PRACTICING THE PRACTICE:
LEARNING TO GUIDE ELEMENTARY SCIENCE DISCUSSIONS IN A PRACTICE-ORIENTED SCIENCE METHODS COURSE

by

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DEDICATION

Dedicated to Mom, Dad and Anish, for supporting me on my journey down the road less traveled; and to Neel, for giving me the guts to take it.

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INTRODUCTION

Defining the Problem Space

"…by almost any standard, many if not most of the nation's 1,450 schools, colleges, and departments of education are doing a mediocre job of preparing teachers for the realities of the 21st century classroom."
(U.S. Department of Education, 2009)

In today's fast-paced, information-rich, globally-aware society, there is a need to prepare future generations to not only be successful in math and reading, but also in science, so they can formulate evidence-based decisions regarding issues such as global climate change, medical breakthroughs, and the role of technology in society. However, "our primary and secondary schools do not seem able to produce enough students with the interest, motivation, knowledge, and skills they will need to compete and prosper in the emerging world (National Academy of the Sciences, 2007, p. 94). For example, U.S. students continue to score lower on international science assessments than their peers in other developed countries (U.S. Department of Education National Center for Education Statistics, 2009).

Waves of reform for over a decade have tried to address this problem with the publication of national, state, and local standards as well as the implementation of high-stakes assessments to monitor student performance (National Research Council, 1996; No Child Left Behind Act of 2001,"). These efforts call for abandoning traditional notions of memorizing scientific facts from textbooks, and instead, pushing for reform-based science teaching, which includes students having opportunities to learn science through inquiry.

In this dissertation, when discussing "reform-based science teaching," I am referring to "teaching and learning science through inquiry." I am not arguing that teaching or learning science through inquiry is the only way to engage students in scientific concepts and practices, nor am I arguing that my definition encompasses all of the ideas of science education reform. In this study, "teaching science through inquiry" will be defined as teachers creating classrooms where science is not transmitted to students as a set of facts to be memorized, but instead, where science is revealed in the "dynamics of the discipline—asking questions, finding ways to explore them empirically, investigating and evaluating competing alternative models, [and] arguing" (National Research Council, 2007, p. 254). Teachers can engage students in learning science through inquiry in the classroom by guiding them to ask questions about objects, organisms, and events in their environment, to plan and conduct simple investigations, to gather and use data and evidence to construct explanations, and to communicate and articulate their ideas with others (National Research Council, 2000). Even young students in elementary school can learn science through inquiry (van Zee, Hammer, Bell, Roy, & Peter, 2005), as there can be "…variations in the amount of structure, guidance, and coaching the teacher provides for students engaged in inquiry" (National Research Council, 2000, p. 29). For example, some teachers may provide questions for students to investigate based on curriculum materials and expected learning goals, while other teachers may have students develop their own questions and design investigations to answer them (Appendix A).

With these high expectations for elementary student science learning come high expectations for elementary science teachers, and therefore increasing pressure on university teacher education programs to do a better job of tailoring the preparation of teachers for the challenges of reform-based teaching.

Many studies have documented how difficult it is for prospective teachers to support students' learning through inquiry in the classroom (Lynch, 1997; Roehrig & Kruse, 2005; L. K. Smith & Southerland, 2007). It is especially challenging because teaching science through inquiry places demands on prospective teachers to teach in ways that are so different from what they experienced as students themselves for many years; therefore, the short exposure to these ideas in teacher education often leaves them with complex and fragile understandings of what science inquiry is, and even less prepared to teach in this way (Haefner & Zembal-Saul, 2004; Lortie, 1975).

Science methods courses, which are offered in most university teacher preparation programs, are often criticized for failing to prepare science teachers for the demands of reform-based science teaching (Clift & Brady, 2005). These courses often spend more time telling prospective teachers *about* reform-based ideals, such as teaching science through inquiry, instead of helping them learn how to actually *enact* them. Therefore, prospective elementary teachers may leave teacher preparation courses being able to name, describe, and even plan lessons that use reform-based teaching practices, but may not be prepared to translate what they learn into teaching with real students in real classrooms on their own (Clift & Brady, 2005). Much teacher education literature pinpoints this "problem of enactment" as a critical barrier to prospective teachers' later success in their own classrooms (e.g., Clift & Brady, 2005; Davis, Petish, & Smithey, 2006; Grossman & McDonald, 2008; Kennedy, 1999; Smith & Gess-Newsome, 2004).

Practice-Oriented Perspectives to Teacher Education

Teaching and learning are situated in interactions between students, teachers, and the content being learned; therefore, greater effort must be placed on designing and studying teacher preparation activities that attempt to bridge opportunities for prospective teachers to learn both "what to do" with opportunities to practice "how to do it" (Ball & Cohen, 1999; Lampert, 2005). In the backdrop of an educational context filled with increased pressure for accountability and access to education for all students, Arthur Levine summarized these expectations by calling for a shift in how teacher preparation is approached in his 2006 report on teacher education in the United States:

> The challenge facing education schools is not to do a better job at what they are already doing, but to do a fundamentally different job. They are now in the business of preparing teachers for a new world: an outcome-based, accountability-driven system of education in which all children are expected to learn. (Levine, 2006)

To address this challenge, there is a movement across many teacher education programs to adopt a more "practice-oriented approach" to teacher preparation, where prospective teachers have opportunities to develop specific teaching practices that are integral to successful teaching.

What is practice?

The term *practice* is currently used many ways across the teacher education literature. Drawing on the recent work of Lampert (2010), I will be using the term *practice* in four ways described in Table 1.1.

Table 1.1
Use of the term "practice" in this study (Lampert, 2010).

