to focus on improving aspects of science teaching that were most salient to them. And arguably, the end result—increased self-confidence for teaching investigation lessons—mattered more than the order in which approximations of practice occurred.

Approximations of practice also provided prospective teachers opportunities to make and learn from their own teaching missteps, thereby gaining confidence in their abilities to self-diagnose and solve problems with their science instruction. Polly provided the textbook example of this point in her RT2. After teaching this lesson, which she admitted had largely failed to help students learn about refraction, Polly stated that such a lesson-gone-wrong was a useful learning experience for her because she realized her own needs and limitations as a science teacher. She also added that she had learned what was difficult for students regarding the content, and recognized her own need to better prepare herself for investigation lessons. Polly noted that she knew she could do this, and so the experience did not leave her feeling dejected. Rather, Polly viewed her RT2 as a learning opportunity and framed it such that she was still able to proceed as a science teacher with confidence.

**Revisiting (and revising) the theoretical models**

The models proposed in Chapter 2 merit discussion and revision in light of the data collected as part of this study. Recall that these generic models were intended to depict the “typical” prospective elementary science teacher. As described in the literature (e.g., Abell, 2007; Davis et al., 2006) and summarized in Chapter 2, the typical prospective elementary science teacher tends to have weak knowledge of science and science teaching, low levels of confidence for science teaching, and little, if any, science teaching experience. By these measures, Hannah did not constitute the typical prospective elementary science teacher, and was therefore not considered as a “typical” prospective elementary science teacher for purposes of evaluating the initial model.

Additionally, the typical prospective elementary science teacher may be influenced strongly by the ways in which s/he learned science in school, guidance from mentors, and implicit and explicit suggestions for instruction embodied in curriculum materials (e.g., Davis, 2006b; Eick & Reed, 2002; Smagorinsky et al., 2004). These features were illustrated in the model depicted in Figure 2.1, and were largely supported by the cases of Bridget, Natalie, and Polly. A notable exception between Bridget, Natalie, or Polly and the initial generic model concerned the starting confidence level for teaching investigation lessons. The generic model predicted a somewhat lower initial level of confidence for science teaching than that indicated by any of these case study teachers. This difference can be explained by prospective teachers’ initial somewhat naïve overestimations of their confidence levels for teaching elementary science, a sentiment Natalie articulated in one of our interviews. Thus, the initial generic model proposed in Figure 2.1 does a satisfactory job of predicting and reflecting the starting point of typical prospective elementary science teachers.

As indicated in the cross-model analysis presented in Chapter 4, the final theoretical model differed from case study teachers’ models in several ways. Hannah’s end of year model warranted the inclusion of a separate construct to represent her previous museum science teaching experience as a factor informing her beginning science teaching experience. Again, Hannah was atypical among case study teachers, and prospective elementary teachers more generally, and for this reason, Hannah's data suggest that an alternate model of more-experienced prospective science teachers may be warranted.

Returning to the generic end of year model and the end of year models for Bridget, Natalie, and Polly, the most evident difference was in case study teachers' continued reliance on their cooperating teachers' guidance and the classroom curriculum materials in shaping their science teaching practice. The end of year model presented in Figure 2.2 presumed that approximations of practice experiences would provide a greater contribution to prospective teachers' beginning science teaching practices, such that they would, by the study's end, rely less upon guidance from mentors and/or curricular resources in shaping their science teaching. That is not to say that prospective teachers would or should not rely on these important additional factors as resources, but rather, that prospective teachers would draw from other resources in the form of approximation of practice experiences that would presumably dilute or temper the contribution of lesson plan directives and cooperating teachers' suggestions. This contention was not supported by the data, as Bridget, Natalie, and Polly all continued to rely on their cooperating teachers and the curriculum materials (although perhaps to a slightly lesser degree than initially) throughout the study. Coupled with the finding that Hannah tended to *not* rely on her cooperating teacher or classroom curriculum materials as major factors shaping her teaching practice, this suggests that much more science teaching experience is necessary before typical beginning elementary science teachers begin to rely more on internal resources than external resources in shaping their teaching practice. This finding is consistent with findings from a longitudinal study of beginning elementary teachers, which found the very heavy influence of curriculum materials in shaping teachers' practice (Forbes & Davis, 2010b). For these reasons and the data that support them, I offer the revised model depicted in Figure 6.1 as a replacement for the model in Figure 2.2. Again, bold text denotes those elements with prominent contributions.

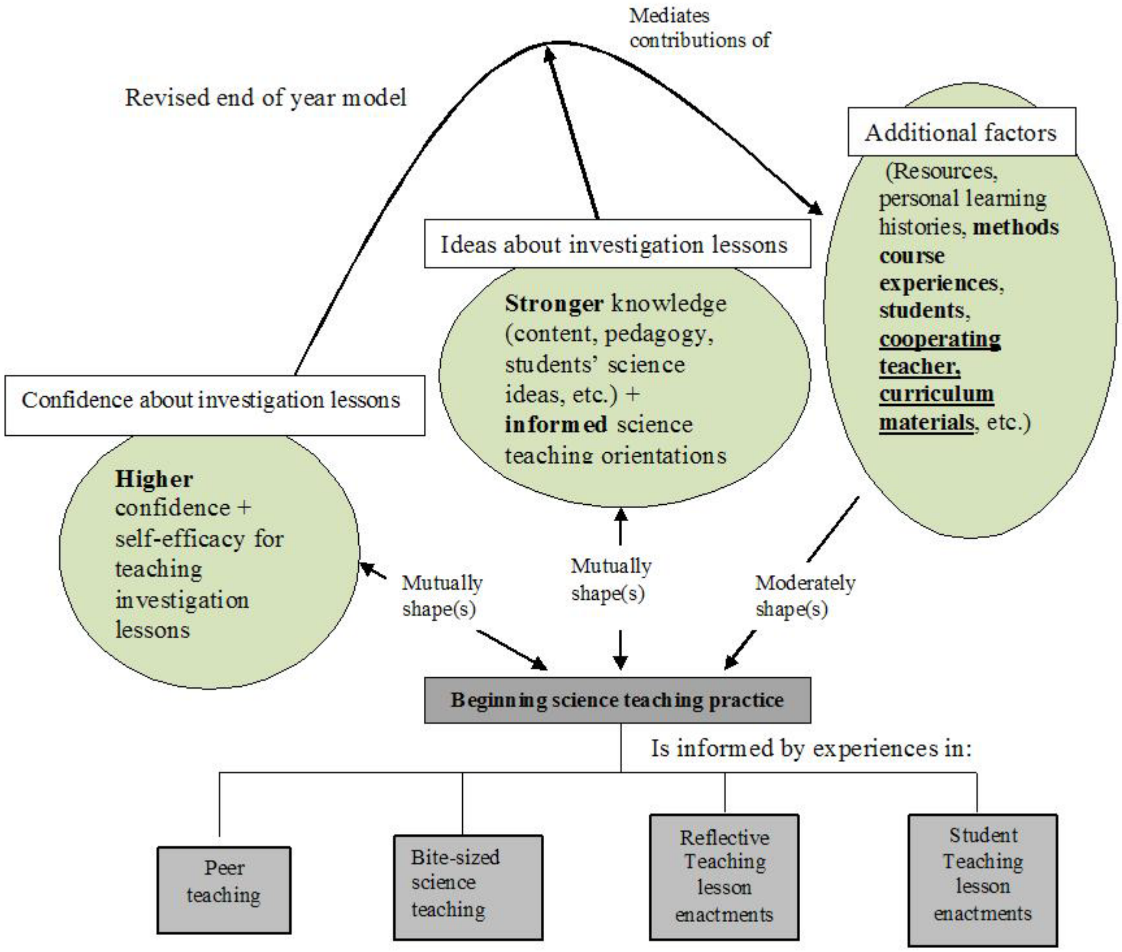



*Figure 6.1* Revised theoretical model illustrating relationships between prospective teachers' ideas about and confidence for teaching investigation lessons, and beginning science teaching practice following completion of methods course and approximations of practice.

As noted, the major difference between this revised model and the model proposed in Figure 2.2 concerns the roles of the cooperating teacher and curriculum materials as factors shaping prospective teachers' science teaching practice following the methods course and student teaching semester approximations of practice. For emphasis, I have underlined this evidence-based revision to the original end of year model proposed in Chapter 2. These changes to the model have two implications for the preparation of beginning science teachers: (1) that different supports and increased coherence between prospective elementary teachers' university-based and field-based science teaching experiences may help prospective teachers begin to rely less on the authority of curriculum materials and mentor teachers and more on their own agency and developing professional judgment (Berliner, 2001), and (2) that an overall increase in the amount of science teaching experience may be necessary before shifts away from close reliance on curriculum materials and/or mentors are evident (Forbes & Davis, 2010b).

**Summary of roles of approximations of practice in the preparation of case study teachers**

In summary, approximations of practice fulfilled a number of important roles in developing prospective teachers' instructional approaches, ideas about and confidence for teaching investigation lessons. For inexperienced beginners, approximations of practice provided an initial foundation upon which future science teaching skills, knowledge, orientations, and confidence might be built. For those with prior science teaching experience, approximations of practice functioned somewhat differently, with more emphasis on further development and refining of science teaching skills, knowledge, orientations, and self-confidence in new contexts. The variability among case study teachers' experiences with their approximations of practice can and should be viewed in a positive light. Unique outcomes from a common set of methods course assignments illustrates how a one-size-fits-all approach to learning to teach science leaves a great deal of room for individual prospective teachers to tailor the suite of experiences to their own particular contexts and needs. In this sense, then, approximations of practice also functioned as a means by which to insure that despite differences in instructional contexts, prospective teachers would have invaluable experience-based opportunities to learn and grow as science teachers.

## Value added by approximations of practice in elementary science teacher preparation

In this section, I elaborate upon the above discussion of this study's findings by connecting them to the existing literature base. In many ways, this work both supports and extends the research base described in Chapter 2. In particular, I discuss the value added by approximations of practice as a set of experiences, as well as considering the value of each type of approximation of practice individually, in the preparation of prospective elementary science teachers.

### Approximations of practice as a set of experiences: Value added

The likelihood that prospective teachers, who spent two afternoons a week in the field during their methods course semester, would witness science instruction is low, especially when trends in the reduction of dedicated instructional time for science are considered (Center on Education Policy, 2008). This likelihood is further decreased when one also considers that science instruction in this district often alternates with social studies instruction and thus, does not happen during every part of the academic year, as many prospective teachers in the methods course learned. Furthermore, whether prospective teachers witnessed cooperating teachers teaching elementary science *investigation* lessons depends on factors such as the classroom science curriculum, availability of resources, the cooperating teacher's instructional preferences, and other factors. Teaching scientific inquiry-oriented lessons, which include investigations, places substantively different demands on classroom teachers than more traditional modes of science instruction (Anderson, 2002; Eick et al., 2005; Jones & Eick, 2007; McGinnis et al., 2004). Taken together, it seems highly unlikely that in the 6 hours a week prospective teachers spent in elementary classrooms, investigative science lessons would be regularly observed.

Approximations of practice, then, provided prospective teachers with multiple exposures to science teaching. Since they were required methods course assignments, prospective teachers were guaranteed that they would witness and/or be part of science teaching on a weekly basis during their methods course semester. As described in Chapter 5, case study teachers appreciated these opportunities to engage with science teaching from the perspectives of teacher as well as student. In this sense, approximations of practice add a common set of teaching experiences to an otherwise hit-or-miss science teaching practicum semester.

**Approximations of practice support teacher development prior to student teaching.** Beginning teachers develop in somewhat predictable ways (Berliner, 2001; Fuller, 1969; Kagan, 1992). Typically, they start out very concerned with the details of their own performance as teachers, which Fuller and others denote “concerns about self” (Conway & Clark, 2003; Fuller, 1969). Classroom management responsibilities can be overwhelming, and demand much of the beginning teacher’s time and effort during lessons. Furthermore, beginning teachers—particularly elementary teachers--often lack confidence in their science instruction, and have difficulty self-identifying as science teachers (Appleton & Kindt, 2002; Kagan, 1992; Luehmann, 2007). After gaining sufficient confidence in themselves as teachers, which usually derives from actual teaching experience, beginning teachers progress to concerns about student learning and their own efficacy in promoting student learning (Appleton & Kindt, 2002; Berliner, 2001; Conway & Clark, 2003; Fuller, 1969).The first year of full-time teaching is often described by beginning teachers in survivalist terms; induction is often “sink or swim” (Feiman-Nemser, 2001; Varah, Theune, & Parker, 1986). In short, learning to teach is difficult work.

Approximations of practice afford prospective teachers a “leg up” when they begin their student teaching semester. While Fuller and others showed that beginning teachers start to transition from concerns about self to concerns about student learning during the student teaching semester (Appleton & Kindt, 2002; Conway & Clark, 2003; Fuller, 1969), shifts of this nature have been observed earlier during teacher preparation (Beeth & Adadan, 2006). My study’s findings support these notions by showing that approximation of practice experiences during the methods course semester can help prospective teachers develop student-learning orientations *prior to* beginning the student teaching semester. Natalie, in particular, demonstrated a shift away from being concerned about her own performance toward a more predominant focus on student learning. As Natalie’s and other data showed, case study teachers made gains in the areas of instructional approaches, ideas about teaching investigation lessons, and self-confidence as science teachers that related directly to their approximations of practice teaching experiences. For example, Bridget, like Natalie, developed classroom management skills, a teacher identity, and self-confidence across her approximations of practice; these developments supported an increased focus on student learning in science. Had case study teachers not engaged in a set of approximations of practice during the science methods course, they would have begun their student teaching in science from a less-prepared, less-informed, and less-effective starting point.

The value a set of approximations of practice adds to beginning teacher development is manifold, as described above. Taken together, approximations of practice permit prospective teachers to advance along their own teacher development trajectories, before having full-time teaching responsibilities. If preparing well-started beginners is the goal of teacher education programs (Avraamidou & Zembal-Saul, 2010; Davis & Smithey, 2009; Hollon, Roth, & Anderson, 1991), approximations of practice may be a key element in advancing current teacher preparation programs.

**Approximations of practice support development of teachers' professional judgment and instructional repertoires.** Approximations of practice, as a set of experiences, also provide a means by which beginning teachers can begin to develop professional judgment and repertoires of evidence-based teaching practices (Dottin, 2009; Traianou & Hammersley, 2008). Discerning and rectifying ineffective instructional practices requires familiarity with the landscape as well as the capacity to imagine and carry out solutions to problems of practice. As described in the expertise literature, these features are characteristic of the transition from "novice" to one who is proficient in a domain (Berliner, 2001; Dreyfus & Dreyfus, 1980; Ericsson et al., 2006). Whether this takes the form of choosing and/or modifying appropriate curriculum materials, or deciding how to manage student off-task behavior, or choosing how to handle errant data during a sense-making discussion, elementary science teachers must make decisions that impact students' learning opportunities, experiences, and outcomes on a daily basis (Forbes & Davis, 2010c; Kern, Bambara, & Fogt, 2002; Nespor, 1987). In this study, Polly provided an example of a teacher who found herself faced with such science teaching dilemmas, including a failed experiment, which demanded in-the-moment changes to instructional approaches. While Polly's responses to these unforeseen glitches were not the most effective for supporting elementary student learning, the situations did serve as "teachable moments" for Polly in their own right by illustrating the importance of solid teacher background knowledge and awareness of alternate representations in the science content being taught. Polly, then, represents a teacher whose instructive missteps serve as opportunities to further develop her vision of effective science teaching through judicious modification of her own teaching practices (Dottin, 2009; Hammerness, Darling-Hammond, & Bransford, 2005).

With an approximations of practice teaching experience base to inform their choices, beginning teachers have a starting point in terms of an instructional repertoire (Smith, 1999), ideas for enacting lessons (Brown, 2009), and the confidence to do so (Appleton & Kindt, 1999). For example, Bridget and Hannah added scientific modeling teaching experiences to their instructional repertoires through enacting their peer teaching and RT lessons. For Hannah, who began the methods semester not knowing what scientific modeling meant, this represented a new idea for how science content could be taught and learned. Bridget, meanwhile, gained additional confidence in her ability to teach science despite not being a science major or minor. Without these experiences, beginning teachers often rely on the authority of theory and/or experienced colleagues (Crawford, 2007; Smagorinsky et al., 2004; van Zee et al., 2003), and/or recommendations in curriculum materials to guide their instructional decision-making (Akerson, Buzzelli, & Donnelly, 2010; Davis et al., 2006; Grossman & Thompson, 2008). Thus, Bridget and Hannah's approximations of practice provided them with teaching experiences that might provide internal, rather than external, guidance for future lesson enactments.

**Approximations of practice offer opportunities to integrate theory and practice.** Integrating theory and practice is another value added by approximations of practice. As discussed in Chapter 1, many have called for an increased focus on teaching practice in the preparation of new teachers (e.g., Ball & Forzani, 2009). Some have studied measures to connect theory and practice by bridging methods course work with field-based experiences (Allsopp et al., 2006; Grossman et al., 2008). Approximations of practice offer one way to integrate what happens in the university with what happens in the elementary classroom (Grossman et al., 2009a). In the approach described in this study, teacher educators, field instructors, and cooperating teachers were active participants in prospective teachers' practice-based learning opportunities. Prospective teachers were supported in making connections among various approximations of practice in several ways, including assignment requirements prompting them to state how they were able to draw upon previous approximations of practice in the enactment of the lesson in question. In addition, prospective teachers made connections between theories discussed in the course and elements of their approximations of practice. For example, Bridget noted that considering science lesson plans in terms of what constitutes (and should constitute) lesson beginnings, learning activities, and conclusions was particularly useful for her in approaching the analysis and modification of science lesson plans that she would then teach in her classroom.

Finally, approximations of practice provided a scaffolded transition (Wood, Bruner, & Ross, 1976) for prospective teachers from to the methods course to their student teaching semesters, in which the university-based support structure was significantly decreased. In our final interview, Natalie, who had no previous science teaching experience when she began the methods course, specifically stated that the approximations of practice had been useful for her because they scaffolded her entry into science teaching. In several ways, approximations of practice served to bridge the gaps between teaching and learning contexts (university and field), temporal teaching contexts (practicum semester and student-teaching semester), and teaching loads (portions of lessons, entire lessons, and for some case study teachers, entire science units).

**Approximations of practice promote conversation and collaboration among prospective teachers.** Finally, approximations of practice provided a forum for the interaction of prospective teachers around instructional approaches, ideas about teaching science, and confidence as science teachers. Particularly in the methods course, prospective teachers had opportunities to converse with one another regarding science instruction and their thoughts and feelings about it during post-peer teaching reflections (Pauline, 1993), as well as weekly class discussions focused on prospective teachers' field-based teaching experiences. This finding is consistent with similar benefits of methods course elements such as these (Choi & Ramsey, 2009; Davis & Smithey, 2009; Howitt, 2007; Ramey-Gassert & Shroyer, 1992; Varma, Volkmann, & Hanuscin, 2009). Practicing teachers also benefit from these types of supports for science instruction (Krajcik, Blumenfeld, Marx, & Soloway, 1994; Palincsar et al., 1998; van Zee et al., 2003).

To further illustrate the benefits of methods course collaborations around approximations of practice, and to show how these ideas, feelings, and practice were interrelated in developing science teaching practices, consider data offered by Bridget and Hannah. Both explicitly acknowledged the recursive relationship between their science teaching practice (which was informed by their orientations about how science should be taught, particularly in Hannah's case) and their confidence as science teachers. Moreover, approximations of practice proved to be highly-generative experiences for prospective teachers in developing aspects of their teaching. Case study teachers gained new ideas, confidence levels, and instructional approaches through the collaborative work entailed in their approximations of practice. Developments in these key areas are crucial to becoming effective science teachers (Appleton & Kindt, 2002; Davis & Smithey, 2009).

### Specific approximations of practice: Value added

I now shift to considering the value added by each different type of approximation of practice in this study. As previously mentioned, experiences and specific benefits varied from individual to individual; however, approximations of practice provided common opportunities for prospective teachers to customize their own experience-based learning.

**Peer teaching: Snapshots of future teaching practice.** The least authentic approximation of practice in this study, peer teaching, was also the most highly-scaffolded approximation of practice. Peer teaching allowed prospective teachers to receive real-time feedback about their instruction from teacher educators as well as their peers (Kilic & Cakan, 2007; Pauline, 1993). Peer teaching also afforded prospective teachers opportunities to focus on engaging their students intellectually, without the typical behavior management concerns associated with actual elementary students. In this manner, the peer teaching approximation of practice provided prospective teachers an opportunity to experience what their own future, highly-effective science teaching might entail once behavior management is no longer a top concern (Stronge, Ward, Tucker, & Hindman, 2007).

Under the guidance of teacher educators, peer teachers were prompted to "rewind and redo" sections of their lessons using more effective instructional approaches. Also, as stated above, peer teachers engaged in science teaching practice without having to worry about managing student behavior. In these respects, the peer teaching approximation of practice served as a means by which prospective teachers could preview aspects of their own visions of themselves as effective and experienced practitioners (Darling-Hammond, Banks, Zumwalt, Gomez, Sherin, & Griesdorn, 2005; Grossman et al., 2008; Hammerness et al., 2005; Luehmann, 2007; Pauline, 1993). By this, I mean that prospective teachers were able to role-play the sorts of ambitious and effective instruction they aspire to realize as experienced practitioners (Lampert, 2005; Lampert & Graziani, 2009). For example, Hannah engaged her peer students in creating three-dimensional scientific models of condensation using a variety of art supplies. After this teaching experience, Hannah noted that such an activity would not be possible in an actual elementary classroom unless students had already proven themselves aware and respectful of norms for working together during science class. Such polite, learning-oriented interaction does not arise spontaneously in elementary classrooms, as we discussed in the methods course, and requires that teachers and students first establish, enact, and enforce ground rules and routines for classroom behaviors (Ghousseini, 2008; Kagan, 1992; Leinhardt, Weidman, & Hammond, 1987). In this manner, then, peer teaching provided prospective teachers a window on and a referent for their own future effective science teaching practice.

**Peer teaching: Food for future reflection.** Whether prospective teachers were aware of this "glimpse of future science teaching practice" during the methods course semester is unknown. However, as the data in Chapter 6 suggests, prospective teachers may continue to re-examine and reframe their early teaching experiences as they continue in their teaching careers. As many have shown, reflection is a key element of beginning teachers' learning and development (e.g., Davis, 2006a; Kagan, 1992; Loughran, 2002; Peterson & Clark, 1978; Zeichner, 1987). As they gain a level of comfort with the many demands they will encounter during their induction years (Davis et al., 2006; Feiman-Nemser, 2001; Kagan, 1992), these teachers might recall their peer teaching experiences and recast them as existence proofs of their own abilities to effectively carry out progressive pedagogies in science. In particular, these case study teachers might reflect on the scientific modeling-based pedagogies they used as peer teachers to remind themselves that they are capable of ambitious science teaching (Windschitl et al., 2008a). They might also use memories of these experiences as the basis for revising and refining their science teaching practice, challenging themselves to incorporate different instructional approaches into their science teaching repertoires. In a sense, then, the data presented in Chapter 5 suggest that there might still be additional, future value in case study teachers' reflections upon their peer teaching approximations of practice. As post-student teaching semester interview data showed, Hannah, in particular, expressed a greater appreciation for her peer teaching experiences in describing how they impacted her thinking about instruction.

**Peer teaching: Opportunities to co-plan lessons.** Peer teaching also afforded prospective teachers an opportunity to co-plan with their peers (who would be simultaneously teaching the same lesson) and a teacher educator. In these co-planning sessions, lesson plans were discussed and the teacher educator highlighted important learning goals, offered suggestions, and engaged prospective teachers in brainstorming about instructional approaches. The value added by this element of the peer teaching experience should not be underestimated, since it allowed prospective teachers access to more expert thinking about how to approach the enactment of the lesson (Berliner, 2001; Krajcik et al., 1994; Smith, 2005), as well as access to colleagues' thinking about how to teach the lesson. Of the prospective teachers represented in this study, Hannah was the most vocal about the benefits of co-planning.

**Peer teaching: Aspects of a community of practice.** Finally, peer teaching in the methods course provided a forum for the post-enactment dissection of the teaching experience (Pauline, 1993). Peer teachers received feedback from teacher educators as well as their peers, and reflected upon their recent experiences. Peer teachers verbalized their own thinking about their instruction, and were able to hear their "students'" impressions of how effective their instructional approaches were (Kilic & Cakan, 2007). This sort of feedback was unique to the peer teaching approximation of practice in both its immediacy as well as its substance. As shown in Chapter 5, case study teachers acknowledged both the affordances and the limitations of this peer- and teacher-educator feedback on peer teaching. Although imperfect, the co-planning, enactment, and co-reflection that comprised peer teaching positioned prospective teachers as members in a joint enterprise, functioning together in the development of a shared repertoire of resources (Wenger, 1998). In this manner, the methods course peer teaching component provided aspects of a community of practice for prospective elementary science teachers (Cochran-Smith & Lytle, 1999; Lave & Wenger, 1991; Palincsar et al., 1998; Smith & Anderson, 1999).

**Peer "studenting:" Observing peers' instructional approaches.** While most of the focus in this study has been on the peer *teacher's* perspective in these less-authentic approximations of practice, the peer *student's* perspective was also extremely valuable for prospective teachers (see Table 5.5). In this role, prospective teachers had the benefit of their colleague's science teaching as a representation of practice (Grossman et al., 2009a). Hannah, in particular, noted the utility of witnessing her peers' instructional approaches in their peer teaching lessons; it was a generative experience for her own thinking about science instruction.

In addition to providing insight into their colleagues' instructional approaches, peer teaching, from the peer student's perspective, was valuable as a "reminder" of what elementary science lessons are like from the learner's perspective (Howes & Cruz, 2009). It was also an important aspect of this approximation of practice because it had been a long time since prospective teachers had experienced elementary science as learners themselves. Polly and Bridget described their more-recent high school and college-level science learning experiences as having "turned them off" to science. Not surprisingly, many prospective elementary teachers express similar sentiments as reactions to the science instruction they experienced as learners (Appleton & Kindt, 1999; Eick & Reed, 2002; Skamp & Mueller, 2001). In the role of peer students, then, prospective teachers had opportunities to acquaint or reacquaint themselves with forms of science learning that were more accessible to younger students, and aligned with current science education reform efforts (Pauline, 1993; Timmerman, 2004).

**Peer “studenting:” Thinking like an elementary student.** Another value added by the peer student role was its affordance in acquainting prospective teachers with elementary student thinking in science (Driver, Guesne, & Tiberghien, 1985; Howes & Cruz, 2009; Otero & Nathan, 2008). Recall that in the methods course, prospective teachers were assigned typical and reasonable alternative ideas about condensation. In the student role, prospective teachers were challenged to adopt this less-sophisticated and/or non-normative scientific idea, and to imagine how an elementary student might have arrived at this thinking. Additionally, prospective teachers were instructed to hold that alternative idea until confronted with evidence that necessitated changing their thinking. At that point, prospective teachers were asked to consider whether, how, and why an elementary student might go about changing his/her thinking, and approach this work “in character.” As case study teachers indicated, this cognitive task was challenging and highly useful for them in thinking about instruction from the students’ perspective (see Table 5.5). Thinking like an elementary student was explicitly noted by Natalie and Polly as being an affordance of the peer student experience. Thus, the peer student role helped prospective teachers examine closely the nature of scientific reasoning from an evidence-based perspective, which in turn, prompted them to consider their own instructional approaches to providing learning opportunities that would support students in arriving at normative scientific understandings (Beeth & Hewson, 1997; Driver, Asoko, Leach, Mortimer, & Scott, 1994).

**Peer "studenting:" Vicarious teaching experience.** Finally, the peer teaching approximation of practice, from the peer student's perspective, provided value as a "vicarious" teaching experience (Bandura, 1994; Brand & Wilkins, 2007; Palmer, 2006). Most representations of practice in the form of videos and observations of experienced teachers do not provide a mechanism for the interaction of teacher and observer, during or after the representation of practice. Moreover, representation of practice teachers and prospective teachers may not know one another or feel comfortable sharing their impressions of the experience. In the methods course, peer teachers and peer students co-experienced and co-reflected upon the approximation of practice. As colleagues and co-learners, peer teachers and peer students were uniquely positioned to envision and learn from each others' teaching experiences (Brand & Wilkins, 2007; Lave & Wenger, 1991; Palmer, 2006; Smith & Anderson, 1999). For example, Hannah wrote that the peer student role afforded her opportunities to observe science instruction that was effective and ineffective, depending on how instruction was approached. Implicit in Hannah's statement is an evaluative component, which suggests that she may have envisioned herself improving upon what she perceived as ineffective instructional approaches by her peers.

**Bite-sized science teaching: Focusing on lesson elements and valuing each part of a science lesson.** As described, these medium-authentic approximations of practice entailed teaching portions of science lessons in elementary classrooms, which allowed prospective teachers to focus on enacting deconstructed elements of science lessons with young learners. In the previous chapters, case study teachers articulated the value of carefully thinking about, planning for, and experiencing teaching discrete portions of science investigation lessons. Of particular value in this approximation of practice was the emphasis placed on investigation lesson conclusions, as this portion of science lessons is often underemphasized (Jiménez-Aleixandre, Bugallo Rodríguez, & Duschl, 2000; Lewis, 1998). Natalie especially acknowledged the importance of lessons conclusions after experiencing a "rushed" BSST3 that did not meet her standards for an effective investigation lesson conclusion.

Having to plan, conduct, and reflect upon each portion of a science lesson helped to emphasize the individual aspects of science teaching and learning that comprise investigation lesson introductions, learning activities, and conclusions. In addition, experience doing this work helped case study teachers to recognize the relevance of each portion of the lesson to the overall lesson goals and objectives. Here, the value added is twofold. First, this study's findings suggest that this approximation of practice supports prospective teachers' recognition of and commitment to creating coherent, complete, and effective investigation lessons. As Bridget stated, these were important benefits of the BSST approximations of practice that framed her thinking about science teaching in general and her analysis of lesson plans. Second, there is value added in terms of understanding prospective teacher learning to engage in science teaching practice, since research studies focusing on prospective teachers learning to enact science lesson portions are currently lacking in the literature.

**Reflective teaching: Authentic teaching challenges ideas and boosts confidence.** As the most authentic approximations of practice during the methods course semester, RTs provided opportunities for prospective teachers to experience the work involved with teaching an entire investigation lesson in elementary science. Prospective teachers cited these opportunities as particularly valuable to their learning to teach science, as they most closely resembled the day-to-day work of teaching science in an elementary classroom. Other sources of value added by the RTs lie in the isolated nature of their experiences as approximations of practice. Prospective teachers completed two RTs during the methods course semester. As Polly and Bridget stated, having two opportunities to teach full-length science lessons in their field placement was extremely valuable because it permitted them to apply what they had learned from their initial RT experience to their second RT lesson. This is not surprising, given the nature of this assignment and its empirical basis (Davis & Smithey, 2009; Zembal-Saul et al., 2000).

Having had two temporally distinct RT experiences during the methods course semester also added value in terms of challenging prospective teachers' ideas about science instruction and boosting their self-confidence for science teaching. As approximations of practice, these opportunities lacked complete authenticity to classroom science teaching, however, in that prospective teachers were asked to consider the lessons at the lesson-level rather than the unit-level. This was somewhat frustrating, as Polly noted on her final exam; she was unable to assess whether students retained the material she taught them. However, RTs provided prospective teachers a sense of science teaching at a functional unit of analysis—the science lesson.

**Student teaching semester science lessons: Fading scaffolds.** The most authentic approximation of practice in this study took place during the student teaching semester, in the absence of methods course support structures. Student teaching lessons, then, afforded prospective teachers opportunities to teach science lessons in a "scaffolds-fading" context (Eick et al., 2005; Wood et al., 1976). While there was a great degree of variability in terms of case study teachers' science teaching experiences during their student teaching semester—some taught entire science units whereas others taught isolated lessons, some taught solo whereas others' cooperating teachers assisted with lessons—these experiences uniformly added value in the form of additional, highly-authentic science teaching experiences that informed prospective teachers' developing instructional repertoires, ideas about, and self-confidence for science teaching. For example, Bridget's opportunity to assume responsibility for all science instruction during her student teaching semester contributed to her evolving and increasingly realistic ideas about herself as a beginning science teacher.

**Summary: Value added by approximations of practice**

In summary, approximations of practice added significant value to prospective teachers' learning about and how to teach elementary science. Each type of approximation of practice added value uniquely owing to the particulars of the approximation of practice, whereas *en suite,* approximations of practice afforded prospective teachers individualizable opportunities to gain and learn from their own science investigation lesson teaching experiences.

## Dissertation research questions, revisited

In this section, I summarize the findings presented in Chapters 4 and 5 and discussed earlier in this chapter as answers to my original research questions.

*1. How do prospective elementary teachers engage in approximations of science teaching practice that involve investigation lessons?*

*1a. In the approximations of practice, which key features of investigation lessons are possible and which are evident during enactment? What instructional approaches do prospective teachers use to achieve these key features in their enactments?*

In general, case study teachers incorporated most anticipated key features but often failed to incorporate instructional approaches associated with Supporting students in creating evidence-based claims. Typically, instructional approaches were teacher-directed in nature for Introducing the investigation purpose(s) and Establishing data collection procedures, and tended to be more student-directed for Fostering students' sense-making with data and Connecting the investigation lesson with students' knowledge, ideas, and experiences.

*1b. To what extent are the instructional approaches for a key feature of investigation lessons consistent across approximations of practice?*

For a given case study teacher, some key features' instructional approaches were highly consistent across approximations of practice (e.g., Polly and Establishing data collection procedures) whereas other key features' instructional approaches showed somewhat more variation across approximations of practice (e.g., Bridget and Connecting the investigation lesson and students' knowledge, ideas, and experiences). This differed from case study teacher to case study teacher.

*1c. What relationship, if any, is apparent between the instructional approaches for a key feature of investigation lessons and the degree of authenticity of an approximation of practice?*

There was no apparent relationship between instructional approaches for key features of investigation lessons and the degree of authenticity of the approximation of practice with one notable exception. Peer teaching approximation of practice instructional approaches tended to be more student-directed and incorporated modeling-based instructional approaches more often (in general) than field-based approximation of practice instructional approaches. This likely reflects major differences in approximation of practice contexts (i.e., peers versus elementary students) and curriculum materials (i.e., scientific modeling unit lesson plans on condensation versus Science Companion lesson plans).

*2. How do prospective elementary teachers' ideas about and confidence for teaching science investigation lessons change as they engage in approximations of practice?*

> *2a. What ideas about teaching science investigation lessons do prospective elementary teachers hold and how do these ideas change during the final year of teacher education?*

In general, case study teachers began the study holding ideas about investigation lessons that promoted student-directed, hands-on science learning. Their ideas became increasingly grounded in their own teaching experiences throughout the study, and came to reflect the realities and particulars of elementary classroom science instruction.

> *2b. What are prospective elementary teachers' confidence levels for teaching science investigation lessons, and how do these change during the final year of teacher education?*

Although three of the four case study teachers initially expressed confidence in their abilities to teach investigation lessons, their confidence levels changed once they engaged in approximations of practice. Some case study teachers realized that their initial confidence levels were naïve and lacked awareness of the practical challenges involved in science teaching. Regardless of whether their initial confidence levels were overrated, all case study teachers expressed increases in their confidence for teaching investigation lessons by the end of the study.

*2c. How do prospective elementary teachers describe changes in their (1) ideas about and (2) confidence for teaching investigation lessons? To what do they attribute these changes?*

Case study teachers attributed changes in their ideas and confidence regarding investigation lessons to their approximation of practice experiences, as well as the influence of curriculum materials, cooperating teachers, and other factors. Case study teachers were highly metacognitive and reflective about changes in their ideas and confidence for teaching investigation lessons.

*3. How do prospective elementary teachers' instructional approaches, ideas, and confidence levels compare across their approximations of practice?*

All case study teachers developed more student-directed aspects of teaching investigation lessons in the form of instructional approaches for certain key features of investigation lessons. These key features and instructional approaches varied by individual (e.g., Polly and Bridget addressed supporting students in Establishing data collection procedures and Fostering sense-making with investigation data in different ways). Some case study teachers added new ideas about teaching investigation lessons from their approximation of practice experiences (e.g., Bridget and Hannah incorporated scientific modeling pedagogies in field-based approximations of practice) while other case study teachers reaffirmed and refined existing ideas about teaching investigation lessons (e.g., Natalie developed a deeper, experiential understanding of working with students' ideas in science). All case study teachers experienced challenges to their confidence regarding aspects of science teaching during one or more approximations of practice; however, overall all case study teachers developed higher levels of confidence for teaching science investigation lessons.

*4. What do prospective teachers perceive as the benefits and limitations of approximations of practice for learning to teach science investigation lessons?*

Case study teachers tended to privilege the more highly authentic approximations of practice (i.e., full-length science lessons in field settings) as tools to enable their learning to teach science. Peer teaching was viewed as helpful but limited due to teacher and student role-related inauthenticities. Prospective teachers' impressions of approximations of practice utilities changed over time and as they gained more teaching experience.