Use	Meaning
1. *Practice* v. Theory	The dichotomy of practice (what teachers do while teaching) versus theory (what teachers know about teaching).
2. Teaching as a collection of *practices*	Practices (plural noun), referring to the things teachers do. In this study, the science methods course will focus on the development of the practice of guiding science classroom discussions.
3. To *practice* doing something	This is the most common everyday use as a verb: to practice means to do something repeatedly to get better at doing it.
4. The *practice* of teaching	Practice here refers to the shared set of work that people in a profession do—just like the "practice of law" or 'practice of medicine." This meaning captures what I mean by "practice-oriented" course.

First, there is the dichotomy of theory and practice that is often referenced when discussing the disconnect between teacher education coursework and student teaching or fieldwork experiences—practice refers to "…what people do rather than what they think or know" (p. 23). Second, there is the idea of teaching practices, or sets of things teachers do while teaching. Practices are defined at different grain sizes in the field; for example, Hatch & Grossman (2009) consider guiding classroom discussions to be a practice while Ball et al. (2009) consider actions like eliciting contributions, and managing collective work, to be practices that make up a larger domain of guiding classroom discussions. Third, is the idea of practicing, or doing something repeatedly to improve performance. Finally, "the practice of teaching," much like "the practice of medicine" or "the practice of law," is the set of shared practices that those in a profession (e.g., teachers) enact in their work (Lampert, p. 29).

What makes teacher education practice-oriented?

Teacher education courses often focus on developing prospective teachers' knowledge and beliefs versus helping them carry out the tasks and activities of teaching itself (Ball & Forzani, 2009; Cochran-Smith & Fries, 2005). Currently, there are efforts to focus teacher preparation on "the practice of teaching," or the fourth definition in Table 1.1. Ball and Forzani pointed out:

> To make practice the core of the curriculum of teacher education requires a shift from a focus on what teachers know and believe to a greater focus on what teachers do. This does not mean that knowledge and beliefs do not matter but, rather, that the knowledge that counts for practice is that entailed by the work. (2009, p. 503)

The literature has proposed teacher education that is "practice-based" (Ball et al., 2009; Grossman, Hammerness, & McDonald, 2009), "practice-focused" (Ball & Forzani, 2009), or "situated in practice" (Ball & Cohen, 1999). While there is no universally accepted definition of a "practice-oriented approach" in teacher education, this dissertation will draw on the work of several researchers to describe "practice-oriented" teacher preparation.

First, "practice-oriented" refers to a teacher education course that gives "…significant attention not just to the knowledge demands of teaching but to the actual tasks and activities involved in the work" (Ball & Forzani, 2009, p. 503). This work of teaching includes a repertoire of teaching practices that may be common across or specific to particular subject-areas (Ball et al., 2009; Feiman-Nemser, 2001; Grossman & McDonald, 2008). These practices may be identified at different grain sizes; some practices may be small, such as the practice of re-stating student ideas publicly so all students are a part of a discussion, while others may be larger, such as the practice of guiding whole-class discussions (Ball & Forzani, 2009). When referring to "practice-oriented" approaches in this dissertation, it is important to note that this does not suggest the teaching and learning of a set of isolated practices taught as a set of behaviors. Instead, it implies learning practices in ways that allows for their flexible and deliberate use when integrated during real teaching (Grossman, Hammerness et al., 2009; Hammerness et al., 2005).

Second, practice-oriented courses "…emphasize repeated opportunities for novices to practice carrying out the interactive work of teaching and not just to talk about that work" (Ball & Forzani, 2009, p. 503). To engage prospective teachers in the interactive work of teaching, there is a need to include *pedagogies of enactment* in addition to *pedagogies of investigation* that are typically used in methods courses (Grossman & McDonald, 2008). Pedagogies of investigation involve studying teaching practice through approaches such as case studies or video cases. Pedagogies of enactment create opportunities for prospective teachers to learn how to actually enact teaching in contexts that are designed for novices. Lampert and colleagues call the cyclic integration of pedagogies of investigation and pedagogies of enactment, "pedagogies of practice." These pedagogies are enacted in a practice-oriented course, as prospective teachers engage in teacher education activities that cycle between learning about and studying teaching practices in a university classroom setting and as prospective teachers learn to use these practices in interaction with children in actual classroom contexts (Lampert, Beasley, Ghousseini, Kazemi, & Franke, 2010, p. 137).

The Practice of Guiding Science Discussions

As discussed above, a practice-oriented teacher education program is focused on engaging prospective teachers in the work of teaching, which is made up of several teaching practices (meaning 2 in Table 1.1). Guiding classroom discussions is an important and challenging teaching practice: it is used across grade levels and subject areas, and involves asking questions, monitoring student participation and developing ideas, and responding to student contributions in ways that guide the discussion towards learning goals (Grossman, Hammerness et al., 2009). Because teaching science through inquiry requires students to actively ask questions and build understandings, science discussions offer opportunities for teachers to make student ideas public so they can monitor student progress and help students work together to refine their understandings over time (NRC, 2000). Therefore, the practice of guiding discussions is important to begin to develop in science teacher preparation courses.

As universities implement redesigned elements in their teacher education programs to better prepare prospective science teachers to enact challenging practices such as guiding science discussions, research is needed to unpack *what* aspects of teaching are being taught, *how* to teach them to prospective teachers, and whether or not this preparation influences prospective teachers' early teaching experiences (Grossman, 2008). This dissertation begins to explore some of these questions in the context of a university science methods course designed to prepare prospective teachers to teach elementary science.

Study Overview

In a report outlining current knowledge, gaps and recommendations for teacher preparation, there is a call for systematic and comparative research on both the content and accompanying instructional methods or pedagogical approaches that are best suited for professional teacher preparation (Wilson, Floden, & Ferrini-Mundy, 2001, p. 16). In an effort to respond to the call for research on content and accompanying methods for professional teacher preparation, my dissertation will study the opportunities-to-learn the practice of guiding science classroom discussions that prospective teachers experience throughout eight course sessions of a practice-oriented science methods course.

The literature base for studying practice-oriented approaches in mathematics education and foreign language education is growing (Ball et al., 2009; Ghousseini, 2008; Lampert & Graziani, 2009), and efforts to focus on particular science teaching practices (Windschitl et al., 2010) and to use pedagogies of enactment such as approximations of practice (Davis, under revision) in science teacher preparation are currently underway.