## Study contributions and implications

In this section, I describe what this work adds to the field of educational research, in the areas of science teacher education and teacher education more broadly. I also explore what this study's findings mean for prospective elementary teacher preparation and teacher educators moving forward.

## Contributions

As a study of prospective elementary science teacher learning, this study contributes to the fields of science teacher education and educational research in many ways. In the following section, I outline specific findings this study contributes to the growing understanding of prospective elementary science teacher practice-oriented learning and development.

**Contributions to elementary science teacher education.** This study represents an initial application of Grossman and colleagues' cross-professional learning framework within the context of the undergraduate elementary science teaching methods course. As such, it extends the work done by Grossman and colleagues by examining how approximations of practice can support the development of profession-specific, interactive discourse *and* the execution of important non-discursive elements of professional practice. In this study, prospective teachers approximated science teaching practice in ways that entailed the use of language while also engaging in aspects of time and investigation materials management and scientific practice. Study of these non-discursive elements of science teaching practice, coupled with the integration of discursive and non-discursive components of science teaching practice, represent a departure from Grossman and colleagues' focus in their approximations of practice studies.

As an initial intervention, this study provides a starting point for future uses of representations, decompositions, and approximations of practice in the preparation of prospective elementary science teachers. The findings from this study, then, suggest that structuring elementary science teacher education in ways that support and offer opportunities to examine and engage in teaching practice from a clinical perspective have positive outcomes for prospective elementary teachers' instructional approaches to, ideas about, and confidence for teaching investigation lessons in elementary science. Additionally, the study's findings suggest areas that might benefit from redesign efforts and other improvements. For example, the peer teaching approximation of practice in this study could be improved by providing additional guidelines for carrying out the teacher and student roles, and by having the teacher educator make explicit the rationales for and benefits of this approximation of practice for both teacher and student roles. By introducing these improvements, prospective teachers would be better positioned to engage in the approximation of practice in ways that maximize learning outcomes from these experiences.

This work also contributes to the bodies of research and practice in science teacher education in ways that illuminate how beginning elementary teachers can learn to successfully engage in the complex work of teaching investigation lessons, an area that is currently underexplored in the literature (e.g., Avraamidou & Zembal-Saul, 2010). Adding to Avraamidou and Zembal-Saul's work with first year elementary teachers (2010), my findings indicate that prospective elementary teachers can make important progress during the methods course and student teaching semesters in their instructional approaches to, ideas about, and confidence for teaching investigation lessons. As the literature base reveals, inquiry-oriented science teaching is challenging for beginning teachers (see Chapter 2), and less-than-successful attempts to teach science in reform-oriented, learner-directed ways often result in reversion to more traditional, teacher-directed science teaching methods (Gee & Gabel, 1996; McGinnis et al., 2004; Roehrig

& Luft, 2004). This study's findings that prospective teachers begin to show progress in addressing the key features of investigation lessons in ways that are consistent with guided inquiry and inquiry science teaching orientations (Magnusson et al., 1999), and support students in engaging in authentic scientific practices (Ford & Wargo, 2007; National Research Council, 2010), are particularly encouraging in terms of the potential they suggest for introducing reform-oriented science teaching in elementary classrooms, particularly if induction programs provide continued science-oriented support (Roehrig & Luft, 2006). That case study teachers were able to take on the multiple demands of teaching investigation lessons and experience increases in confidence for science teaching while also recognizing and articulating the benefits of investigation lessons for students' science learning suggests that these positive experiences will continue to inform their orientations toward science teaching as they become classroom teachers in their own right.

This study's findings also shed light on which authentic science practices are particularly difficult for prospective elementary teachers to implement in their teaching practice (Ford & Wargo, 2007). As the case study data indicate, prospective teachers, for various reasons, often did not incorporate the key feature of supporting claims with evidence in their approximations of practice. This finding corroborates others' findings that suggest the importance of well-designed teacher supports for successful incorporation of evidence-based explanations in science classrooms (e.g., Avraamidou & Zembal-Saul, 2005; Beyer & Davis, 2008). Additionally, my findings indicate that although this aspect of science teaching was discussed in the methods course, improvement in this course element is warranted to help prospective teachers effectively support students in crafting evidence-based claims in an investigation lesson. More generally, the data suggest that prospective teachers may not know how to achieve some of the key features of investigation lessons using less teacher-directed instructional approaches. Consequently, teacher educator modeling more student-directed approaches as part of a methods course lesson plan analysis and/or a mock teaching exercise, coupled with teacher educator metatalk to verbalize instructional decisions and their rationales, might help support prospective teachers' increased awareness of these alternative instructional approaches, and envision how to incorporate them into their own teaching practice (Shah, 2011).

**Contributions to teacher education theory and practice.** As this work shows, approximations of practice can provide a range of learning opportunities and learning outcomes for prospective teachers. In this study, approximations of practice assignments were required of all prospective teachers, regardless of field placements or other considerations. In this manner, the assignments had a "one size fits all" element, into which a significant degree of flexibility had been engineered to insure that each prospective teacher could adapt the assignment particulars to the affordances and constraints of his/her unique field setting. Despite the uniformity of the assignment across prospective teachers, learning opportunities and learning outcomes varied a great deal in concert with the details of approximation of practice lessons, contexts, and other considerations. For example, Polly indicated that she did not feel comfortable modifying lesson plans given to her by her cooperating teacher, and tended to enact them as written. As a counterexample, Hannah stated that she used the lesson plan as a general guideline for what the lesson should entail, but did not feel compelled to enact the lesson plan as written. These two case study teachers, then, experienced very different learning opportunities in their field-based approximations of practice, particularly in terms of modifying and enacting modified lesson plans. Reflection data on indicated that learning outcomes for these two case study teachers were also quite different: Hannah was much more confident than Polly in her ability to make and enact productive modifications to lesson plans.

Situated and sociocultural learning theories purport that each prospective teacher's experience, learning, and development would be unique and reflect the details of approximation of practice components, culture, and contexts (Brown et al., 1989; Edwards & Protheroe, 2003; Putnam & Borko, 2000). This study's findings uphold these notions, and specifically indicate aspects of prospective teachers' beginning teaching practice that benefit from a range of differently-situated learning opportunities.

What is perhaps surprising about this study's finding is the highly individualized nature of the knowledge and experience case study teachers gained from their approximations of practice. No two case study teachers' approximations of practice enactments or reflections were identical, and despite constraints that were both real and perceived, each case study teacher focused on elements of science teaching that were most salient to her as a developing science teacher. In this regard, then, approximations of practice provided some opportunity for self-directed learning (Butler & Winne, 1995; Schraw, Crippen, & Hartley, 2006; Zimmerman, 1998), which was an unforeseen benefit of this suite of experiences.

Another contribution of this work to teacher education theory and practice more broadly concerns findings that illuminate how prospective elementary teachers view and value different aspects of approximations of practice. In examining case study teachers' perceptions of approximation of practice utility, this study provides an underexplored perspective on teacher learning from simulated teaching experiences: that of the prospective teacher (Howes & Cruz, 2009). Gaining this insight is instrumental to the design and execution of effective learning opportunities in teaching methods courses (e.g., Britner & Finson, 2005). As this study shows, case study teachers appreciated the various approximations of practice for the learning opportunities they afforded, and often noted different benefits deriving from their experiences. For example, Natalie noted the utility of feedback from teacher educators and her peers in the peer teaching approximation of practice. Bridget, meanwhile, added that gaining experience with scientific modeling pedagogy was an affordance of her peer teaching experience.

Examining prospective teachers' perceptions also illuminated ways in which approximations of practice may have missed the mark, which is valuable to the improvement of these learning opportunities. For example, Polly pointed out that it was difficult to get critical feedback from her peers because nobody wanted to hurt anyone's feelings; this led to a re-examination of how teacher educators trained and supported prospective teachers in providing useful, critical feedback in the subsequent year's methods course.

Finally, this study's findings revealed that prospective teachers viewed approximations of practice utilities through unique lenses colored by their own perceptions of their developmental needs. Hannah, for instance, valued the reflective teaching assignment because it provided her an opportunity to work on planning lesson enactment in advance, an area of perceived developmental need. Natalie, meanwhile, repeatedly spoke of the ways in which approximations of practice helped boost her confidence as an inexperienced science teacher. These findings have important implications for teacher educators, who should be mindful of individual prospective teachers' perceived needs and who should challenge and support prospective teachers to take advantage of approximations of practice in light of other, perhaps less obvious, developmental opportunities they offer, such as the ability to try out challenging and unfamiliar pedagogies.

A third novel contribution of this work to teacher education theory and practice focuses on the ways in which approximations of practice experiences continue to inform prospective teachers' thinking and practice in different ways over time. As the case study teachers' end of year models indicate, their approximations of practice were shaped by ideas about investigation lessons, confidence for teaching investigation lessons, and other factors; and vice versa (these constructs were also shaped by their approximations of practice). The degree to which each model component influenced and was influenced by another model component varied from individual to individual. When enacting and later reflecting on their approximations of practice, case study teachers integrated contributions from these various model components to create their own impressions of how to teach and, subsequently, how to process the teaching experience. Studies of reflection in preservice teacher learning illustrate how reflection upon learning opportunities can benefit beginning teachers (Conway & Clark, 2003; Davis, 2006a; Loughran, 2002; Zeichner, 1987). This study's findings support the importance of reflection upon beginning teachers' learning, and suggest that prompted reflection at different time points after learning opportunities can reveal ways in which prospective teachers continue to reframe and reintegrate their approximation of practice knowledge and experiences as they continue to develop as teachers (Davis, 2004; Linn, Davis, & Eylon, 2004). Moreover, such opportunities for stimulated reflection may promote reframing and reintegration of these experiences; further studies are needed in this area.

Finally, it is important to reiterate that the information gleaned from this study simultaneously supports, informs, and extends theories of teacher learning and development in elementary science and more broadly. For example, the finding that approximations of practice were linked to case study teachers' transitions to concerns about student learning both supports current understandings of teacher learning and development (Appleton & Kindt, 2002; Fuller, 1969) and builds upon them by illuminating one way in which practice-oriented opportunities to learn science teaching can support and perhaps accelerate prospective teacher development (Beeth & Adadan, 2006). While the theoretical models in Chapter 2 were applied to this specific study, applications of these models should not be limited to prospective elementary science teachers. Additional studies involving approximations of practice in the preparation of teachers in other disciplines will reveal whether this model receives more general empirical support.

**Implications**

Findings from this study have important implications for the preparation of elementary science teachers, specifically, and teachers in general. One major implication of this work is that opportunities to engage in approximations of practice present tremendous learning opportunities for prospective teachers, therefore, approximations of practice and other "pedagogies of enactment" (Grossman & McDonald, 2008) should be mainstays of teacher education programs. In this study, prospective teachers learned *about* and *to do* the work of teaching scientific investigation lessons in elementary school classrooms by engaging in a range of simulated teaching experiences. Such opportunities to directly engage in the work of teaching were related to improvements in instructional practices, self-confidence for effectively teaching investigation lessons, and more learner-centered ideas about science (Bhattacharyya et al., 2009; Brand & Wilkins, 2007; Palmer, 2006; Timmerman, 2004). Because this study's design was not experimental in nature, it cannot be concluded whether such gains would have been realized in the absence of approximations of practice, or the presence of an alternate intervention. However, case study teachers attributed much of their development as beginning teachers to these teaching experience-oriented opportunities, which suggests that they are crucial to the outcomes observed in this study (Hancock & Gallard, 2004).

Another implication of this work is that early opportunities to develop teaching experience may help prospective teachers make additional progress toward proficiency (Beeth & Adadan, 2006; Ericsson, Krampe, & Tesch-Römer, 1993; Fuller, 1969). Teacher development trajectories have been well-studied, and experience has been shown to play an important role (Appleton & Kindt, 2002; Conway & Clark, 2003; Fuller, 1969). In other performance-related fields, expertise is developed through deliberate practice, range of experiences, and metacognitive reflection (Ericsson et al., 2006). Accelerating prospective teachers' progress from novice toward proficient beginning practitioner through the use of approximations of practice and similar practice-based pedagogies has far-reaching implications in terms of connecting instructional quality and student achievement (Stronge et al., 2007).

This study's findings also have implications for teacher educators and teacher education programs, for several reasons. First, the findings imply that teacher educators should consider incorporating approximations of practice into their methods courses. Making approximations of practice part of the curriculum, however, is no small task. In addition to figuring out how to train prospective teachers to engage in the work, teacher educators must gain cooperating teachers' buy-in, and must educate and prepare themselves for the effective, educative use of approximations of practice in methods courses. In hindsight, this was a more complex task than I had initially envisioned, and case study teachers' feedback revealed many areas for continued improvement. For example, future versions of these methods course approximations of practice could benefit from the following revisions:

- Provide more structure/definition around peer teaching roles for prospective teachers as well as teacher educators
- Work to get cooperating teachers and university teacher educators to a shared understanding of the rationales for field-based approximations of practice and agreement on what execution of these assignments entails
- Articulate the support roles and responsibilities of cooperating teachers and teacher educators in the execution of approximations of practice
- Incorporate videorecording of approximations of practice to permit prospective teachers' self-study and facilitate reflection upon practice
- Continue to design methods for prompted reflection and other scaffolds to support prospective teachers in integrating their approximation of practice experiences into a personal schema for science teaching

While this list is hardly exhaustive of the possible improvements that could be made to the approximations of practice in this study, it provides some starting places for future revisions.

Second, as indicated in the list above, this work implies that even closer connections between university courses and field-based practica are warranted to improve approximations of practice (Allsopp et al., 2006; Grossman et al., 2008). As case study teachers revealed, logistical concerns and cooperating teachers' lack of buy-in to and/or understanding of the assignments generated difficulty in scheduling and enacting field-based science lessons, which translated into missed or compromised learning opportunities. More generally, variation among approximation of practice contexts, participants, and other elements yielded very different learning opportunities, experiences, and outcomes for prospective teachers, which may have resulted in inequities. Differences between university-based approximations of practice and field-based approximations of practice may have contributed to prospective teachers' sustained reliance on cooperating teachers and curriculum materials in shaping their science instruction. For example, Polly revealed her inexperience with and lack of confidence for modifying and enacting approximations of practice lesson plans in the field, largely because her cooperating teacher discouraged this aspect of science teaching in her classroom. By contrast, Hannah's cooperating teacher allowed Hannah a great deal of freedom in determining what lessons would entail, as long as the lesson objectives were satisfied. As their teacher educator and peer teaching co-planner, I advocated for peer teaching lesson plan analysis and modification in principled, criterion-supported ways. By working together more closely, cooperating teachers, university teacher education personnel, and prospective teachers could co-construct a more coherent, comprehensive, and equitable set of learning opportunities for prospective teachers in their field-based approximations of practice (Akerson et al., 2010; Grossman et al., 2008). Additionally, involving university-level science content educators in the conversation and co-construction of approximations of practice would help insure that the integrity of scientific practices are maintained even as they are adapted for educational purposes in elementary classrooms (Ford & Wargo, 2007).

Finally, this study's findings suggest that prospective teachers may benefit from additional support in the form of stimulated reflection upon approximation of practice experiences. As the data showed, prospective teachers continued to revise and reframe their thinking about their approximations of practice over time. A combination of open-ended and targeted reflective prompts (Davis, 2003a) coupled with the use of videorecordings of prospective teachers' approximations of practice (e.g., Peterson & Clark, 1978) may provide additional support for continued prospective teacher learning and development in conjunction with approximations of practice. Moreover, such supports could be integrated into the student teaching semester and throughout induction to sustain and extend the benefits of approximations of practice experiences. Thus, prompted reflection in conjunction with approximations of practice could mutually support the development of beginning teachers' science teaching practice (Conway & Clark, 2003).

**Summary of study contributions and implications**

In summary, I have identified several of this study's contributions and implications for teacher education, in elementary science and more broadly. Within elementary science teacher education, this work shows how approximations of practice can be useful in supporting prospective teachers' learning how to negotiate the many demands of teaching investigation lessons that entail inquiry and authentic scientific practices. Moreover, the findings showed that prospective elementary science teachers made important gains in their instructional approaches, ideas about, and confidence for teaching investigation lessons *prior to* student teaching.  Additionally, this work sheds light on which key features of investigation lessons present enactment challenges for prospective teachers, who are simultaneously gaining experience and developing ideas and confidence for teaching investigation lessons. Implications of these findings have suggest that well-designed improvements to existing methods course approximations of practice may enable prospective elementary science teachers to develop science teaching skills, ideas, and confidence to even greater levels prior to beginning student teaching.

Within the broader landscape of teacher education theory and practice, this study's findings show that approximations of practice provide a range of learning opportunities, experiences, and outcomes that differ on the basis of contextual and situational details. This finding has widespread implications for teacher learning theory and practice that include considerations of equitable learning opportunities for prospective teachers. Another contribution of this work is that prospective teachers view and value different aspects of approximations of practice, often highlighting those aspects that are most salient to their perceived developmental needs. An implication of this finding is that teacher educators should familiarize themselves with prospective teachers' individual needs—both perceived and not-yet-perceived by prospective teachers—and support prospective teachers' development in multiple areas through their approximations of practice. Finally, this study shows that approximation of practice experiences continue to inform prospective teachers' thinking and practice in different ways over time. Strategic, prompted reflection upon approximation of practice experiences, perhaps coupled with videorecords of practice, in the student teaching semester and beyond may provide a new form of support for continued teacher learning and development.

## Directions for future research

As this study's findings indicate, there are several areas ripe for additional study concerning the roles played by approximations of practice in the preparation of elementary science teachers. One area for further study concerns the longer-term value of approximations of practice: Do they continue to factor into beginning teachers' instructional approaches, ideas about, and confidence for teaching science lessons during the induction years, and if so, how? Another area for additional research concerns the teacher educator's role in approximations of practice experiences: How does feedback from a teacher educator influence prospective teachers' instructional approaches, ideas about, and confidence for teaching elementary science lessons? These are but two examples of research questions that might reasonably be asked on the basis of this study's outcomes; the possibilities for research in this area are numerous, and will hopefully lead to improvements in the preparation of effective elementary science teachers.

## Chapter summary

In this chapter, I have discussed my interpretations of the study's findings, connected those findings to the literature base, and identified unique contributions and implications of this work. Most notably, I have shown that approximations of practice supported case study teachers' development of instructional approaches, ideas about, and confidence for teaching investigation lessons earlier than typically indicated in the teacher development literature. I have also identified candidate areas for future research. As this chapter suggests, future studies of approximations of practice will undoubtedly prove fruitful as researchers and teacher educators work to further understand and improve elements of teacher preparation.