In their course development, Ball et al. acknowledged that "…developing a professional curriculum focused on teaching practice-requires specifying aspects of teaching practice to be our content of the course and designing ways to teach the content to prospective teachers" (Ball et al., 2009, p. 440). Similarly, in this study, I am defining *opportunities-to-learn* (OTLs) as a combination of the content (what is being taught), and pedagogical approaches (how is it being taught). To study these OTLs in a practice-oriented science methods course, I will explore the following two research questions:

1. What was the content of guiding science classroom discussions that surfaced during practice-oriented course activities and
2. In what ways did the pedagogical approaches make this content of guiding science discussions available to interns[1] to learn?

In Chapter 2, I will review the literature that examines what teachers need to know to teach, and how and where they learn these things. I will look across teacher education literature in general, and specifically at studies focusing on elementary science teachers. Chapter 3 outlines the methodology of this study, including data sources, analysis procedures, and issues of validity and reliability. Chapter 4 will describe the content of guiding science discussions that came up throughout the course, and Chapter 5 will introduce the pedagogical approaches used during course activities to prepare interns for guiding science discussions. In Chapter 6, I will discuss my findings and will use Grossman's framework for teaching practice (i.e., decomposition, representation, and approximations of practice) as a lens for analyzing the pedagogical approaches in greater depth. Finally, in Chapter 7, I will summarize my findings, provide implications, and will suggest future studies that build on the findings from this work.

[1] The literature refers to people preparing to become teachers as pre-service teachers, prospective teachers, novice teachers, beginning teachers, etc. At the University of Michigan, graduate students enrolled in the Elementary Masters of Arts with Certification program (ELMAC) were called "interns," so I will adopt that term for the rest of this dissertation.

CHAPTER 2
LITERATURE REVIEW

The following literature review draws on a range of studies from teacher education, science education, science teacher education, math teacher education, and general practice of teaching literature bases. The goal is to elaborate on the following statements that form the backbone of this study:

- Teachers draw on a large knowledge base for teaching that includes subject-matter knowledge, pedagogical content knowledge, specialized content knowledge for teaching, and pedagogical knowledge.
- Teacher knowledge itself is not enough to prepare prospective teachers for enacting teaching practices.
- Teacher knowledge cannot be learned completely outside of practice, so opportunities must be made available for teachers to learn in practice.
- Closer links between coursework in teacher education and fieldwork should be designed to help translate theory to practice
- Practice-oriented approaches to teacher education offer one way of helping interns translate their knowledge and beliefs into action while teaching, and to continue to learn from their practice over time.

What Elementary Science Teachers Should Know

Knowledge base for teaching

Over several decades, there have been shifts in the focus on what teachers need to learn to be successful teachers (Cochran-Smith & Fries, 2005). In the mid-1900s, there was a push to teach prospective teachers specific observable behaviors, such as using wait-time or using particular management techniques. This approach was often criticized for focusing too much on discrete behaviors and neglecting any discussion of the teacher's intentions, cognitions, judgments and reasoning (Shulman, 1992). In the 1980s to early twenty-first century, there was a shift to expanding what teachers needed to know beyond a set of actions, and to now include particular kinds of subject-matter and pedagogical knowledge, decision-making skills, and particular attitudes, beliefs, and dispositions towards solving problems of teaching practice (Abell, 2007; Cochran-Smith & Fries, 2005). Today, there is an effort to teach core teaching practices in ways that they can be integrated and used flexibly based on a teachers' set of beliefs and dispositions towards learning (Grossman & McDonald, 2008).

Elementary science teachers are often expected to teach science in addition to other key subject areas such as math, reading, and social studies. Most elementary teachers learn science content or subject-matter knowledge (SMK) from high school or undergraduate science course experiences, and need both substantive knowledge (facts, principles, concepts) and syntactic knowledge (the rules of proof and validity in a discipline) in science (Schwab, 1964 in Shulman, 1987, p. 9). Often, prospective elementary science teachers enter teacher education programs with many of the same misconceptions or alternative ideas about science content that children have (Abell, 2007). Their syntactic knowledge of science, such as the need for providing evidence to support claims, may or may not be developed in their science coursework before entering a teacher education program. Davis, Petish, and Smithey reviewed the literature on science teachers' knowledge and beliefs about science inquiry and the nature of science and noted that while there are mixed findings, often pre-service teachers tend to have "unsophisticated understandings of inquiry and related skills," and often hold naïve beliefs about the nature of science (2006, p. 614).

While understanding science content and science inquiry practices is a part of the knowledge base for elementary science teachers, "…the capacity of a teacher to transform the content knowledge he or she possesses into forms that are pedagogically powerful and yet adaptive to the variations in ability and background presented by the students" is what separates science teachers from content experts in science (Shulman, 1987, p.15). This specialized knowledge for teaching is what Shulman labeled pedagogical content knowledge (PCK) (Shulman, 1987). Building and refining PCK, created in the context of real classrooms and students, occurs over time as teachers gain more experience in the classroom (Sherin, 2002). In addition to SMK and PCK, general pedagogical knowledge (PK) includes knowledge of general ways of approaching teaching. For example, PK provides the strategies for general classroom management, while PCK offers insights into the management of ideas within classroom science discourse (Shulman, 1987, p. 1). Similarly, high PK can help a teacher organize her classroom and run daily routines smoothly, but without SMK and PCK, she may be less equipped to introduce students to key science concepts and practices.

Magnusson, Krajcik, and Borko (1999) provided an in-depth definition of PCK for science teaching; they unpacked what science teachers need to know to translate their SMK for the purposes of teaching (see Figure 2.1). I will summarize the main components of the components they identified. The orientation towards teaching science that is the goal of most science reform efforts is that of classroom inquiry which involves students engaging in scientifically-oriented questions, giving priority to evidence, formulating explanations from evidence, and communicating their explanations (National Research Council, 2000). The particular orientation of a teacher will then influence the other components of PCK.