APPENDICES

Appendix A
Fall 2009 EDU 421 course syllabus

# Teaching Elementary Science
# Education 421 Fall 2009

**Course Information**

| | | |
|---|---|---|
| Instructor: | Betsy Davis | Michele Nelson |
| Section: | Section 1 | Section 2 |
| Office: | 4107 SEB | 4025 SEB (inside hi-ce suite) |
| Mailbox: | 4218 SEB (or outside 4107) | 4025 SEB |
| Phone: | 647-0594 (office) | 358-5353 (cell) |
| Email: | betsyd@umich.edu | mishmash@umich.edu |
| Class time: | Monday 1:00-4:00 | Tuesday 1:00-4:00 |
| Classroom: | 2241 SEB | 2241 SEB |
| Office hours: | Tuesdays, 4:30-5:30<br>Fridays, 9:30-11:00 | Mondays, 4:30-5:30<br>Thursdays, 10:30-12:00 |

Professor Betsy Davis is the lead instructor for the course. Students from either section are welcome to speak with her.

Additional apprentice instructors:

James Hagerty, haijs@umich.edu
Mandy Benedict-Chambers, mbenedi@umich.edu
Seshini Pillay, seshini@umich.edu

If you have special needs for which accommodations may be needed, please inform your instructor as soon as possible.

**Course Objectives and Organization**

In Elementary Science Methods, we will build on current research and best practice to prepare you to foster science learning in elementary school students. Our main goals are for you to:

- develop an understanding of scientific inquiry and scientific practice more generally—including supporting students' sensemaking—and how you can incorporate these ideas into effective elementary science teaching
- develop your ability to anticipate, assess, identify, and work with students' ideas in science
- develop your ability to make science accessible to *all* students, including through connecting it to their lives
- develop your ability to analyze and adapt curriculum materials so they're more effective (especially with regard to supporting students' sensemaking, working

with students' ideas, and making science accessible), and to use those curriculum materials in practice

Through working directly on the four goals above, we hope to achieve a fifth overarching goal:

- develop your ability to prepare, teach, and analytically reflect on elementary school science lessons

In doing so, we will continually connect what you're learning about science teaching to what you have learned and are learning about teaching other subjects.

The expectations are high this semester. You've already experienced two semesters of coursework in the School of Education and two semesters in the field. This semester, we'll help you make connections between what you've learned already, and what you're learning now. In fact, there's a note about "connections" for each week of the syllabus. What other connections do you see?

Throughout the semester, we will work on the goals listed above. We'll read relevant chapters and articles that can help us unpack the ideas related to these, and we'll also use other records of practice (video, student work, etc.) to help bring some of the ideas to life. Each week, we'll be working on some key teaching practices, and most weeks you'll be practicing those practices in our ED421 class, in the field, or both. By the end of the semester, you should feel better prepared to put the pieces together to teach science effectively as a beginning teacher.

We'll try to weave a few threads through each week, in addition to and as part of working on these overarching goals. We'll try to help you think about issues like:

- What did you see, do, or learn in your placement this week about science teaching that you want to remember?
- How is science being made visible in your classroom or in other classrooms you visit?
- What issues related to *time* are you experiencing? What strategies are you seeing for when a lesson is running too long, or too short?
- What is happening in the world with regard to current events in science? How could you make some of these accessible to your students?

We've structured the class around natural cycles of science lessons. Every lesson has a beginning, a middle, and an end. Those elements, and the sub-elements within them, can take a range of amount of time. We'll work through two cycles of these elements—one cycle focused on using text in science, and one focused on using investigation.

What are possible beginnings, middles, and ends for science lessons? What are the structures that teachers can use, and what are the sub-elements that get incorporated? Watch for these elements and sub-elements when you observe science teaching. For example, you might see a teacher use a KWL or journal writing to elicit students' ideas at the beginning of a lesson, and/or the teacher might review previous lessons at the beginning of a lesson. For the learning activity that makes the core of a lesson, a teacher might use an experiment or demonstration—or might have students read a text, watch a video, or conduct research using the Web. To end a lesson, the teacher might have students look for patterns in data, make claims based on evidence, construct a consensus model, or all of the above—and/or the lesson might end with a formal or informal assessment, a workbook page, or just cleaning up the materials and transitioning to what's coming next.

## Course Reading Materials

*Required Readings and Other Course Expenditures*

Michaels, S., Shouse, A., & Schweingruber, H. (2008). *Ready, set, science! Putting research to work in K-8 science classrooms*. Washington, DC: The National Academies Press.

*Ready, Set, Science!* (abbreviated in the syllabus as RSS!) presents the most up-to-date discussion of reform-oriented science teaching. The book focuses on how you can incorporate scientific practices, such as scientific inquiry, into your elementary science teaching. Written for practitioners, it includes lots of nice descriptions of effective science teaching at the elementary level. You can purchase *Ready, Set, Science!* at Ulrich's or online at http://www7.nationalacademies.org/bose/TSS_RSS_FAQ.html.

The other required readings are provided on CTools under "Resources" and within the "Weekly Resources" folder, by week.

In addition to the required readings, you should expect to need to spend no more than $25 to cover expenses associated with your science teaching in your elementary classroom.

*Additional Resources:*
You may find some of the following books to be useful, as well. At least portions of these books are available online. Each is linked from the CTools site and from the CASES Resources page.

American Association for the Advancement of Science. (1993). *Benchmarks for Science Literacy*. New York: Oxford University Press.

*Benchmarks* "specifies how students should progress toward science literacy, recommending what they should know and be able to do by the time they reach certain grade levels" (AAAS, p. xi). The Benchmarks are available at http://project2061.aaas.org/tools/benchol/bolintro.html. You may want to purchase this book if you are a science major; the URL is http://project2061.aaas.org/tools/bsl/index.html

American Association for the Advancement of Science (AAAS). (2001). *Atlas of science literacy*. Washington, DC: American Association for the Advancement of Science.

The *Atlas* provides a concept map view of the Benchmarks described above, demonstrating how the different concepts are interconnected. Some of the Atlas' maps are available on-line at http://www.project2061.org/tools/atlas/sample/toc.htm. You may want to purchase this book if you are a science major; the URL is http://www.project2061.org/tools/atlas/default.htm

National Research Council (NRC). (1996). *National Science Education Standards (NSES)*. Washington, DC: National Research Council.

*National Science Education Standards* are another set of national standards for science teaching; though many states have their own standards or frameworks, they are generally in line with the NSES. They are available on-line at http://books.nap.edu/html/nses/html/index.html . You may want to purchase this book if you are a science major at http://www.nap.edu/catalog/4962.html

National Research Council (NRC). (2000). *Inquiry and the National Science Education Standards*. Washington, DC: National Academy Press.

This book builds on the NSES and discusses specific ways of incorporating inquiry into your science teaching. See http://www.nap.edu/catalog.php?record_id=9596.

Michigan Department of Education. *Michigan Grade Level Content Expectations*.

The Michigan Department of Education has developed a set of standards for teaching science in Michigan. These science standards can be found in the Michigan Grade Level Content Expectations (GLCEs), available at
www.michigan.gov/documents/mde/Item_C_194161_7.pdf .

**Course Requirements and Grading**

The percentages listed here are approximate, but will give you a sense of the relative weight of each assignment. Expectations for these assignments will be discussed in more detail in class, and detailed assignment sheets will be provided. All written work, unless otherwise specified, is due by the start of class on the due-date, and should be uploaded to your drop-box on the ED421 CTools site.

*Class Attendance and Participation (20%)*

"Attendance" means being in class on time and staying till the end. If you must miss class, send me email in advance explaining the situation. In keeping with ongoing discussions in the School of Education, three absences—excused or unexcused—will constitute failure of the course. "Participation" means that you need to be in the habit of speaking up and being engaged in whole class and small group discussions and activities, including online opportunities.

*Written Assignments (30%)*

You should complete all written assignments by their due dates. This includes the write-ups for the getting started assignment, your science teaching conversation with your CT, the content conversation with a child, the three lesson plan analyses, and the final exam, as well as any additional written assignments.

*Bite-Sized Science Teaching Assignments in ED421 (one time) and in the Field (three times) (20%)*

There will be two types of opportunities for you to work on elements of science teaching. One type will involve teaching in the science methods classroom with your peers. This will happen once during the semester. The other type will involve teaching in the elementary classroom with at least a small group of students. This will happen three times during the semester. In both cases, the goal is to apply ideas being learned in ED421 to practice small elements of science teaching, sometimes in low-stakes environments, so that when you are teaching entire science lessons (with multiple elements), you will have already developed some expertise.

*Reflective Teaching Assignments (30%)*

You will teach a full science lesson in your practicum classroom twice during the semester. For each reflective teaching (RT) assignment, you will develop a science lesson plan using existing science lessons and other curricular resources, teach it to children, reflect on your teaching, and analyze some student work.

## Class Policies and Additional Information

*Contacting Us*

Email is the best way to reach us.  You can also call us, come to our office, or leave something in our mailboxes.

*Grading and Late Work*

If you cannot complete an assignment on time, please contact your instructor by email and request an extension. Typically we will give an extension of one week; after that, the work will be counted as late and your grade will be affected.

You may request a re-grade on any assignment. The request must be made via email and you must turn in the revision within one week of the assignment being handed back.

*Readings*

You are expected to do all the reading in advance of class. Our work in class depends on it.

*Written Assignments*

For turning in your written assignments, you will use the drop box area in the CTools site.

*CASES*

The CASES learning environment is available at: http://cases.soe.umich.edu. CASES is a learning environment we developed to help preservice and new teachers like you as they learn to teach inquiry-oriented science. CASES includes links to many useful science teaching resources, including some inquiry-oriented science units. The project is funded by the National Science Foundation.

*Participating in Research*

In addition to teaching, we do research on preservice and new elementary teachers. We will circulate a consent form asking for your permission to look at your assignments for class and/or talk with you about science teaching, for research purposes. The research is aimed at improving elementary science teacher education, and wouldn't necessarily take any additional time or effort on your part—so we hope you'll agree to participate.

*Questions, Comments, or Concerns*

If you have any questions, comments, or concerns about the class, please do not hesitate to contact us! We're looking forward to working with you this semester!

**Summary of Assignment Due Dates** (see syllabus and handouts for more complete explanations)

(mostly) increasing complexity ————————————————→ (mostly) increasing authenticity

| Week & Date | Today's In-Class Topic | Reading / Video for Today | Assignments due today | Bite-sized science teaching in ED421 class today | Bite-sized science teaching in placement this week... | Additional in-placement assignments this week... |
|---|---|---|---|---|---|---|
| (0)<br>T 9/8 | Elementary science | | | | | |
| (1)<br>M 9/14<br>T 9/15 | Introduction | | | Create "Rules for science in our classroom" | | Get familiar with your classroom |
| (2)<br>M 9/21<br>T 9/22 | Cycle 1: Planning for instruction: Science education standards and CMs | Preview lesson plan for LPA#1<br>GLCEs<br>RSS! ch. 1, 2, & 4 | **Getting Started with Science Teaching** | Model lesson plan analysis using criteria<br><br>Begin LPA#1 in class | Prep for content conversation | Prep for conversation with CT |
| (3)<br>M 9/28<br>T 9/29 | Cycle 1: Beginning a lesson: Students' ideas | Watson & Konicek<br>Benchmarks ch. 15<br>MSTA misconceptions<br>RSS! ch. 3 | **LPA#1 due** | Role-playing with alternative ideas | Prep for content conversation | Conduct conversation with CT |
| (4)<br>M 10/5<br>T 10/6 | Cycle 1: Learning activity: Text-based discussion in science | Palincsar<br>RSS! ch. 5<br>video | **Conversation with CT due 10/5 or 10/6** | Text-based discussion using science text | Conduct content conversation | Prep for *or* conduct RT#1 |
| (5)<br>M10/12 T 10/13 | Cycle 1: Closing a text-based lesson | | **Content conversation due 10/12 or 10/13** | Exiting a text-based discussion | Prep for BSSTs coming up | Prep for *or* conduct RT#1 |
| 10/19<br>10/20 | NO CLASS! | | | | BSSTs | Prep for *or* conduct RT#1 |
| (6)<br>M 10/26<br>T 10/27 | Cycle 2: Planning: Investigations | RSS! ch. 6 & 7 | **LPA#2 due 10/26 or 10/27** | Co-planning an investigation | BSSTs | Prep for *or* conduct RT#1 |

| Week & Date | Today's In-Class Topic | Reading / Video for Today | Assignments due today | Bite-sized science teaching in ED421 class today | Bite-sized science teaching in placement this week... | Additional in-placement assignments this week... |
|---|---|---|---|---|---|---|
| (7)<br>M 11/2<br>T 11/3 | Cycle 2: Beginning instruction: Launching an investigation | RSS! ch. 5, 6, & 7 | **RT#1 due 11/2 or 11/3** | Launch investigation | BSSTs | Prep for *or* conduct RT#2 |
| (8)<br>M 11/9<br>T 11/10 | Cycle 2: Learning activity: Investigations | RSS! ch. 5, 6, & 7 | | Running a station | BSSTs | Prep for *or* conduct RT#2 |
| (9)<br>M 11/16<br>T 11/17 | Cycle 2: Closing investigation, part 1 | Abell et al. | | Data-based sensemaking discussion | BSSTs | Prep for *or* conduct RT#2 |
| (10)<br>M 11/23<br>T 11/24 | Cycle 2: Closing investigation, part 2 | Kenyon et al. Incorporating Modeling... | | Evaluate & revise models and construct consensus model | BSSTs | Prep for *or* conduct RT#2 |
| (11)<br>M 11/30<br>T 12/1 | Curriculum materials and assessment<br>Making science accessible to all students | INSES ch. 7<br>RSS! ch. 5 | **LPA#3 due**<br><br>**all BSSTs due by 11/30 or 12/1** | Parent/teacher conference | | Prep for *or* conduct RT#2 |
| (12)<br>M 12/7<br>T 12/8 | Course wrap-up (T class) or other (M class) | | **Final exam** (done in class)<br>**RT#2 due 12/7 or 12/8** | | | |
| (13)<br>M 12/14 | Course wrap-up (M class) | | | | | |

**Tentative Course Schedule and Assignments**

The schedule on the following pages is likely to change as the course progresses! Homework assignments may be assigned in addition to the assignments listed here. **All assignments are due by the time class starts**, unless otherwise noted by the instructor. Readings other than chapters in *Ready Set Science!* are posted on CTools.

Week 0 Tuesday, September 8 *Elementary Science*

*Learning Goals:* Introduce the course, think about personal experiences as science learners, and introduce scientific inquiry. Begin to establish a culture of intellectual respect. Get to know others in the class. Think about your goals for yourself as a science teacher.
*Connections:* Reflect on your experiences learning science and ideas about what effective science teaching entails. What is your history as a science learner? What are your goals for yourself as a science teacher? How does effective elementary science teaching connect to effective teaching in other subjects?
*Bite-sized Science Teaching in ED421:*

- Begin to explore some representations of science teaching practice.
- Experience different ways of learning about a single science topic, in the form of stations. How does each of these stations foster science learning? How does each of these stations limit science learning? Which stations represent teaching methods that are most familiar to you and which are new or uncommon in your experience as a science learner? What are your thoughts and feelings about teaching elementary science in each of these ways?

Week 1 Monday, September 14, or Tuesday, September 15 *Teaching Science: Why and How*

*Learning Goals:* Introduce the course, think about personal experiences as science learners, and introduce scientific inquiry. Begin to establish a culture of intellectual respect. Get to know others in the class. Think about your goals for yourself as a science teacher.
*Connections:* Reflect on your experiences learning science and ideas about what effective science teaching entails. What is your history as a science learner? What are your goals for yourself as a science teacher? How does effective elementary science teaching connect to effective teaching in other subjects?
*Practices to Work On:*

- Establishing a culture of intellectual respect—risk-taking, respect for others' ideas, respect for science materials, etc.
- Involving learners in establishing ground rules.

*Bite-sized Science Teaching in ED421:*

- Create “Rules for science in our classroom.”

*Additional In Placement Tasks:*

- This week, work to get familiar with your classroom. How is science visible? What are the classroom rules and how were they developed? How is the teacher fostering a culture of intellectual respect? Does the physical layout allow all students to participate equitably?

Week 2 Monday, Sept. 21, or Tuesday, Sept. 22 *Cycle 1: Planning – Using Standards & Curric.*

*Learning Goals:* Begin to understand what is meant by scientific inquiry, and what it can look like in the elementary classroom. Explore ideas related to the inquiry continuum. Develop an understanding of the role of learning goals and their connection to standards. Gain familiarity with science standards. Begin to develop skills in analyzing science lesson plans.

*Connections:* In social studies methods you focused on learning goals and standards. You learned about the importance of big ideas, and about historical inquiry. How can you build on this knowledge in science? You've learned about equity and diversity issues in all your teacher ed courses last year. How can you make *science* accessible to all learners? You learned about the importance of students' ideas in ed psych and other classes. How can you elicit, identify, and work with kids' ideas in *science*?

*Practices to Work On:*

- Using science education standards to guide planning (GLCEs, AAAS Benchmarks, National Science Education Standards).
- Addressing content and inquiry learning goals.
- Analyzing science curriculum materials (critiquing to identify strengths and weaknesses, and adapting to address weaknesses). In addition to envisioning the *time needed for each lesson element* and *conceptual and logistical issues* likely to arise, we will address a few main criteria:
    - *Alignment with standards and learning goals*
    - *Elicit, identify, work with student ideas*
    - *Make science accessible to all learners*
    - (Later, we will add *promoting students' sensemaking* as a criterion.)

*Readings:*

- Preview lesson plan for LPA#1
- Michigan Grade Level Content Expectations (GLCEs) for science
- Ready Set Science! chapters 1, 2, and 4

*Assignment Due:*

- Getting Started with Science Teaching

*Bite-sized Science Teaching in ED421:*

- We will model lesson plan analysis in class.

*Bite-sized Science Teaching in Your Placement:*

- Begin to get organized for your content conversation (due 10/12 or 10/13).

*Additional In Placement Tasks:*

- Begin to get organized for your conversation with your CT (due 10/5 or 10/6).

Week 3 Monday, Sept. 28, or Tuesday, Sept. 29 *Cycle 1: Beginning a Lesson – Students' Ideas*

*Learning Goals:* Develop strategies for finding out about and working with kids' ideas in science.
*Connections:* You learned about the importance of students' ideas in ed psych and your other classes. How can you elicit, identify, and work with kids' ideas in *science*?
*Practices to Work On:*

- Anticipating students' ideas—using resources to help us know what kids are likely to think
- Eliciting students' ideas
- Working with students' ideas—using students' ideas for planning but also responding to students' ideas "in the moment"
- Distinguishing between students' ideas (prior knowledge, current understandings, etc.) and their predictions (what they think will happen in a certain set of circumstances). Prediction means something specific in science.