Science teachers must also have knowledge of science curricula. This includes an understanding of what must be covered based on national, state, and district standards for the grade they are teaching, as well as what is covered in the grades before and after. This way the teacher can find ways to link new learning to knowledge students may bring with them to class, and prepare them to make further connections in later years. Also, they should have a sense of what curriculum materials are available for their particular subject-area and grade level in science.

Knowledge of students' understanding of science includes knowing the types of prior understandings (e.g., photosynthesis) and skills students need to have (e.g., analyzing graphs) to learn specific concepts. It also includes knowing why a particular concept is confusing and how students' misconceptions may prevent them from accepting the scientifically accepted view.

Knowledge of assessment of scientific literacy includes understanding what is important to assess about particular topics and the range and purposes for particular assessment formats in the classroom (e.g., performance-assessments, paper-pencil tests, formative versus summative assessments).

Finally, knowledge of instructional strategies includes knowing a range of strategies for teaching the subject of science in general (e.g., how to teach science through inquiry) or for particular topics (e.g., how to teach moon phases, magnets, or ecosystems). Instructional strategies can also include knowledge of the types and appropriate uses of particular representations for different topics (e.g., illustrations of photosynthesis or models of the phases of matter), as well as activities (e.g., investigations, demonstrations, simulations) that help teach aspects of a concept.

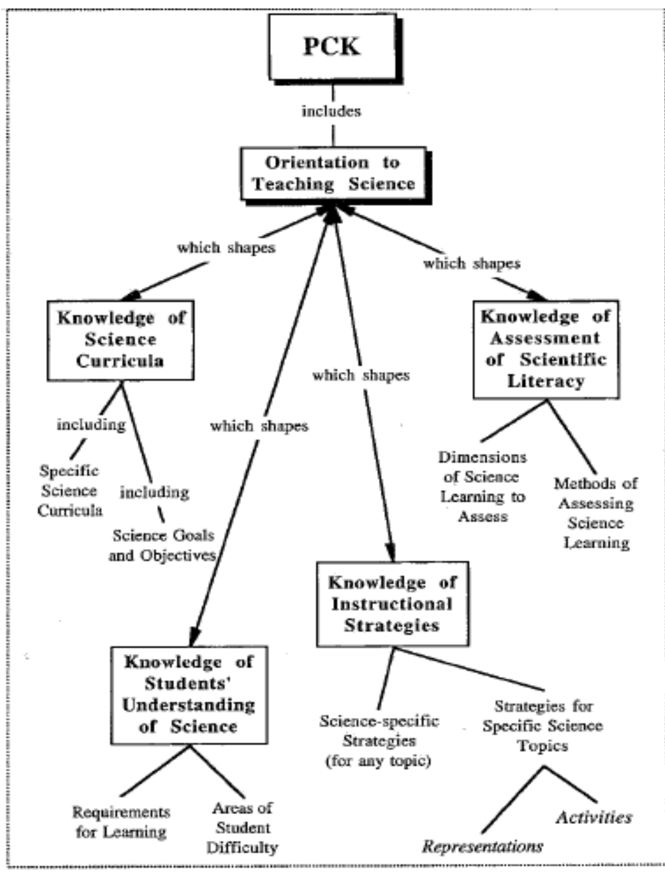

Figure 2.1. Components of pedagogical content knowledge for science teaching (from (Magnusson et al., 1999, p. 138).

In addition to SMK, PK, and PCK, Ball, Thames and Phelps proposed the need for specialized content knowledge, which includes knowledge needed solely for the tasks of teaching (2008). For example specialized content knowledge for teaching science would not be taught in science courses preparing future researchers in science. Instead, this knowledge is particular to the work teachers must do when engaging students with content. This knowledge may include noticing patterns in student errors in a particular subject-area or figuring out if a student's nonstandard generalization will always apply across situations in a subject (Ball et al., 2008)

More than knowledge is needed to teach

As discussed, the knowledge base for teaching science is large, including PK, PCK and specialized content knowledge, SMK, along with additional considerations, such as the knowledge of the context of particular students in particular school settings and larger state and national level context in terms of requirements (Magnusson et al., 1999; Shulman, 1987). Subject-specific methods courses in university teacher preparation programs often provide introductions to common misconceptions among students in different grade levels, the type of activities that help to teach big ideas, and requirements for good teaching practice. However, it is not until teachers are actually practicing how to teach that they learn to negotiate among the knowledge base and to make decisions in the midst of classroom interactions. That is, along with the knowledge base of SMK, PK, and PCK, it is important to engage in pedagogical reasoning, where teachers "…learn to use their knowledge base to provide the grounds for choices and actions" (Shulman, 1987, p. 13).

While SMK is thought to be primarily developed in college coursework and PK is thought to be introduced in general education courses (Floden & Meniketti, 2005; Wilson et al., 2001), the subject-specific PCK is often left to be developed in methods courses, which do not last long enough to provide interns opportunities to integrate all the components of their knowledge base. Even more important, simply having any of this knowledge is not enough, as there is a difference between having knowledge and knowing how to enact it: that is, "we must see knowledge as *a tool at the service of knowing* not as something that, once possessed, is all that is needed to enable action or practice" (Cook & Brown, 1999, p. 387). In knowing how to teach science, teachers must actually be able to draw on their orientation to science, use their knowledge of science curricula, capitalize on their knowledge of the understandings students bring in about particular science topics, create and use appropriate science assessments, and enact instructional strategies to guide student learning. They translate what they know and believe and put it into action while teaching. In other words, "to be accomplished in a profession, discipline, or craft, for example, is necessarily tied up with practicing it" (Cook & Brown, 1999, p. 387). Unfortunately, science methods courses often fall short of helping pre-service teachers move from knowledge to knowing during enactment of teaching practice. For example, in their review of research on methods course, Clift & Brady summarized:

> …the difficulty of enacting the practices recommended by methods courses and adopted by prospective teachers tells us that even when preservice teachers believe in teaching a certain way, they often do not know how to act on that desire

or how to deal with difficulties they encounter. *Moving to action is more difficult than the intention to do so* [italics added]. (Clift & Brady, 2005, p. 322)

Finding ways to help prospective teachers move to action while also developing the knowledge base needed is often the challenge for teacher education programs. Today, efforts to shift methods courses to be more practice-oriented offers one way of tackling the struggles prospective teachers have in moving from beliefs about reform-based teaching to actually starting to enact reform-based teaching. It is important to note that the responsibility of preparing prospective teachers with *all* the knowledge and experiences to be expert teachers is not the expectation of a methods course in a teacher education program. Instead, the goal is to prepare "well-started beginners" who are starting to build their initial repertoire of practices and ways of looking at their teaching so they can continue to learn from their experiences over time (Avraamidou & Zembal-Saul, 2010; Feiman-Nemser, 2001).

A Practice-Oriented Approach to Teacher Education

…learning about a method or learning to justify a method is not the same thing as learning to do the method with a class of students, just as learning about piano playing and musical theory is not learning to play the piano. The later requires getting one's hands on the instrument and feeling it "act back" on one's performance.
(Lampert, 2005, p. 35)

Situating teacher learning in practice

The situated perspective focuses on the physical and social contexts where learning take place, and the ways learners interact with each other and the tools and materials in those particular contexts (Putnam & Borko, 2000). This perspective suggests that there are limits to what knowledge can be gained in more abstract, formal learning settings like universities, versus the settings in which that knowledge is actually used

(Brown, Collins, & Duguid, 1989). The university and schools where prospective teachers learn have their roles as settings in teacher education: some learning goals may be supported better at the university, without the complexities of real classrooms and students, while others may require opportunities to gain knowledge of learners that is situated in a particular classroom culture.

Specifically, university classrooms can be good settings for learning about science content, learning theories, and pedagogical approaches; however, the use of such knowledge "…cannot be learned entirely in advance or outside of practice" (Ball & Cohen, 1999, p. 12). For example, the university setting may be appropriate for discussing the role of classroom discussions in eliciting and guiding student ideas and for providing opportunities for interns to plan classroom discussions or to adapt curricular materials to include more opportunities for discussion. However, these university settings provide fewer opportunities to experience the interaction between teachers and students in a classroom where teachers must actually respond to elementary students' ideas in meaningful ways. Furthermore, there is often a disconnect between the methods coursework and student teaching or fieldwork, as the fieldwork instructor or cooperating teacher may or may not know what occurred in the methods course and vice versa (Clift & Brady, 2005, p. 313; Crawford, 2007). Therefore, it is left up to the prospective teachers to translate what they learn in the methods course setting into their early teaching experiences without the supports of coherent messages across these settings (Feiman-Nemser, 2001; Hammerness et al., 2005). Figure 2.2 illustrates this disconnect.

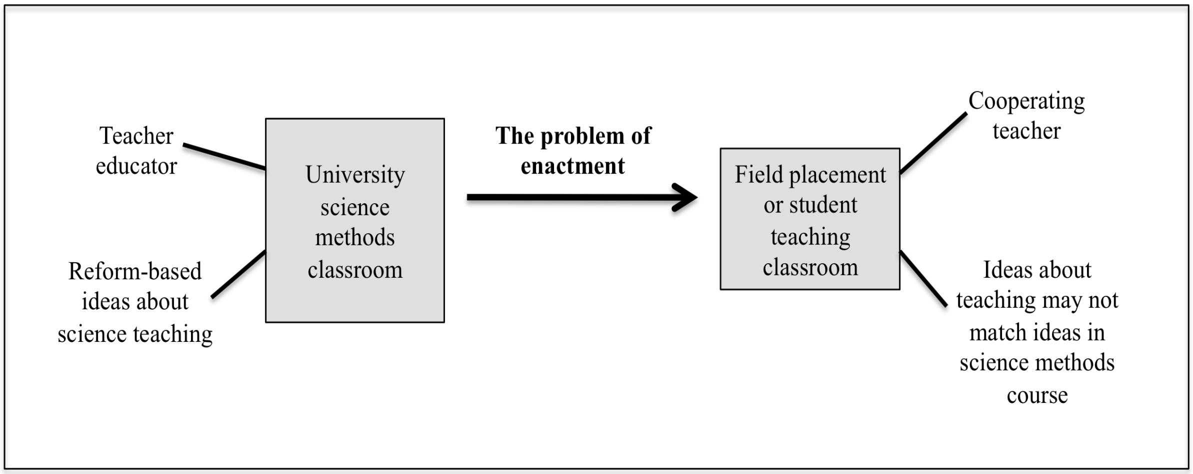

Figure 2.2. Disconnect between ideas encountered by interns in university methods coursework and field placement or student teaching classroom.

Designed settings, which allow teacher educators to "…control certain conditions so that a student teacher can engage in learning practices in a more efficient and effective manner," offer one setting where prospective teachers can practice teaching in ways that align with methods course messages (Lampert, 2006; Teacher Education Initiative, 2011).

Ball and Forzani acknowledge: "Situating teachers' learning in practice is less about where the learning takes place than it is about whether it is centered in the work of teaching itself," (2009, p. 506). For example, teacher educators can bring artifacts such as student work, videos of teaching, and curriculum materials from real classrooms to the methods course to represent the work of teaching. By working with these items that came from practice, the teacher education experiences can still be situated, in a way, "in practice." For instance, in mathematics education, samples of students' work on two-digit multiplication, combined with the relevant curriculum materials and videotapes of the class in which the topic was taught, could be used to inquire into what students learned, and whether it was what the teacher intended (Ball & Cohen, 1999, p. 14).