*Readings:*

- Ready Set Science! chapter 3
- Watson & Konicek (1990): Teaching for Conceptual Change
- Benchmarks Chapter 15: The Research Base
- MSTA misconceptions lists (physical science, earth science, life science)

*Assignment Due:*

- LPA#1

*Bite-sized Science Teaching in ED421:*

- Role-play about alternative ideas likely to come up in content conversation. (All)

*Bite-sized Science Teaching in Your Placement:*

- Begin to get organized for your content conversation (due 10/12 or 10/13).

*Additional In Placement Tasks:*

- Conduct conversation with CT this week (due 10/5 or 10/6).
- Talk to your CT about the topics and timing of the reflective teaching assignment lessons and the BSSTs. Talk to your field instructor, too, if you have trouble identifying dates to teach.
- Come to class with a written plan for what topics you'll teach for your reflective teaching lessons and your BSSTs, and when you'll teach each. This may change, but it's good to start getting it mapped out now.

Week 4 Monday, Oct. 5, or Tuesday, Oct. 6 *Cycle 1: Learning Activity — Text in Science*

*Learning Goals:* Develop your abilities related to reading science texts with children.
*Connections:* You've had two semesters of literacy methods. How can you use schools' emphasis on language arts as a way of incorporating more science into your classroom? How can you use what you've learned about text-based discussion to guide your thinking about using texts in science? How do the discussion moves from *Questioning the Author* apply in reading and discussing science texts? What might a "text" be in science besides print?
*Practices to Work On:*

- Reading text (textbook, tradebook, story book) in science—interactive read aloud, text-based discussion, pair reading, etc.
- Making science texts authentic and meaningful to learners
- Highlighting key scientific ideas (without getting bogged down in details)
- Using a text to launch another activity in science
- Connecting science and literacy goals

*Readings:*

- Palincsar: Reading in Science
- Ready Set Science! chapter 5
- Harvard/Smithsonian video

*Assignment Due:*

- Conversation with CT write-up

*Bite-sized Science Teaching in ED421:*

- Text-based discussion using a science text (opportunity for peer teach).

*Bite-sized Science Teaching in Your Placement:*

- Conduct content conversation this week (due 10/12 or 10/13).

*Additional In Placement Tasks:*

- Begin to get organized for Reflective Teaching #1 (due 11/2 or 11/3).

Week 5 Monday, Oct. 12, or Tuesday, Oct. 13 *Cycle 1: Closing a Text-based Lesson*

*Learning Goals:* Develop strategies for effectively closing a text-based lesson in science. Recognize consistencies and idiosyncrasies in students' ideas about particular science topics. Begin to consider where these ideas may come from. Reflect on Cycle 1 – using text in science lessons.
*Connections:* You've had two semesters of literacy methods. How can you use the emphasis on language arts as a way of incorporating more science into your classroom? How can you use what you've learned about text-based discussion to guide your thinking about using texts in science? Also, how can you use what you've learned about assessment in prior coursework to guide your thinking about informally assessing students' ideas in this context?
*Practices to Work On:*

- Reviewing the main points of a text
- Reviewing connections to other ideas from prior lessons
- Relating key ideas to real-world examples
- Informally assessing student learning

*Assignment Due:*

- Content conversation write-up

*Bite-sized Science Teaching in ED421:*

- Closing a text-based lesson and exiting a text-based discussion. (opportunity for peer teach)

*Bite-sized Science Teaching in Your Placement:*

- Begin to get organized for the bite-sized science teaching assignments in your placement. All three need to be completed by 11/30 or 12/1. You can start to enact these as early as this week.

*Additional In Placement Tasks:*

- You might teach RT#1 this week. It is due 11/2 or 11/3.

Monday, Oct. 19, or Tuesday, Oct. 20 *No class! Enjoy the break!*

*Bite-sized Science Teaching in Your Placement:*

- Continue working on the bite-sized science teaching assignments in your placement. All three need to be completed by 11/30 or 12/1.

*Additional In Placement Tasks:*

- You might teach RT#1 this week. It is due 11/2 or 11/3.

Week 6 Monday, Oct. 26, or Tuesday, Oct. 27 *Cycle 2: Planning – Investigations*

*Learning Goals:* Begin to understand what is meant by "scientific practice", "scientific inquiry", "investigation", "phenomenon", "prediction", etc. Develop beginning understanding of the inquiry continuum (from more teacher-directed to more student-directed).
*Connections:* In your social studies methods class, you worked a lot on representing how history is "done." Investigation of natural phenomena is one characteristic that makes *science* unique. As in history, students will use evidence to support claims in science. The evidence will be a little different!
*Practices to Work On:*

- Taking account of multiple considerations in planning science investigations: learning goals (for content and for inquiry), students' ideas, availability of materials, time availability, student behavior issues to preempt, etc.
- Identifying and planning for safety issues and clean-up issues
- Planning for distribution of materials
- Using appropriate investigations
- Lesson plan analysis in the context of science investigations. In addition to envisioning the *time needed for each lesson element* and *conceptual and logistical issues* likely to arise, we will address a few main criteria:
    - *Eliciting, identifying, and working with student ideas*
    - *Making science accessible to all learners*
    - *Promoting students' sensemaking*

*Readings:*

- Ready, Set, Science! chapters 6 & 7

*Assignment Due:*

- LPA#2

*Bite-sized Science Teaching in ED421:*

- Co-planning an investigation (All)

*Bite-sized Science Teaching in Your Placement:*

- Continue working on the bite-sized science teaching assignments in your placement. All three need to be completed by 11/30 or 12/1.

*Additional In Placement Tasks:*

- You might teach RT#1 this week. It is due 11/2 or 11/3.

Week 7   Mon., Nov. 2, or Tues., Nov. 3   *Cycle 2: Beginning a Lesson – Launching Investigation*

*Learning Goals:* Begin to be able to envision a science investigation lesson. Learn how to support students in making predictions about phenomena.
*Connections:* You'll be continuing to apply what you know about teaching (in general) to how you can teach in science. Also, as with mathematics (and other subjects sometimes as well), you need to think about how you will make physical materials available to students without causing distractions.
*Practices to Work On:*

- Anticipating and planning for management concerns during investigations
- Setting the stage for an investigation
- Activating prior knowledge in preparation for an investigation
- Setting expectations for an investigation
- Supporting students in making predictions ("what do you think will happen when…")
- Distributing materials

*Readings:*

- revisit Ready, Set, Science! chapters 5, 6, and 7

*Assignment Due:*

- Reflective Teaching #1

*Bite-sized Science Teaching in ED421:*

- Launch an investigation (opportunity for peer teach)

*Bite-sized Science Teaching in Your Placement:*

- Continue working on the bite-sized science teaching assignments in your placement. All three need to be completed by 11/30 or 12/1.

*Additional In Placement Tasks:*

- Begin to get organized for Reflective Teaching #2 (due 12/7 or 12/8).

Week 8   Monday, Nov. 9, or Tuesday, Nov. 10 *Cycle 2: Learning Activity – Investigation*

*Learning Goals:* Continue to develop skill in teaching a lesson involving an investigation. Learn how to support students in collecting, organizing, analyzing, and representing data.
*Connections:* Continue to apply your knowledge about teaching (in general) to thinking about *science* teaching.
*Practices to Work On:*

- Anticipating, planning for, and dealing with management concerns during investigations
- Setting the stage for an investigation
- Activating prior knowledge in preparation for an investigation
- Setting expectations for an investigation
- Supporting students in making predictions (what do they think will happen when…)
- Distributing materials
- Pushing student thinking during individual or small group work
- Circulating
- Scaffolding data collection, data organization, and data analysis
- Improving worksheets

*Readings:*

- revisit Ready, Set, Science! chapters 5, 6, and 7

*Bite-sized Science Teaching in ED421:*
- Running a station (opportunity for peer teach)

*Bite-sized Science Teaching in Your Placement:*
- Continue working on the bite-sized science teaching assignments in your placement. All three need to be completed by 11/30 or 12/1.

*Additional In Placement Tasks:*
- You might teach RT#2 this week. It is due 12/7 or 12/8.

Week 9 Mon., Nov. 16, or Tues., Nov. 17 *Cycle 2: Closing an Investigation Lesson (part 1)*

*Learning Goals:* Continue to develop skill in teaching a lesson involving an investigation. Learn how to support students in making sense of data that have been collected. Learn how to support students in making claims based on evidence.
*Connections:* In social studies methods, you learned about primary and secondary sources. These are sort of like "data" or "evidence" in science. How could you help students learn about scientific inquiry and historical inquiry? How could you help them see connections between the two subject areas?
*Practices to Work On:*
- Supporting students in revisiting predictions
- Supporting students in making sense of data and looking for patterns in data
- Supporting students in making claims supported by evidence
- Supporting students in evaluating models
- Dealing with abrupt endings (what happens if you run out of time?)
- Continuing ongoing investigations from one day to the next
- Assessing student learning in and from an investigation

*Readings:*
- Abell et al.: Science as Argument and Explanation

*Bite-sized Science Teaching in ED421:*
- Data-based sensemaking discussion (opportunity for peer teach)

*Bite-sized Science Teaching in Your Placement:*
- Continue working on the bite-sized science teaching assignments in your placement. All three need to be completed by 11/30 or 12/1.

*Additional In Placement Tasks:*
- You might teach RT#2 this week. It is due 12/7 or 12/8.

Week 10 Mon., Nov. 23, or Tues., Nov. 24 *Closing an Investigation Lesson (part 2)*

*Learning Goals:* Continue to develop skill in teaching a lesson involving an investigation. Learn how to support students in evaluating and revising models. Learn how to support class in constructing a consensus model.
*Connections:* How is constructing a consensus model similar to how you tie ideas together in other subjects?
*Practices to Work On:*
- Supporting students in evaluating and revising models.
- Supporting students in constructing a class consensus model.
- Assessing student learning in and from an investigation

*Readings:*
- Kenyon et al.: The Benefits of Scientific Modeling
- Incorporating Modeling in Elementary and Middle School Classrooms

*Bite-sized Science Teaching in ED421:*

- Evaluate and revise models and constructing consensus model (opportunity for peer teach)

*Bite-sized Science Teaching in Your Placement:*

- Continue working on the bite-sized science teaching assignments in your placement. All three need to be completed by 11/30 or 12/1.

*Additional In Placement Tasks:*

- You might teach RT#2 this week. It is due 12/7 or 12/8.

Week 11 Monday, Nov. 30, or Tuesday, Dec. 1 *Curriculum Materials, Assessment, and Equity*

*Learning Goals:* Develop skill in looking at students' written work over time. Practice assessing student work in science. Practice interacting with parents about student learning. Learn more about teaching science so it is accessible for all students. Learn more about how making real-world connections can help make science accessible.
*Connections:* You've learned about assessment in all of your classes. Here, we'll be focused on closely examining student work and being able to make claims about their development over time. Also, you should be able to apply some of your knowledge about developing literacy skills. In ED392 you learned a lot about the importance of supporting all children in learning. Here, we're focused on helping all children learn *science*. What are some strategies you can apply from your previous coursework for making science accessible to all students?
*Practices to Work On:*

- Assessing student work and describing development over time
- Using accessible language in talking with parents
- Making science accessible to all students
- Planning with different students in mind
- Using real-world connections as a way of making science accessible to all students

*Readings:*

- INSES Chapter 7: Frequently Asked Questions about Inquiry
- revisit Ready, Set, Science! chapter 5

*Assignment Due:*

- LPA#3
- All Bite-Sized Science Teaching write-ups must be completed by today.

*Bite-sized Science Teaching in ED421:*

- Parent/teacher conference. (All)

*Additional In Placement Tasks:*

- You might teach RT#2 this week. It is due 12/7 or 12/8.

Week 12 Monday, December 7, or Tuesday, December 8 *Wrapping Up*

*Learning Goals:* Pull back to consider the broader implications of what we've learned about effective science teaching.
*Connections:* Think about how what you've learned this semester about effective science teaching connects to what you've learned in your other teacher ed coursework and in the field. What do you want to make sure to work on during student teaching?
*Practices to Work On:*

- Putting the pieces together for science teaching

*Assignment Due:*

- Final exam (given in class)

- Reflective Teaching #2

Week 13 Monday, December 14 *Wrapping Up*

*Learning Goals:* Pull back to consider the broader implications of what we've learned about effective science teaching.
*Connections:* Think about how what you've learned this semester about effective science teaching connects to what you've learned in your other teacher ed coursework and in the field. What do you want to make sure to work on during student teaching?
*Practices to Work On:*

- Putting the pieces together for science teaching

Appendix B

Assignment description for bite-sized science teaching experiences

# Bite-Sized Science Teaching Assignment Overview

## *What is "bite-sized science teaching?" Peer teaching and in the field*

Rather than always teaching an entire science lesson to a classroom of children, we'd like to provide you opportunities to teach smaller portions of science lessons. Talking elementary students through an experiment before they actually do it. Activating students' prior knowledge about a science topic. Making sense of data students have gathered from an observation. We call these "bite-sized science teaching" opportunities—chances to test out teaching portions of science lessons. The purpose of this assignment, then, is to provide you with opportunities to try out teaching these smaller, "bite-sized" elements of science teaching. This assignment has two components:

1) Peer teaching in EDU 421
2) Teaching elementary students in your field placement classroom

**The Peer Teaching Component (1 time)**

In this portion of the assignment, you'll teach a part of a science lesson to your EDU 421 colleagues, who will be acting as elementary students (intellectually, not behaviorally). The part of a science lesson that you'll teach will correspond with the topic(s) we are covering in class that day. Each of you will be responsible for leading one bite-sized science teaching experience. These bite-sized science teaching experiences will require you to do some thinking and planning in advance, and we will help you with this. Before teaching your peers, you'll need to meet with your instructor during office hours to co-plan. Immediately after you teach, we will "co-reflect" as a class, to debrief the peer teaching BSST assignment. This re-framing will let us all have a chance to talk about what went well and what could have gone better, and work collaboratively on developing your science teaching skills.

When you are not teaching your peers, you will fulfill the role of elementary students for your peer teacher colleague. As the student, you'll get to experience what your own future students will experience. Your impressions and feedback for your peer teacher colleague will be invaluable for developing his/her teaching skills, and will also help you think through your own science teaching.

Peer teaching (and learning) offers several advantages to you as beginning teachers:

1) It allows you a "safe environment" in which to test-drive some of the methods we talk about in class. By maintaining an environment of respect for each others' ideas and teaching practices, and an attitude that we're all learning together and that mistakes are part of the learning process, we'll encourage you to take chances and try out teaching approaches that may not yet be totally comfortable or natural for you.

2) It allows you to take chances without fear of "screwing up someone's learning."
3) It provides an opportunity for you to get more experience with science teaching and learning. Unfortunately, science often takes a back seat to other subjects in elementary classrooms, so we hope that this gives you more overall exposure to science teaching.
4) It is a way for you to gain confidence in your science teaching abilities. Every opportunity to practice science teaching should help you see that you have developing knowledge, skills, and abilities to teach science.
5) It provides an environment in which you can receive constructive feedback and coaching from your instructor and your colleagues about your science teaching—something that is not often possible when you are teaching in the field.
6) It allows you to experience science instruction from the viewpoint of your learners. You can think about what elementary students are likely to do in response to some of these teaching moves, and what sorts of ideas kids are likely to have.

**The Field Placement Teaching Component (3 times; all due by Nov. 30 or Dec. 1)**
In this portion of the assignment, you will be teaching students in your field placement classroom. We know that this may not be the easiest thing to arrange, especially if you are in a classroom in which science is not taught on a regular basis, and so we will do our best to give you as much flexibility as possible in completing this portion of the assignment. We also encourage you to talk with us, your field instructor, and your cooperating teacher about creative approaches to carrying out this part of the assignment. For example, if science is not currently being taught in your field placement classroom, you might enact a bite-sized science teaching "meal" with 4 "volunteers" during 10 minutes of one of your students' recess periods.

What bite-sized science teaching experiences will you teach? We'll give you a menu of possibilities, from which we'll ask you to choose and enact three "meals"—one that begins a science lesson, one that entails a full learning activity, and one that concludes a science lesson. You may complete these BSSTs at any point during the second half of the semester, although we encourage you to space them out over the 6 weeks to better allow you to reflect upon your experiences before taking on the next BSST. You should *not* combine multiple BSSTs in the same lesson—the point is to give you smaller chances to really practice specific kinds of skills. After you have completed each field placement BSST, you will write a brief reflection on the experience. (See the BSST in the Field handout for more detail, including the menu.)

This portion of the assignment offers additional advantages to you as beginning teachers:
1) It allows you to gain more experience teaching science to actual elementary students.
2) It allows you to work in a more focused way with a handful of elementary students.
3) It gives you a chance to focus on teaching one element of a science lesson rather than trying to teach an entire lesson at once.

4) It provides you a chance to get better acquainted with some of your students' ideas and thinking in science.
5) It provides more opportunities for you to interact with your cooperating teacher about science teaching and to participate in science teaching in your field placement classroom.

These are just some advantages of this assignment… we hope that you will find others that we haven't listed here, and feel free to tell us about them. ☺

# Bite-Sized Science Teaching in the Field

*Bonjour!* You will have the opportunity to create three “meals” using the menu below. You'll enact each “meal” in your field placement classroom, with at least 4 elementary students. (You may enact your "meals" with your whole class if you want to and can arrange it.) You will need to work closely with your cooperating teacher to carry out this assignment. Ideally, you'll be able to collaborate to teach a portion of a science lesson that your CT is already planning to teach. However, if you will be teaching your "meal" without the rest of a lesson, then you need to make sure it will work as a stand-alone. (For example, it wouldn't make sense to lay the ground rules for an investigation if there weren't going to be an investigation.)

You may “serve” these meals in any order; however, you will need to create one of each meal type. This will give you an opportunity to practice beginning a lesson, enacting a learning activity of some sort, and concluding a lesson. If you have an idea for a “meal choice” that is not listed here, please discuss it with your methods course instructor.

**All three Field Placement BSSTs must be completed by November 30 (Monday) or December 1 (Tuesday).**

For each meal, you will need to develop a plan, enact the portion of the lesson, and then reflect on the enactment. We are glad to co-plan with you if you'd like; however, we know the timing may make this difficult. We encourage you to co-plan with *someone* if possible (if not your methods instructor, then your CT or your field instructor would be great).

**Planning**
Include a brief outline of your BSST and how you will go about carrying it out. This doesn't need to be a formal lesson plan, but does need to be clear enough for us to understand what you intend to do. If possible, include a copy of the curriculum materials you are using as a starting point for your BSST. Indicate whether this BSST is for Meal One, Two, or Three (beginning, learning activity, or concluding a lesson), as well as the BSST "menu item" you are teaching). Turn this in **before** you teach the BSST.