Pedagogical approaches for a practice-oriented course

There are many pedagogical approaches used to help prospective teachers analyze and study practice: for example, they may read or watch cases of teaching and complete write-ups that identify teaching issues in each case (Grossman, 2005). Or, they may observe teaching and analyze what is happening by writing their own case report. Grossman and McDonald refer to these types of pedagogical approaches as, "pedagogies of investigation," which support the study of complex aspects of teaching. They point out that while analyzing teaching practice to better understand it is important, prospective teachers must not only be able to talk about teaching, but also be able to actually do teaching. Therefore, they call for "pedagogies of enactment," that move from learning to study practice to learning to actually enact practice (Grossman & McDonald, 2008, p. 189).

Lampert & Graziani (2009) studied the use of instructional routines in a program preparing language teachers. These routines provided a structure for teachers to respond to students, and were not to be confused with inflexible scripts. Instead, these routines helped teachers manage some aspects of the interaction so they could listen carefully to student ideas and respond meaningfully (Lampert, 2005, p. 16). Current work by Lampert and colleagues is studying how instructional activities using exchange routines, or ways of scaffolding interactions among students and teachers (see Leinhardt & Steele, 2005), can act as a tool for mathematics teacher education (Lampert et al., 2010).

There is current work on practice-oriented pedagogical approaches in science teacher education as well. For example, Windschitl introduced a framework for thinking about four-high leverage practices which led to the development of shared tools that prospective teachers could use in the university classroom and while teaching in the field (2010, p. 16). While there was resistance from some cooperating teachers in the classrooms where prospective teachers were assigned to the framework for encouraging teaching that was too time-consuming or not aligned with their curricula, others supported their prospective teachers in using the framework to develop their science teaching practice (Windschitl et al., 2010, p. 18). Other efforts to study practice-oriented preparation of science teachers includes the design and study of approximations of practice (see next section) in elementary science methods courses (Davis, under revision) and the role of approximations of practice in developing prospective teachers' confidence for and ability to teach science investigation lessons (Nelson, in progress).

Grossman's Framework for Teaching Practice

After studying how novices learn professional practice in the clergy, teaching, and clinical psychology, Grossman and her collaborators proposed a framework for thinking about the teaching of practice that includes decomposition, representations, and approximations of practice (Grossman, Compton et al., 2009). Representations, such as lesson plans or narratives of practice, make some aspects of practice visible and leaves others hidden (Grossman, Compton et al., 2009). Examining a lesson plan with a list of questions to ask would focus on practice by illustrating ways to anticipate student misconceptions and ways to help students make sense of their observations; however, the interactive aspects of teaching, where teachers must respond in real-time to student ideas would be hidden.

Decomposition involves breaking down complex practice, such as leading science discussions, into identifiable components that are "integral to the practice and can be improved through targeted instruction" (Grossman, Compton et al., 2009, p. 11). By decomposing larger practices, students can work on learning to enact particular parts of a practice at first, and can received targeted feedback on those specific aspects instead of general feedback on the practice as a whole. To decompose practice in a field, a common language for describing practice must be available, so parts of a practice can be named, taught, and practiced (Grossman, Compton et al., 2009). This is difficult in the field of teacher education, where progress is being made[2], but a universally accepted way of talking about teaching within and across subject areas and grade levels does not exist (Feiman-Nemser, 2001; Grossman & McDonald, 2008; Lortie, 1975).

Finally, the third type of pedagogy for teaching practice identified by Grossman and her colleagues are approximations of practice, which address the dilemma of science methods courses taking place in the university setting or field. Ball and Cohen asserted:

> The key to our answer is that being "centered in practice" does not necessarily imply situations in school classrooms in real time. Although the bustle of immediacy lends authenticity, it also interferes with opportunities to learn. Being situated in a classroom restricts attention to the sort of teaching underway in that particular class. Further, being so situated confines learning to the rush of minute-to-minute practice. (1999, p. 14)

Approximations of practice simulate aspects of practice so students can work on "doing" the practice without being faced with the complexity of enacting the whole practice in a real context all at once. They range in their authenticity and complexity to actual teaching. These experiences can simulate both pre-active (e.g., lesson planning) and

[2] Grossman & McDonald (2008, p.188) mention progress in establishing common terms in the area of primary reading (Snow, Burns, & Grifith, 2006) and the identification of common instructional routines in elementary mathematics (cf. Kazemi, Lampert, & Ghousseini, 2007; Rowan, Harrison, & Hayes, 2004).

active (e.g., discussing a scientific text with students) phases of teaching (Grossman & McDonald, 2008). Often, approximations focus on elaborated versions of real practice so novices can think deeply about what they are doing and why. In this way, approximations support learning at the cost of being authentic to real practice: for example, in teacher education, prospective teachers can watch a video of a teacher using different prompts to elicit students' prior knowledge. The teacher educator may stop the video after viewing a student's response, and then ask prospective teachers to think about how they would respond to the student's comments. The task of responding to students is something teachers do in real teaching; however, by watching a video of instead of teaching themselves, the prospective teachers can focus specifically on the difficult task of choosing appropriate follow-up comments and questions without being overwhelmed by managing a classroom full of students or facing time constraints. Over time, they would become more comfortable with making decisions about how to respond to students in real-time, and would be prepared to take on more of the complexity responding in the midst of full classroom teaching. Because errors made in some professional fields can have profound impacts on people's health or development (e.g., psychologists on clients, teachers on students), approximations offer a way for novices to make mistakes in low-stakes situations. Grossman and colleagues pointed out:

> If we accept that the novice's earliest attempts will be fraught with awkwardness and uncertainty, then it is far better for those experiments to take place within the safety of the [professional education] classroom than in the presence of vulnerable students, clients, or congregants (2009, p. 2091)

Selecting practices to teach prospective teachers

Simply re-structuring *where* the science methods course meets, such as both university and elementary school settings, is not all that should be shifted when attempting to support prospective teachers in developing science teaching practice; there must also be careful attention to *what* is being taught in each of these settings (Kennedy, 1999).

Because there is often only a short period of time to learn how to teach science in a teacher education program, as elementary teachers often teach many subjects, it is not possible to cover all the science content and science teaching practices a teacher would one day be expected to teach. Instead, teacher educators must focus on a smaller set of practices that may be used frequently across subject areas and grade levels, that provide opportunities for all students to learn the subject matter, and that can be articulated, taught, and practiced by prospective teachers (Ball et al., 2009, p. 460). These core practices have been labeled "high-leverage practices." In addition to the criteria put forth by Ball and colleagues (2009), Hatch & Grossman added that high-leverage practices should help teachers face common problems in the classroom, and allow novices to continue to learn from their own teaching" (2009, pp. 76-77).

As discussed earlier when defining teaching practices, teacher educators and researchers define the size of a practice in different ways (see Figure 2.3). For example, Grossman and colleagues consider "leading a classroom discussion" as a high-leverage practice that is made up of smaller instructional routines such as choosing rich problems to discuss or revoicing student answers (2009, p. 278). On the other hand, Ball and colleagues (2009) consider actions like eliciting contributions, and managing collective work as practices that make up a larger domain of guiding classroom discussions.

While there have been previous efforts to study this practice of facilitating classroom discussions in mathematics education courses at the University of Michigan (e.g., Ghousseini, 2008), my dissertation study will define and study this practice in the context of elementary science teaching.

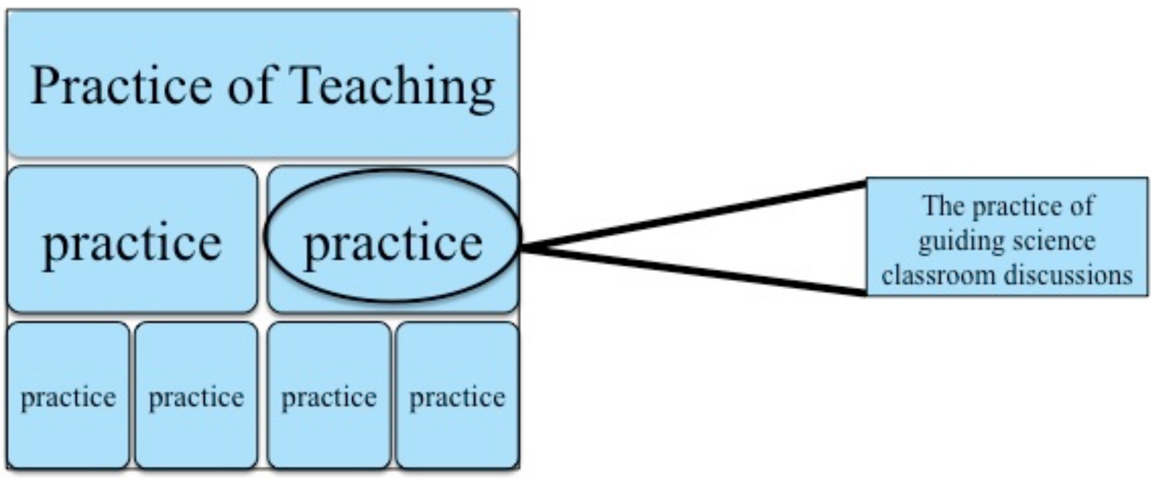

Figure 2.3. This study will focus on one practice, the practice of guiding science discussions, of the many that make up the practice of teaching.

The high-leverage practice of guiding science discussions

The role of discussions in science teaching. Drawing on the social constructivist learning perspective, engaging in science classroom discussions allows students to learn by actively constructing an understanding of scientific concepts by engaging in scientific practices and by participating in the scientific community of the classroom (Blumenfeld, Marx, Patrick, Krajcik, & Soloway, 1997; National Research Council, 2007; Palinscar, 1998). Participating productively in scientific practices and discourse is also an important part of learning science through inquiry (National Research Council, 2007). The National Science Teaching Standards (National Research Council,

1996) provide general guidelines for what science teachers teaching science through inquiry are expected to do. Science Teaching Standard B asserts part of the science teacher's role: "teachers guide and facilitate learning. In doing this, teachers orchestrate discourse among students about ideas" (National Research Council, 1996, p. 32).

Orchestrating discourse about science ideas is likely to occur in the form of a science classroom discussion, and several studies have investigated the types of interactions students and teachers can have to support learning in this way (e.g., Herrenkohl & Guerra, 1998; van Zee et al., 2005; van Zee & Minstrell, 1997). By sharing their developing ideas about scientific concepts in class discussions, students are able to experience some of the "authentic activities" of scientists when they test and share new ideas, solicit and provide feedback, articulate and evaluate scientific explanations, develop and share models and representations and reach consensus by communicating with one another (Brown, Collins, & Duguid, 1989, p. 34; National Research Council, 2007). Science discussions in the elementary classroom provide opportunities for students to engage in these scientific practices in age-appropriate ways (National Research Council, 2007; Zembal-Saul, 2009); for example, elementary students can be encouraged to develop the science disciplinary norm of explaining one's reasoning and providing evidence for contributions during a discussion (Engle & Conant, 2002).

Three phases of the practice of guiding discussions

Guiding science discussions, like other teaching practices, require teachers to engage in three distinct phases of teaching (Mangal & Mangal, 2009, p. 152). The pre-active phase is the planning stage, where teachers prepare to enact particular practices. The interactive phase occurs during the implementation of the plan itself. Finally, the post-active phase is an evaluation phase, where teachers reflect on the interactive phase and determine where to go next in their teaching. All three phases are important: if you do not plan properly, you may struggle to enact a practice successfully, and if you do not reflect properly, you may not learn from your experiences in ways that help you plan for the next enactment. Traditionally, methods courses have focused teaching prospective teachers how to engage in the pre-active and post-active phases (using pedagogies of investigation), and have left opportunities to engage in the interactive phase (pedagogies of enactment) to fieldwork experiences or student teaching that are often disconnected from the ideas of the methods course (Clift & Brady, 2005; Grossman & McDonald, 2008).