**Written Reflection**

Indicate whether this BSST was for Meal One, Two, or Three (beginning, learning activity, or concluding a lesson), as well as the BSST "menu item" you taught. Indicate how many students participated, and their grade level and school. Then, write a brief reflection that addresses the following questions. Turn this in **within 48 hours after** teaching the BSST. (If you'd like, you can also turn in any audio or video you'd like us to see.)

- What went well with this BSST? Give specific examples
- What went not-so-well? Give specific examples
- What surprises came up during your enactment? How did you handle these?
- If you could repeat this experience, what would you do differently and why?
- What did you learn about science teaching? What do you want to remember for your future science lessons?
- Any additional thoughts that are relevant to this BSST.

## *Le Menu pour les "Field placement BSSTs": Your menu choices*

**Meal One choices: Beginning a Lesson**

- Activating students' prior knowledge (e.g., reviewing the previous lessons)
- Eliciting students' ideas about new science content (e.g., beginning a KWL, journaling, constructing a model, etc.)
- Engaging students in a shared experience with a phenomenon (e.g., using a battery, bulb, and wire to make a bulb light up)
- Setting ground rules for the learning activity
- Talking through an investigation protocol (e.g., leading a whole-class discussion of how variables will be controlled)
- Reading a text
- Making predictions

**Meal Two choices: The Learning Activity**

- Conduct a learning activity using a science text
- Have students do an investigation (e.g., run an experiment, make observations, etc.)
- Carry out a demonstration of a scientific phenomenon
- Watch a video, use a scientific simulation, etc.

**Meal Three choices: Concluding a Lesson**

- Help students identify trends in and/or make sense of data
- Support students in making claims supported by evidence
- Evaluate and revise a scientific model
- Construct a consensus model
- Revisit predictions
- Complete page(s) in science workbook, notebook, or journal
- Assess student learning/understanding (formally or informally)
- Review what was done and what was learned in today's lesson
- Facilitate student presentations of their work
- Complete a KWL
- Connecting today's lesson to other ideas in science (or other subjects)
- Set the stage for the next science lesson

Appendix C

Reflective teaching assignment description

## ED421 Reflective Teaching Assignment

You will teach a full science lesson in your practicum classroom twice during the semester. Each cycle of planning, teaching, and reflecting is called a reflective teaching (RT) assignment. For each RT assignment, you will use existing curriculum materials to develop a science lesson, teach it to students in your placement classroom, reflect on your teaching, and analyze some student work. The reflective teaching assignments are intended to help you

- modify existing science lessons to be more inquiry-oriented and appropriate for your class
- build on your bite-sized science teaching experiences in ED421 and in the field, moving toward more complex and more authentic experiences with science teaching
- practice teaching science lessons effectively, including envisioning how long different elements will take and what conceptual and logistical issues are likely to arise
- learn how to use written student work to understand and assess kids' ideas
- reflect on your lesson and students' work to figure out changes to make for the future
- develop an artifact that's appropriate for inclusion in your teaching portfolio

How should you plan, and what lesson should you teach?

In preparing to teach this lesson, you should find an **existing lesson plan**, rather than developing one from scratch. Your CT will probably give you lessons to teach. If not, ask him or her for resources to help you find an appropriate lesson, or find one yourself (for example, check on CASES to see if there's a lesson that fits your needs). Also **talk with your CT** about your plans well in advance. Be sure your CT understands what you plan to do, and has budgeted the necessary time. Also **go through the experiment or activity in advance** with the actual materials you'll use in the classroom. Use this as a chance to anticipate any management issues that might come up and develop a plan for dealing with them.

Ideally, you'll be able to **co-plan** your lessons with your methods instructor, your field instructor, your CT, and/or a trusted colleague in the program.

Your lessons should involve having students develop some kind of **written or physical artifact**. This could be a worksheet, a picture, a journal entry, a model, or anything else that you can analyze to get a sense of the students' ideas. You will be required to analyze this written student work, so be sure your lesson includes this feature.

The second lesson (RT#2) should, if at all possible, involve some kind of an **investigation**—something that involves making observations about a natural phenomenon (e.g., light, mixtures, living things, weather, rocks and minerals, etc.), collecting data, doing an experiment, etc. (It is great if RT#1 involves an investigation, too.)

**Due Dates:**

RT1 assignment should be completed and taught by November 2 (Mon.) or 3 (Tues.).

RT2 assignment should be completed and taught by December 7 (Mon.) or 8 (Tues.).

Upload your **RT assignment** as a Word document to your CTools drop-box by the above due dates. This Word document should include your **lesson plan** (using the lesson plan guidelines in this document) and your **reflection** (see guidelines at the end of the lesson plan guidelines). On the due dates, also turn in during class hard copies of (1) your **original lesson plan** (the one you received from your CT, or found); (2) **3-5 examples of student work** that you refer to in your reflection; and (3) copies of any **handouts, activity sheets,** etc. that you used in your lesson. (Scanned copies of these can instead be included in the Word file you upload, if you prefer.)

## Lesson Plan Guidelines for Reflective Teaching

This is a version of the lesson plan format you've used in the past and will use in your student teaching; we've modified it a bit to draw your attention to a few things that are particular to effective science teaching, so be sure you read the text for each section. Write specific information for each of the sections below.

Title of Lesson
Grade Level
School

### Purpose/Rationale and Connections to Students' Ideas

*Include assessment information about students that you may have gathered from a variety of sources including discussions with your cooperating teacher, pre-assessments, daily work, etc. that provide a rationale for the teaching of this lesson. Also include here what alternative ideas students MAY have about this science content, and provide at least one strategy you can use to address each of those ideas. Remember to draw on the resources you have for anticipating students' ideas (CASES, MSTA lists, Benchmarks ch. 15, etc.).*

### Connections to Standards/Benchmarks/Curriculum

*1. Reference curriculum materials from which this lesson is adapted. What sources did you use in the creation of this lesson plan? Did you build from any existing materials? List them here. Include website addresses if applicable. When you turn in your lesson plan for your Reflective Teaching assignment, be sure to attach a marked-up copy of the original lesson plan you started with.*
*2. Reference to local, state and/or national standards and benchmarks. Make sure you include one or two science content goals and one or two science inquiry goals, and say how the inquiry goals support the development of the content understandings. For all learning goals, refer to the appropriate GLCEs (grade level, discipline, and standard).*

## What I did to prepare to plan and teach this lesson:

*For example: practiced the experiment with the actual materials, answered the worksheet questions myself, thought through timing, researched materials, etc. Make sure you're anticipating any logistical or conceptual issues that may come up.*

## What connected lesson preceded this lesson and what do you know about students based on that work that informs this plan?

## Objective(s): The students will be able to…

## Materials needed to have ready:

## Management considerations:

*Be sure you think through how you will distribute materials, what guidelines you will give students in advance about proper use of the materials, how you will keep them from playing with them during your intro or other discussions, what you will do if students use materials inappropriately, and how you will have students help with any necessary clean-up.*

## Introduction/hook (include time estimates)

*Consider how you will elicit students' ideas and how you will connect the science to their lives.*

## Outline of your lesson sequence, including teaching strategies used. (include time estimates)

*Consider gradual release of responsibility, discussion, recitation, inquiry.*
*Be specific about what you will do and how long each activity will take. Try to envision each main element of the lesson and make a realistic estimate of how long it will take—remember to account for distributing materials, confusion about setting up the investigation, etc. Consider what portion(s) of the lesson would you shorten or eliminate, if things are running longer than you'd expected.*
*How will students achieve the goal of the activity? Review your outline to consider whether the activities in the sequence provide the opportunity for your students to achieve your goals.*
*Make sure you include a sense-making component. How will you help them (for example) make sense of the data, see patterns in the data, use data as evidence to support claims, etc.?*
*Think about at least 5 questions to use at specific points or throughout the lesson sequence that will help move students toward understanding.*

## What accommodations did you make to meet the full range of your students?

*Make specific annotations that show differentiation to meet the learning needs of the full range of your students. Pay particular attention to the students you are focusing on this year and comment on how this lesson will support their science learning.*

## Closing/wrap up: (include time estimates)

## Assessment:

*How will you judge if the students have attained the objective(s) you set for the lesson? What is your evidence of student learning? How will you assess what each student has learned about the science content and about science inquiry? Remember that you need to analyze some student work for your reflective teaching assignment; this student work may serve as a form of assessment for your lesson. Include or provide any student artifacts (handouts, activity sheets, etc.) you will use. Be sure you think carefully about the specific questions or tasks you're giving students as well as the format. (Is there enough room for children's large writing? Are the page breaks in the right spots? Are the instructions clear? Is everything spelled correctly? Will a parent be glad you're teaching their child, when they see these artifacts?)*

## Next steps

*What lesson will follow this lesson? What do you want to follow up on? What will you do to extend student learning?*

## IF being observed: On what aspect(s) of your lesson would you like the observer to focus? Or, if NOT being observed, what is your learning goal for yourself?

*Think about: What is your own learning goal for yourself, with regard to science teaching? What are you working on with respect to your science teaching?*

## Lesson reflection: (*add notes to annotate your plans. See specific reflection questions below for Reflective Teaching assignments.)*

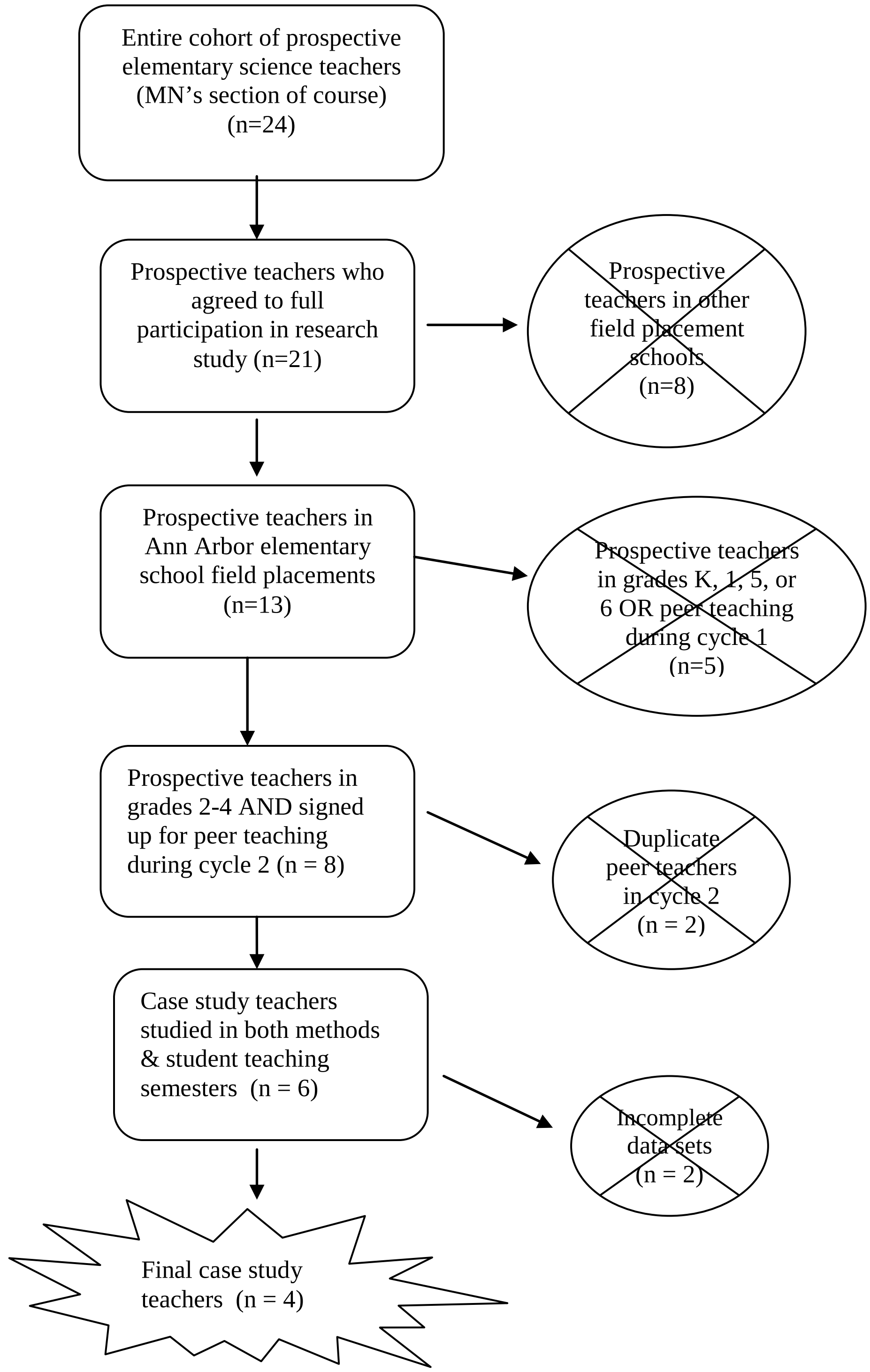
After you've taught your lesson, reflect on your lesson enactment and on your students' work. We've specifically included some questions for you to answer in your reflection.

- How did it go? What went well? What didn't go so well? Refer back to specific portions of your lesson plan.
- Did your students meet your learning goals? Analyze at least 3-5 examples of your students' work and make evidence-based assertions about their learning with regard to each of your learning goals (related to content and to inquiry). Include analysis of your focal students' work.
- Did you adequately make science accessible to all your students? Attend to your students' ideas? Support your students' sensemaking?

- How did the timing go, compared to what you had planned? How did the anticipated logistical issues go? Had you planned adequately? What came up that you hadn't anticipated?
- What did you learn about science teaching from this experience? Did you meet, exceed, or fall short of your own expectations for yourself, including the goal(s) you were focusing on?
- How were you able to build on your bite-sized science teaching experiences in ED421 and in the field? How was this different from those experiences?
- What would you change next time?
- Please feel free to address anything else you think is relevant.

Appendix D

Case Study Teacher Selection Flowchart



Appendix E
Approximation of Practice Enactment Observation Guide

Name of preservice teacher:

Date of observed instruction:

Name of observer:

Rough transcript of the lesson or lesson portion taught (topic and general structure of lesson):

1. Setting the purpose: How did the preservice teacher establish the purpose for the investigation? (What did the preservice teacher do to "set up" the purpose for the investigation?--e.g., PT introduced an investigation question for the students to answer, posed a problem/question to the students for them to answer, students and PT developed the purpose together, etc.)

2. Connecting to prior knowledge, experience, and/or ideas: How does the preservice teacher connect the investigation to what the students have been learning/doing up until now (if applicable) and/or how does the preservice teacher connect the investigation to what ideas/experience students have or are likely to have about the phenomenon in question? (e.g. PT tells student important points from previous lessons and connects them to the investigation in this lesson, PT asks students to describe what they know and connects this to the investigation in this lesson, PT asks students how they have experienced this topic/phenomenon in their lives, PT does not do this, etc.)

3. Establishing data collection: How does the preservice teacher support the students in determining what counts as data and how it will be collected and/or recorded? (e.g., PT gives students a worksheet that scaffolds their data collection, PT gives instructions on what to do, PT allows students to work out their own system for determining what counts as data and how it will be collected/recorded, PT models how the data should be collected and recorded, etc.)

4. Fostering sense-making with data: How does the preservice teacher support students in doing the conceptual work of making sense of data from an investigation (both during and after the investigation)? (e.g., PT writes investigation results from all groups on board and helps students look for trends in the data, PT pushes student thinking during the investigation, PT tells students what their data mean, etc.)

5. Supporting claims with evidence: How does the preservice teacher support students in making claims and supporting them with investigational evidence? (e.g., PT models what a reasonable claim and evidence would look like based on the investigational evidence, PT scaffolds students' construction of claims with evidence through written or verbal prompts, PT facilitates small group work with students to develop claims that can be supported by evidence, etc.)

Additional comments relevant to the preservice teacher's teaching experience: (e.g., Were there class management issues that arose and if so, how did the PT address these? Did the PT run out of time or end early? When during the school day was the lesson or lesson portion taught? At what point in the unit did this lesson take place? Where did the lesson take place? Were there issues that arose with materials, student questions, unexpected data, etc.?)

# Appendix F
## Initial Fall 2009 interview protocol

MN begins by explaining structure of interview, nature of questions
MN: Start by telling me your name, your major in the SoE, a little bit about your field placement
MN: Are you seeing science being taught in your field classroom?
MN: I'd like to switch and talk a little bit now about your own experiences as a science learner and the knowledge that you have about science, and so I noticed on the Getting Started journal that you had taken X science courses in high school and Y here at UM, can you clarify for me if those were semesters or years?
MN: Can you tell me which areas of science you've taken courses in?
MN: So if you think about your own knowledge of science and what it means to do science, what would you say would be the biggest sources of that knowledge? An example would be "textbook from class."
MN: Have you done any science teaching at this point or not yet?
MN: Now, I'll ask more questions getting specifically at your knowledge and beliefs about how science should be taught, then a couple questions about your own confidence in yourself as a science teacher. OK? So first set of questions are scenario-sort of questions. So I'm going to ask you to imagine that you're going to be teaching a unit about magnets. What can you imagine that an elementary teacher might do as part of a lesson about magnets? What might a lesson look like?
MN: Same question, different topic—states of matter.
MN: Now is a more general question. What do you think investigations in elementary science lessons entail? What kinds of things does the teacher do, the students do?
MN: OK, short of giving a definition can you say more about what the term "investigation" means to you?
MN: Next one is a scenario: Ask you to imagine that you are helping a colleague think through how to teach a $5^{th}$ grade science lesson that involves an investigation about sinking and floating. First thing I'll ask you to do is just give me an overview of what a lesson that has an investigation about sinking and floating might look like, and then I'll ask you to comment on what sorts of things you would tell your colleague to think about at different stages—like during the planning stage, during the beginning of the lesson, while the investigation is going on, and at the end of the lesson. So first let's start with the overview.
MN: What would you have your colleague think about when planning to teach this lesson?
MN: Why did you choose _____?
MN: How about at the very beginning of the investigation? What would you advise your colleague to think about when launching the lesson?
MN: A few words about why those are important?
MN: And how about when the investigation is underway?
MN: A little more about why?
MN: Lesson conclusion?
MN: Why?

MN: So now, a different scenario—I'm the elementary teacher, I'm going to engage my students in scientific modeling as part of a lesson about evaporation. What does that make you think of, what might a lesson like that look like? What would I as the teacher be doing, what would the students be doing?
MN: More general question: what does the term scientific modeling mean to you?
MN: How might a teacher choose to use an investigation and scientific modeling together—why would a teacher want to do that?
MN: Why might a teacher choose to use those together in a lesson?
MN: And what do you see as being potential benefits of using them together?
MN: Any drawbacks of using them together?
MN: Switch to questions about beliefs. In what ways do you think science can and should be taught at the elementary level?
MN: Next set of questions is card-sorting task, different instructional approaches on each card, I'm going to ask you pull ones that you'd be likely to use and you can pull as many as you'd like, for 4 different topics, and the first topic is light (how does light move). And then we'll talk just a little bit about what you chose and why.
MN: Why did you choose those?
MN: Ok, and the next topic is plant life cycles
MN: Why?
MN: OK. And the last one is erosion.
MN: Why?
MN: Next question is more general—what do you think it's most important for elementary students to get out of science?
MN: Next question you can use cards again, I'm going to ask you to imagine that you've been asked to teach a class of 5th graders about decomposition. So what are some instructional methods you might use to teach decomposition to 5th graders?
MN: A couple more words about why?
MN: Now ask you about some other approaches you didn't name, tell me whether you would be likely to use these, unlikely, and a little bit about why (read a story, create model, field trip, etc.)
MN: Now switch to questions about confidence in self as science teacher. Question from getting started journal; in terms of your confidence in yourself as a science teacher, you said ___, I was wondering if you could tell me a little bit about why you answered the way you did?
MN: Please fill out form, rate self and see where you are now, we'll talk about it briefly.

1. Even if I try very hard, I will not teach science as well as I will most subjects.
   Strongly Disagree Disagree Unsure Agree Strongly Agree
2. I will typically be able to answer students' science questions.
   Strongly Disagree Disagree Unsure Agree Strongly Agree
3. I wonder if I will have the necessary skills to teach science.
   Strongly Disagree Disagree Unsure Agree Strongly Agree
4. When teaching science, I will usually welcome student questions.
   Strongly Disagree Disagree Unsure Agree Strongly Agree
5. I do not know what to do to turn students on to science.
   Strongly Disagree Disagree Unsure Agree Strongly Agree
6. I will not be very effective in teaching science investigations.

Strongly Disagree Disagree Unsure Agree Strongly Agree

7. I will find it difficult to explain to students why science investigations work.
   Strongly Disagree Disagree Unsure Agree Strongly Agree
8. I will be able to evaluate and adapt existing science investigations for use in my classroom.
   Strongly Disagree Disagree Unsure Agree Strongly Agree
9. I will be able to effectively teach elementary science lessons that involve scientific modeling.
   Strongly Disagree Disagree Unsure Agree Strongly Agree
10. I will find it difficult to support students' sense-making using data they have gathered in science investigations.
   Strongly Disagree Disagree Unsure Agree Strongly Agree
11. I will be effective in supporting students' use of modeling to learn science content.
   Strongly Disagree Disagree Unsure Agree Strongly Agree
12. I will find it difficult to effectively introduce, monitor, and conclude a lesson that involves an investigation.
   Strongly Disagree Disagree Unsure Agree Strongly Agree

MN: Last question—do you feel like your confidence in your science teaching has changed at all since you did the getting started journal assignment? If so, why?

Appendix G
End Fall 2009 interview protocol

MN: Start by telling me your name, your major in the SoE, a little bit about your field placement
MN: So if you think about your own knowledge of science, what would you say would be the biggest sources of that knowledge?
MN: So, now that it's the end of the semester, and I know you've done all the required science teaching in your field placement for the methods course, have you done any additional teaching beyond that at this point or not yet?
MN: More questions specifically getting at your knowledge and beliefs about how science should be taught, then a couple questions about your own confidence in yourself as a science teacher. OK? So first set of questions are scenario-sort of questions. So I'm going to ask you to imagine that you're going to be teaching a unit about magnets. What are some ideas that you have that a unit about magnets might involve?
MN: Same question, different topic—states of matter. What might a unit about states of matter look like?
MN: Now is a more general question. I know we talked a little bit about investigations in the methods course, when you think about that term, what does it mean to you? What do investigations entail?
MN: What do you see the teacher's role in that being? The student's role?
MN: Next one is a scenario: I'll ask you to imagine that you are helping a colleague think through how to teach a 5$^{th}$ grade science lesson that involves an investigation about sinking and floating. First thing I'll ask you to do is just give me an overview of what a lesson that has an investigation about sinking and floating might look like, and then I'll ask you to comment on what sorts of things you would tell your colleague to think about at different stages—like during the planning stage, during the beginning of the lesson, while the investigation is going on, and at the end of the lesson. So first let's start with the overview.
MN: How about at the very beginning of the investigation? What would you advise your colleague to think about when launching the lesson?
MN: And how about when the investigation is underway?
MN: Lesson conclusion?
MN: So now, a different scenario—I'm the elementary teacher, I'm going to teach my students about evaporation using a scientific modeling approach. What do you imagine that that might look like?
MN: A more general question: what does the term scientific modeling mean to you?
MN: How might a teacher choose to use an investigation and scientific modeling together—why would a teacher want to use these different approaches together?
MN: And what do you see as being the benefits of using them together?
MN: Any drawbacks of using them together?
MN: Switch to questions about beliefs. In what ways do you think science can and should be taught at the elementary level?
MN: Next set of questions is card-sorting task, different instructional approaches on each card, I'm going to ask you pull ones that you'd be likely to use and you can pull as many

as you'd like, for 4 different topics, and the first topic is light. And then we'll talk just a little bit about what you chose and why. [light]
MN: OK. Next topic is motion.
MN: Ok, and the next topic is plant life cycles
MN: OK. And the last one is erosion.
MN: Next question is more general—what do you think it's most important for elementary students to get out of science?
MN: So next question can use cards again, I'm going to ask you to imagine that you've been asked to teach a class of 5th graders about decomposition. So what are some instructional methods you might use to teach decomposition to 5th graders?
MN: Now ask you about some other approaches you didn't name, tell me whether you would be likely to use these, unlikely, and a little bit about why (read a story, create model, field trip, etc.)
MN: Now switch to questions about confidence in self as science teacher. Couple questions in common on getting started journal and final exam; one question that was in common asked you to rate your confidence in your own science knowledge, and at beginning of semester you said ___, at end of semester you said ___, do you think there was change there and why? In terms of your confidence in yourself and being able to teach science lessons, you went from ____ to _____, I was wondering if you could tell me a little bit about what caused that or may have contributed to that shift?
MN: Please fill out form, rate self and see where you are now, we'll talk about it briefly.

1. Even if I try very hard, I will not teach science as well as I will most subjects.
   Strongly Disagree Disagree Unsure Agree Strongly Agree
2. I will typically be able to answer students' science questions.
   Strongly Disagree Disagree Unsure Agree Strongly Agree
3. I wonder if I will have the necessary skills to teach science.
   Strongly Disagree Disagree Unsure Agree Strongly Agree
4. When teaching science, I will usually welcome student questions.
   Strongly Disagree Disagree Unsure Agree Strongly Agree
5. I do not know what to do to turn students on to science.
   Strongly Disagree Disagree Unsure Agree Strongly Agree
6. I will not be very effective in teaching science investigations.
   Strongly Disagree Disagree Unsure Agree Strongly Agree
7. I will find it difficult to explain to students why science investigations work.
   Strongly Disagree Disagree Unsure Agree Strongly Agree
8. I will be able to evaluate and adapt existing science investigations for use in my classroom.
   Strongly Disagree Disagree Unsure Agree Strongly Agree
9. I will be able to effectively teach elementary science lessons that involve scientific modeling.
   Strongly Disagree Disagree Unsure Agree Strongly Agree
10. I will find it difficult to support students' sense-making using data they have gathered in science investigations.
   Strongly Disagree Disagree Unsure Agree Strongly Agree
11. I will be effective in supporting students' use of modeling to learn science content.
   Strongly Disagree Disagree Unsure Agree Strongly Agree

12. I will find it difficult to effectively introduce, monitor, and conclude a lesson that involves an investigation.

| Strongly Disagree | Disagree | Unsure | Agree | Strongly Agree |
|---|---|---|---|---|

MN: General question—now that you've had another semester of field experience and the methods course, I'm wondering how you feel now about teaching a science lesson that involves an investigation?
MN: And how do you feel now about teaching a science lesson that involves modeling?
MN: On final exam I asked you to talk a little bit about different experiences—BSSTs, etc.—and I have your answers here if you want to refer back to them, wondering if you could talk a little bit about how each of those helped and hindered you in learning to teach science?
MN: Last question: if you had to pick one thing from this semester, anything at all, that has helped you learn to teach science the most, what would you say that one thing would be and why?

# Appendix H
## End Winter 2010 interview protocol

MN: First, have you had any additional opportunities to teach science in your field placement or elsewhere this semester? Approximately how many/how often? Can you describe those for me?
MN: The first set of questions has to do with what you know and understand about science instruction that involves investigations. What do you think investigations in elementary science lessons entail… From the student's perspective? From the teacher's perspective?
MN: Can you describe what this term "investigation" means to you?
MN: Now, I'm going to ask you describe the elements that make up an elementary science investigation lesson.
MN: Here is another general question: When I say the term "scientific modeling," what does this mean to you?
MN: How might a teacher use an investigation and scientific modeling together to teach a science lesson? Why?
MN: Why might a teacher choose to use these two in conjunction with one another? What might be the benefits of this combined approach?
MN: What might be the drawbacks?
MN: Have you had any opportunities to teach lessons that involve scientific modeling this semester? If so, can you describe them—how were models and/or modeling part of the lesson and why did you use models/modeling?
MN: Now I'm going to ask you some questions that pertain more to your own beliefs about science teaching. Using the cards provided, please choose which instructional approach (es) you would be most likely to use to teach about (1) Light
MN: (2) Motion (speed & distance)
MN: (3) Plant life cycles
MN: (4) Erosion
MN: Can you tell me a little bit more about why you chose that approach/those approaches?
MN: What do you think is most important for elementary students to "get out of" science? Why?
MN: Do you feel that your beliefs about how science should be taught have changed at all during your student teaching semester? Why?
MN: Now I'd like to ask you some questions that have to do with your feelings about your own confidence level about teaching science. First, using a scale from "not very confident" (1) to "very confident" (5), how would you rate your comfort level with teaching a science lesson that involves an investigation? Do you feel this has/has not changed this semester? Why?
MN: Now I'll ask you to fill out the form and we'll talk about your confidence ratings for some but not all of the items.

1. Even if I try very hard, I will not teach science as well as I will most subjects.
   Strongly Disagree  Disagree  Unsure  Agree  Strongly Agree
2. I will typically be able to answer students' science questions.
   Strongly Disagree  Disagree  Unsure  Agree  Strongly Agree

3. I wonder if I will have the necessary skills to teach science.
   Strongly Disagree Disagree Unsure Agree Strongly Agree
4. When teaching science, I will usually welcome student questions.
   Strongly Disagree Disagree Unsure Agree Strongly Agree
5. I do not know what to do to turn students on to science.
   Strongly Disagree Disagree Unsure Agree Strongly Agree
6. I will not be very effective in teaching science investigations.
   Strongly Disagree Disagree Unsure Agree Strongly Agree
7. I will find it difficult to explain to students why science investigations work.
   Strongly Disagree Disagree Unsure Agree Strongly Agree
8. I will be able to evaluate and adapt existing science investigations for use in my classroom.
   Strongly Disagree Disagree Unsure Agree Strongly Agree
9. I will be able to effectively teach elementary science lessons that involve scientific modeling.
   Strongly Disagree Disagree Unsure Agree Strongly Agree
10. I will find it difficult to support students' sense-making using data they have gathered in science investigations.
    Strongly Disagree Disagree Unsure Agree Strongly Agree
11. I will be effective in supporting students' use of modeling to learn science content.
    Strongly Disagree Disagree Unsure Agree Strongly Agree
12. I will find it difficult to effectively introduce, monitor, and conclude a lesson that involves an investigation.
    Strongly Disagree Disagree Unsure Agree Strongly Agree

MN: I will not be very effective in teaching science investigations.
MN: I will find it difficult to explain to students why science investigations work.
MN: I will be able to evaluate and adapt existing science investigations for use in my classroom.
MN: I will be able to effectively teach elementary science lessons that involve scientific modeling.
MN: I will find it difficult to support students' sense-making using data they have gathered in science investigations.
MN: I will be effective in supporting students' use of modeling to learn science content.
MN: I will find it difficult to effectively introduce, monitor, and conclude a lesson that involves an investigation.
MN: How do you feel *now* about teaching a science lesson involving an investigation? Why?
MN: Involving modeling? Why?
MN: What has influenced your thoughts & feelings?
MN: How have your science teaching experiences from ED421—the BSSTs, peer teaching, reflective teaching--been relevant and/or irrelevant to your science teaching as a student teacher?
MN: When you are *planning* a lesson that involves an investigation, what sorts of things do you pay attention to?

MN: When you are *teaching* a lesson that involves an investigation, what sorts of things do you pay attention to?
MN: How do you determine if the investigation was "successful?"
MN: What are the biggest influences on how you have taught science lessons this semester?
MN: Looking back, what other teaching experiences (in science or not) have been the most helpful for you in teaching science lessons as a student teacher? Why?
MN: One recurring theme I have noticed about your science teaching is ________. Is this a fair statement? Can you tell me why this is important to you?
MN: Now I'm going to ask you to describe for me the relationships you see (or don't see) between some aspects of science teaching and your own science instruction (teaching practice) over this year. For example, if I were to ask you to describe the relationship between the time of day science was taught and your science instruction, you might say "because science was taught last thing in the day, I found that I was really tired by the time we got to science, and because I was tired, I didn't always teach science the way I would want to because I didn't have the energy to manage behavior during investigations and so I didn't have them do investigations very often." Or you might have said "because science was the last thing in the day and only lasted 20 minutes, I found myself always being rushed in teaching the lessons." Does it make sense what I'm asking?
MN: Can you please describe the relationship between the classroom curriculum materials in science (Science Companion) and your science instruction this academic year?
MN: Can you please describe the relationship between your CT and your science instruction this academic year?
MN: Can you please describe the relationship between your knowledge of the science topics you taught and your science instruction this academic year?
MN: Can you please describe the relationship between your own beliefs about how those science topics should be taught and the science instruction you did this academic year? For example, were they in agreement or not always? How and why?
MN: Can you please describe the relationship between your self-confidence in your ability to teach science (for the topics/lessons you taught) and your science instruction this academic year?
MN: Are there other relationships between your science instruction and other important factors that I haven't touched on here that you would like to mention?
MN: Have your ideas about science teaching changed over the past year and if so, in what ways? What do you see as being the most important drivers of/influences on those changes?
MN: In what ways has your science teaching practice changed over the past year, and what do you see as being the most important drivers of/influences on those changes?

## Appendix I
## Post-approximation of practice enactment interview protocol

MN: Can you tell me where this science teaching experience fits in with your other science teaching experiences in the field?
MN: Can you tell me where this lesson fits into the unit?
MN: What instructional materials did you use in this lesson?
MN: How & why did you choose these materials?
MN: Did you have a lesson plan to work from?
MN: Did you make any changes to the lesson plan you used to teach this lesson? Why?
MN: What aspects of teaching the lesson did you focus on when you were planning this lesson?
MN: Why was that important to you?
MN: Now some questions that have to do more with how you were thinking/feeling during your teaching and how you were thinking about things after the lesson. How did you feel while you were teaching the lesson?
MN: What “resources” did you draw upon in order to teach this lesson (for example, advice from your CT, methods course knowledge, prior experience, knowledge of students, etc.)?
MN: What went as you had anticipated and what didn’t go as you had anticipated?
MN: If you were to teach this lesson again, would you do anything differently next time? If so, what and why?
MN: Can you give me an outline of the lesson?
MN: What do you feel helped prepare you to teach this lesson?
MN: Is there anything that you felt unprepared for when you taught this lesson?
MN: What do you feel were the benefits of engaging in this science teaching experience?
MN: Any drawbacks from having had this science teaching experience?
MN: Has this experience teaching changed how you feel about teaching science?

Appendix J
Pre/post test items

**Pretest only:**

Please indicate the number of science courses you have taken
In high school:
Biology_______
Chemistry_____
Earth Science_______
Physics_______
Anatomy & Physiology_____
Other (please specify)__________

In college:
Biology_______
Chemistry_____
Earth Science_______
Physics_______
Anatomy & Physiology_____
Other (please specify)__________

In the School of Education, what is your major and minor?

| Majors: | Minors: |
|---|---|
| Language Arts ______ | Fine Arts_______ |
| Mathematics _______ | Language Arts________ |
| Integrated Science________ | Mathematics________ |
| Social Studies ________ | Integrated Science______ |
| | Social Studies________ |

**Both pretest and posttest**

How confident are you in your knowledge of science?
a. Not confident at all
b. Not quite confident
c. Unsure
d. Confident
e. Very confident

How confident are you in your ability to effectively teach elementary science?
a. Not confident at all
b. Not quite confident
c. Unsure
d. Confident
e. Very confident

If you had to choose one word to describe how you feel about teaching elementary science, it would be:

What concerns, if any, do you have about teaching elementary science?

**Posttest only:**

What is the most important thing you have learned about teaching elementary science this semester?

This semester you have had a range of different kinds of science teaching experiences associated with EDU 421. Each, of course, has strengths and limitations. Please comment on your perceptions of how each helped you learn to teach science.

**Peer teaching BSST in 421**

<u>Teacher role</u>

a. What did this help me learn or improve?
b. What were the limitations or challenges of this experience

<u>Student roles</u>

c. What did this help me learn or improve?
d. What were the limitations or challenges of this experience?

**BSSTs in the field**

e. What did this help me learn or improve?
f. What were the limitations or challenges of this experience?

**Reflective teaching assignments**

g. What did this help me learn or improve?
h. What were the limitations or challenges of this experience?

**Overall**

i. Overall, based on these science teaching experiences, I feel well prepared with regard to….

Appendix K
Peer teaching co-reflection worksheet

# Bite-Sized Science Teaching in ED421

## *Peer teaching co-reflection pre-write*

Name____________________________ Date__________________

Name of BSST "Teacher" ______________________________

1) Were you the teacher or student in this BSST?

   Teacher Student

2) What did the teacher do effectively? Please cite a specific example.

3) What was interesting or surprising about the students' thinking? Please cite a specific example.

4) What could the teacher have done differently to improve his or her science teaching? Please give a specific suggestion.

5) What did you learn about science teaching from this BSST?

6) Any additional thoughts about today's BSST?

Appendix L

Coding scheme for approximation of practice observation data

| Key feature of investigation lesson | What it might entail (Codes) | Explanations/Examples |
|---|---|---|
| Identifying the investigation purpose | Answering a question or problem-solving | Using the investigation as a means to answer a scientific question or problem. (e.g., “Will a heavier or lighter ball will fall faster?” or “How can we make ice melt faster?”). Question or problem is posed explicitly. |
| | Scientific modeling | Gathering evidence for the stated purpose(s) of creating, revising, and/or refining a scientific model. |
| | Developing authentic process skills | Learning how to design/conduct an investigation using authentic scientific investigation skills. (e.g., learning how to measure temperature or learning to incorporate controls into an experiment.) Stated explicitly. |
| | Telling the purpose | Informing students of investigation purpose (i.e., telling students why they will carry out/ did carry out the investigation) |
| | Other | Anything not captured in other codes. For example, completing an investigation to fill in worksheet or notebook pages, or having students determine their own purpose(s) for doing the investigation. |
| | Not done | Purpose not stated and/or purpose implied; reason for doing the investigation was not made explicit in lesson |
| Connecting the investigation lesson to students’ prior knowledge, ideas, and/or experiences (outside of the context of this lesson) | Connecting to real world examples | Making connections between the investigation lesson and instances of the science concepts and/or processes in the world outside school with which students are likely to have experience or familiarity. |
| | Relating to a scientific model | Linking the investigation lesson to an existing scientific model (student- , teacher-, or scientist-generated) OR having students represent their ideas about the phenomenon/concept through creation of an initial expressed (i.e., not mental) scientific model |
| | Eliciting students’ ideas | Asking students to communicate their ideas, knowledge, and/or experiences about the science concepts verbally or through text (i.e., not through modeling). Includes prompting students to explain their reasoning and posing investigation-related questions for students to consider in advance of carrying out the investigation. |
| | Connecting to previous lessons | Reviewing or otherwise reminding students of what they have learned about the concept(s) to this point in the unit OR in previous grades. May involve Q&A. |

| Key feature of investigation lesson | What it might entail (Codes) | Explanations/Examples |
|---|---|---|
| | Not done | Investigation not explicitly connected to students' ideas, prior knowledge, and/or experiences. |
| | Other | Anything not captured in above codes. |
| Establishing data collection procedures | Supported data recording | Use of pre-existing or co-constructed system for keeping track of data. May be part of a worksheet or can be created by students and/or teacher during the lesson. |
| | Teacher modeling | Teacher demonstrates how to collect and/or record investigation data by doing an example. |
| | Directions | Teacher gives students verbal and/or written step-wise directions on what students should do to collect and/or record investigation data. Includes clarifying student uncertainties related to carrying out the investigation. |
| | Discovery | Investigation is predominantly student-directed in terms of how the investigation is carried out, what constitutes data, and/or how data are recorded. |
| | Directed discovery | Intermediate between "directions" and "discovery." Teacher mediates investigation by prompting students to consider what counts as data and/or how to collect it and/or how to record it. |
| | Not done | What constitutes data and its collection and recording not entailed in this lesson. |
| | Other | Anything not captured in the above codes. |
| Fostering sense-making with data (During and After investigation) | Pattern-seeking | Looking for trends or patterns in the investigation data |
| | Scientific model-based | Seeing how investigation data fit/do not fit with scientific models and/or changing models to account for empirical findings |
| | Discourse-based | Engaging in discourse to determine what the data mean by developing descriptions of what students have learned from the investigation data. May involve use of Q&A and/or written and/or verbal supports. |
| | Relating findings to real world | Translating from investigation datum/data to its/their conceptual and/or real-world significance based on the student's knowledge or experience in real life. For example, relating an observation that ice melts at a higher temperature when salt is added than it does in the absence of salt to the use of salt on icy winter roads. |
| | Telling | Teacher directly tells students what the investigation data mean. For example, "We learned that objects that float are less dense than water." |
| | Not done | No classroom time or effort spent on making sense of the investigation data |

| Key feature of investigation lesson | What it might entail (Codes) | Explanations/Examples |
| --- | --- | --- |
| | Other | Anything not captured by the other codes |
| Supporting claims with evidence | Using written supports | Students record evidence-based conclusions from investigations on worksheets or in science notebooks. For example, “I think _______ because ________.” |
| | Discursive | Explicitly developing claims or conclusions that are supported by evidence and/or reasoning as part of a discussion about the investigation outcome. |
| | Scientific model-based | Explicitly developing claims based on evidence from investigation data using scientific models as a guide |
| | Not done | Claims and/or conclusions based on investigation outcomes not explicitly part of the lesson |
| | Other | Anything not captured in the other codes |

| Key feature of science investigation lesson | Teacher-directed | Student-directed | Intermediate or Mixed |
|---|---|---|---|
| Identifying the purpose | Teacher (or text) sets the investigation purpose. Heavily scaffolded with little to no room for students to determine their own ideas of the investigation purpose. | Students determine the investigation purpose; little to no scaffolding from teacher or texts. | A mix of teacher-directed and student-directed approaches OR a collaborative approach to determining investigation purpose. |
| Connecting to students' prior knowledge, ideas, and experiences | Teacher (or text) directs students in forming connections between the investigation and students' prior knowledge, experiences, and/or ideas. Heavily scaffolded with little to no room for students to determine their own connections. | Students develop connections between the investigation and their prior knowledge, experiences, and/or ideas in a largely student-driven manner; little to no scaffolding from teacher or texts. | A mix of teacher-directed and student-directed approaches OR a collaborative approach to connecting the investigation to students' ideas, prior knowledge, and experiences. |
| Establishing data collection | Teacher (or text) directs students in what constitutes data in the investigation and how it should be recorded. Heavily scaffolded with little to no room for students to determine their own systems of determining data and how to record it. | Students determine what counts as data in the investigation and how to record it; little to no scaffolding from teacher or texts. | A mix of teacher-directed and student-directed approaches OR a collaborative approach to determining what counts as data in the investigation and how it should be recorded. |
| Fostering sense-making with data | Teacher (or text) interprets what investigation data mean (how the data relate to larger concepts in science and/or the topic of interest). Heavily scaffolded with little to no room for students to determine their own interpretations of the data. | Students determine what investigation data mean (how the data relate to larger concepts in science and/or the topic of interest); little to no scaffolding from teacher or texts. | A mix of teacher-directed and student-directed approaches OR a collaborative approach to determining what data in the investigation mean (how they relate to larger concepts in science/the topic of interest). |
| Supporting claims with evidence | Teacher (or text) directs students in how to form conclusions or claim + evidence from the investigation. Heavily scaffolded with little to no room for students to determine their own conclusions. | Students develop investigation conclusions or claim + evidence in a largely student-driven manner; little to no scaffolding from teacher or texts. | A mix of teacher-directed and student-directed approaches OR a collaborative approach to determining conclusions and claims + evidence. |

Appendix M

Bridget's feelings during and after her methods semester approximations of practice (elaborated version of Table 4.9)

| Approximation of practice | During approximation of practice ("How did you feel while you were teaching?") | After approximation of practice ("Has this experience had any impact on how you feel about teaching science?") |
|---|---|---|
| BSST1 | … I was pretty much confident and knew what I was doing. (I) | It's definitely a lot more enjoyable to me than I thought it was going to be, I think it's a lot of fun, so there's that. (I)<br>I am beginning to LOVE teaching science! (W) |
| BSST3 | … it seemed very small to me…it seemed very non-scary, it was like "oh, I'm doing this, oh sure." (I) | The more I do it, the more I like it….And I'm not a science major or minor at all, so the teaching of it has definitely impacted that, at least. (I)<br>Science is becoming my favorite subject to teach. It was difficult to "stay out of" the teaching of the intro and activity. (W) |
| BSST2 | With the exception of the first minute or two of trying to "ok, what's already been said" kind of getting my bearings, aside from that it was like, nothing. I mean, it felt completely natural. (I) | Not any more than the last 2 times we talked about it. (I)<br>Science is becoming my favorite subject to teach. It was difficult to "stay out of" the teaching of the intro and activity. (W) |
| Peer teaching | … definitely more nervous than I am with second graders just because they're in the same spot that I am so they can kind of see "oh well you didn't do that right" … (I) | Not really. I like it… (I) |
| RT2 | Yesterday, it was very…there was a lot of chaos. So once that was over it was like a big, take a deep breath, because it was a little more chaotic than I had pictured. But today it was a lot more calm so I felt a lot better today than I did yesterday. (I) | I definitely really like it… (I) |

Appendix N

Hannah's feelings during and after her methods semester approximations of practice (elaborated version of Table 4.19)

| Approximation of practice | During enactment ("How did you feel while teaching this lesson/lesson portion?") | After enactment ("Did this experience impact how you feel about teaching science?") |
|---|---|---|
| Peer teaching | I was feeling pretty good, it was pretty exciting….I think it worked really well. (I) | NA |
| BSST1 | Pretty good…sometimes I felt like the discussion was getting out of control and…other times I felt like they were doing a really good job of talking to each other. I felt a little bit lost parts of the time, like "where are we going to go from here?" but I think that was because it was a really student-led discussion... (I) | No (I)<br>I was really happy with my work facilitating the discussion in this class…I felt like this part of the discussion went really well. …I was a little less happy with the discussion itself. I don't really think that leading students toward a desired answer is something that is helpful in a discussion, and I think that because of this belief, I didn't really succeed in leading the students toward choosing the sun as the most important of the three components. (W) |
| BSST3 | Pretty good. I didn't have a plan, and I usually don't have a lesson plan, but I usually have at least an outline of at least 3 main points and I kind of had to just go with my instincts, I didn't know what I really wanted them to do, I mean I had a really vague idea but I hadn't written it down…I was really responding to what they were doing. (I) | No, I don't think so (I) |
| BSST2 | I really liked this lesson. I actually, I sort of planned this lesson, I had an idea for it and I proposed it, I pitched it to my CT and he added another piece to it that made me the "expert" in the room …I was really happy with it and I thought it was cool that it was | No (I)<br>This station went really well, and I felt especially proud of my work. …My CT and I "invented" this lesson together…I felt like I had been in charge of the goals for |

| Approximation of practice | During enactment ("How did you feel while teaching this lesson/lesson portion?") | After enactment ("Did this experience impact how you feel about teaching science?") |
|---|---|---|
| | different from what I had been doing and that he let me do that, so that was pretty cool. I felt very proud. (I) | the station, and as a result I had a very clear idea of what my comments and contributions should be in order to achieve these results. (W) |
| RT2 | I felt pretty good about this lesson, I had gone over it a couple times and I had actually written out the lesson plan just last night and so I was really familiar with it. And I kind of talked to my CT and I actually talked to one of the other 3rd grade teachers too about the lesson and so I kind of had some ideas about what might happen in it, and the kids were really engaged and they were really interested and they asked all the right questions to make it go where it needed to go, so that was really helpful. (I) | No. I thought it was really interesting, I felt like my CT was really frustrated that it went over [time allotment], but I really didn't think it was that important … the kids were so engaged and like I said it was recess that they were missing and I thought it was interesting how he said we need to work more on our timing, and I was like "I don't think so, I think we need to work on having more science and less recess." (W) |

Appendix O
Natalie's feelings during and after her methods semester approximations of practice (elaborated version of Table 4.29)

| Approximation of practice | During enactment ("How did you feel while teaching?") | After enactment ("Did this experience impact how you feel about teaching science?") |
|---|---|---|
| BSST1 | Natalie did not directly answer this question | NA |
| RT1 | At the beginning when everybody was calm and sitting down, [I felt] pretty confident, things were going well so that was good. I sort of lost confidence when my CT had to step in more, I felt like "what am I doing wrong?" and started questioning myself and started feeling really flustered. But at the times when she was [not involved] I felt more comfortable. (I)<br><br>I felt really uncomfortable during …the time I let students work in groups because I wanted to give them enough time to work and I wanted them to arrive at an answer. I felt flustered when students could not finish their work in the allotted time and I also was unsure of when to guide students as opposed to telling them. I wanted them to leave with a certain answer, but I did not think that I should just tell them something.(W) | It's a bit scary…I'm more like, I like structured things and following a specific plan, and having inquiry so like…the only way I can think of it is abstract. It's harder for me because I want the students doing some things like have an exact time for what exactly it is…to step back from it and let them [go], that's harder for me. (I)<br><br>I felt really confident about my ability to teach science prior to this lesson and after this lesson I felt like there was a lot to improve on. I expected to have to make improvements no matter what, but I envisioned my lesson running smoother and better than it actually did. (W) |
| Peer teaching | In the beginning when the experiment was going well, I was a little bit nervous with the first one [station enactment] but I felt like it went really well. I think the last two groups the experiment didn't work at | I'm feeling maybe a little bit more confident but I don't know if a room full of second graders is more intimidating than a group of five college students.(I) |

| Approximation of practice | During enactment ("How did you feel while teaching?") | After enactment ("Did this experience impact how you feel about teaching science?") |
|---|---|---|
| | all and I could feel myself getting a little flustered and I was like "well sometimes your experiments don't go as planned" and B. kind of interjected and was like "why don't you use the data from the last group where it did work" and so I went with that. (I) | |
| RT2 | A little bit frazzled, there was a lot of people in here watching, 4 of you, and one of the student's parents was there. So during the investigation was when I actually started sweating, because there's a lot of groups and there was a lot of questions and I wanted to make sure everything was running well and I don't miss anybody…but before that I felt really confident, I felt like things were going really smoothly with the introduction. (I) | I think that every time there's an investigation there's going to be some amount of frazzledness, so I feel like I just need to get comfortable with that…The more lessons I do, the more practice, the more confidence I have and this time I was a little less frazzled, a *lot* less frazzled than I was the first time. Once I feel more confident in the classroom, I think that things will run a lot more smoothly, I think that will reflect upon my students too. (I)<br><br>I think I exceeded my goals for myself in this lesson. I definitely felt more confident teaching this lesson than I had during my first RT. I felt better prepared for the lesson and I knew what was expected of me and what I expected from my students. I am glad that I had the opportunity to teach another full length science lesson, especially one that included an investigation. (W) |
| BSST3 | Rushed. Very rushed. We were running out of time, and I forgot where the kids had to | I think that the conclusion is important for students to know why they're doing something, I |

| Approximation of practice | During enactment ("How did you feel while teaching?") | After enactment ("Did this experience impact how you feel about teaching science?") |
| --- | --- | --- |
| | go, but my CT was just in the back of the room giving me the "hurry up, move it along" sign which she tends to do, which is kind of good because I tend to take my time, but other than that, I felt ok about it. I would have liked to have been able to talk more about it. (I)<br><br>I felt extremely rushed during my BSST because we were running out of time for the science lesson. (W) | still feel the need for that as a student. (I) |

Appendix P

Polly's feelings during and after her methods semester approximations of practice (elaborated version of Table 4.39)

| Approximation of practice | During enactment ("How did you feel while teaching this lesson/lesson portion?") | After enactment ("Did this experience impact how you feel about teaching science?") |
|---|---|---|
| RT1 | I actually, I wasn't nervous at all, I've kind of overcome that with teaching, because I think either way, I can present something and kids know you make mistakes and stuff. I actually had a lot of fun with it, I didn't think I would because I'm not a great science person… I was so nervous that I was not going to be able to teach them opaque, translucent, and transparent, I literally was studying them this morning like it was a quiz…but I knew all the answers when they were asking things, and I really surprised myself with that, so I definitely think it was fun.… (I)<br><br>I look forward to future lessons and feel I am on my way to becoming a confident and experienced teacher of science. (WR) | I'm excited to do the next few, and I really like that I used the lessons… I haven't seen a science lesson in here that they haven't used the materials or done some kind of investigation so that really lets me see that I need to do, and hope to do more with another lesson...(I)<br><br>It was the first science lesson I have ever taught, and I was worried I would not be confident and would not be able to answer students questions related to the topic. However, I found myself both confident and able to answer questions throughout the lesson. I also enjoyed the lesson and had fun teaching it, something I was not sure I was capable of doing because of my lack of science knowledge and experience…for my next science lesson I plan to have some higher expectations going into the lesson. (W) |
| BSST1 | Fine…I really enjoyed doing it … I liked it because I was comfortable going up there so I could just focus on other things and making sure my wording was right and I kind of wrote out what I wanted to say on my little sheet, which I didn't even look at, but I had written it kind of focused on what exactly I wanted to say so that came across in the best way that the students got it, | It just reassured that I know I can do it. And that it reassured me too in my past lesson, that they were getting the material, and that's kind of reassuring for me to know OK I did it last and something must have worked...(I)<br>I appreciated the fact that I got to just focus on one portion of a lesson, and really make sure I knew what I was doing. (W) |

| Approximation of practice | During enactment ("How did you feel while teaching this lesson/lesson portion?") | After enactment ("Did this experience impact how you feel about teaching science?") |
|---|---|---|
| | understood it. (I) | |
| Peer teaching | I wasn't nervous, then when I started doing it I kind of was because … I felt like I really had to push the students to talk and that's when I would just say their name and ask for their ideas … it was on the slower end and less exciting, so that kind of was hard to keep going in terms of getting the motivation of the students, but I think trying to take all of their ideas and … trying to relate everything. (I) | It really was important to pay close attention to details and really make sure that you think about all the possible ways and students' ideas and what could come up ...(I) |
| RT2 | The beginning was great and then I felt overwhelmed because it wasn't working like it should have and some groups were getting it… but it is really hard to see that [the phenomenon] so I was frustrated … the investigation part kind of failed in a sense so kind of from there I was like "ok this is not going well" …but I thought the beginning and obviously doing the review again really helped (I) | No, actually, interestingly enough, I'm still really excited to teach. I was more nervous this time, I don't know why, but I'm still excited to teach more science lessons and especially with this group because they are so engaged and even though they didn't get it, they still were sticking with me and trying to understand what I was saying, and that just made me feel important, they really were trying to understand what I was saying. (I)<br><br>Even though my immediate reaction to my science lesson was discouraging I think I learned a great deal from this experience and have a lot of expectations of myself for the next science lesson I teach. I also know with time I will get better at teaching science, and even with science lessons I have taught I know I have already surprised myself more than I could have imagined. I am very grateful for having these opportunities and believe I am becoming a confident |

| Approximation of practice | During enactment (“How did you feel while teaching this lesson/lesson portion?”) | After enactment (“Did this experience impact how you feel about teaching science?”) |
| --- | --- | --- |
| | | teacher of science and I look forward to having successful and not so successful lesson in the future because I believe I will benefit from both types of experiences. (W) |
| BSST2/3 | Good! I thought it was fun, I mean it was definitely a cool science lesson… it’s so interesting how different the classroom setting is when there’s only 16 [students], and I had fun with it …it was fun to be able to walk around and do that part of it. (I) | It just reconfirmed that the students in this class in particular are very engaged and it just makes the whole science learning process more enjoyable for them and for me because I’m excited to do it. …even if I’m not confident in myself, they really look up to me like even if I kind of think I don’t know what I’m talking about, they tell me, they get it, they’ll let me know if they don’t get it, and I really appreciate that… because it just helps me know OK as a teacher I didn’t clarify that enough.(I)<br><br>It did not go as well as I would have liked but I still believe it gave me an opportunity and something I can work on for next time. (W) |

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