Role of the science teacher as facilitator during discussions. Due to the importance of discussions in guiding students to develop deeper understanding of science content and practices, the role of science teachers as *facilitators* of discussion, not *tellers* of information, is important to highlight. The teacher's role in small and large group interactions during classroom discussions is to listen, encourage participation, and judge where next to guide the discussion: this includes monitoring what ideas to follow, what ideas to question, what information to provide, and what connections to make (NRC, 1996).

In order to facilitate these discussions effectively, science teachers must understand their students as learners, value the prior knowledge students bring to the classroom, and guide student thinking as they actively construct new understandings (Bransford, Brown, & Cocking, 2000; Davis et al., 2006; Scott, Asoko, & Leach, 2007). To meet these goals, they must develop a set of discourse moves for eliciting, monitoring, and responding to student ideas (Chapin, O'Connor, & Anderson, 2003; Ghousseini, 2008; van Zee & Minstrell, 1997).

Traditional classroom discussions are often characterized by triadic discourse, which involves the teacher asking a question, a student offering an answer, and the teacher evaluating that answer in some way (Lemke, 1990). Below is an example of this type of discourse that I observed during a fourth-grade classroom discussion of plant growth:

> Teacher: Okay, using our data, does anybody know where plants get their energy?
>
> Student: They get it from the dirt that they eat.
>
> Teacher: No that's not it. Can someone else help out by telling us where plants get their energy?

In this way, the teacher maintains control of the dialogue and pushes students to come up with the expected "correct" answer. Elementary students, however, are capable of taking an active role in their learning, and engaging in higher-order practices like complex scientific reasoning (e.g., Songer, Kelcey, & Gotwals, 2009; van Zee et al., 2005; Zembal-Saul, 2009). To that end, elementary science teachers need to respond to student contributions in ways that guide the student and the rest of the class to make connections and build understanding instead of just receiving the "right" answer from the teacher or another student (van Zee & Minstrell, 1997). This is a challenging task, and unfortunately, research suggests that novice teachers often struggle to assess and attend to children's ideas before, during, and after instruction (Davis et al., 2006; Zembal-Saul, Blumenfeld, & Krajcik, 2000).

Overall, guiding classroom discussions that promote students' active learning are a complex high-leverage practice used across subject-areas and also an important part of engaging students in discourse about science ideas. In this study, I will explore what aspects of this complex practice are taught and how they are taught to prospective teachers in the context of a practice-oriented science methods course.

Why this work is needed

While there is variation in how doctors practice medicine, there is an agreed-upon, common set of language for talking about particular tests, diagnoses, and treatments: if a medical student asks a physician at one teaching hospital how to complete a chest exam, and then asks a physician at another, he is likely to get the same response. There is an agreed upon set of parts to a chest exam and an accompanying rationale for why they are done in a particular order and for particular purposes to rule out particular diagnoses.

In teaching, however, we are still in the early stages of building a common language, where teacher educators can refer to particular practices and have a shared understanding of what the parts of a practice are and what the best ways to teach them look like (Grossman & McDonald, 2008). In their interviews with six teacher educators about their science methods courses, Smith & Gess-Newsome found that teacher educators varied in their description of inquiry-based activities and their importance: "it was also apparent that this variation influenced both the goals and objectives of each course, as well as the assignments associated with those objectives" (2004, p. 99). While science teacher educators may all start from similar reform and standards documents about what teaching science through inquiry means, the way that is presented in science methods course activities is not always consistent (Clift & Brady, 2005).

If science methods courses are where many of the nation's teachers are being prepared to teach science through inquiry for today's classrooms, then a closer look at their design and goals is needed. With teacher education turning to practice-oriented approaches, there is an even greater need to define which practices are being taught, how they are being taught, and to what extent interns are able to leave these practice-oriented courses prepared to support student learning in their first years of teaching. Ball & Forzani summarized this need:

> Building a practice-focused curriculum in teacher education requires specifying the *content*—what teachers need to learn to do—and unpacking it for learning. It requires developing instructional approaches to help teachers learn to do these things for particular purposes in context. Particularly challenging is how to design ways to teach practice that do not reduce it to propositional knowledge and beliefs. (2009, p. 503)

In this study, the content that "teachers need to learn to do," is guiding an elementary science classroom discussion. As mentioned earlier, science teachers are expected to "…orchestrate discourse among students about ideas," (National Research Council, 1996, p. 32). The standards document includes vignettes illustrating the activities teachers do in their classrooms to meet several of the science teaching standards. However, there is no explicit set of guidelines for translating the expectation of "orchestrating discourse" into a set of actions teachers can actually take while teaching. Therefore, teachers and teacher educators must face the challenge of translating the standard and asking, "What does this discourse sound like," "Who is saying what to whom, and why?" (Windschitl et al., 2010, p. 7). By studying the content of science discussions as it develops during course activities and the pedagogical approaches used to help prospective teachers develop the practice, I hope to contribute to the call for a common language in science teacher education about what is taught and how it is taught in a practice-oriented course.

This study explores the ways prospective teachers experience opportunities-to-learn (OTLs) the practice of guiding science discussions in a practice-oriented science methods class (ED 528). In this study, I define opportunities-to-learn as a combination of a pedagogical approach and a content focus (see Figure 2.3). The pedagogical approach can include the way content is represented, the instructional discourse between teachers and students, or tasks and assignments used (Grossman, 2005). In this study, the content focus for ED 528 is not referring to scientific content topics, such as photosynthesis or the components of cells. Instead, it is the content about teaching that is the goal of the science methods course, such as phrasing questions to push student thinking or using state standards to modify curricular activities. For example, to create an opportunity-to-learn the practice of guiding science discussions, a teacher educator may show a video of a third grade science talk (pedagogical approach), in an effort to provide interns with an example of how teachers elicit students ideas at the beginning of a unit (specific content of teaching).

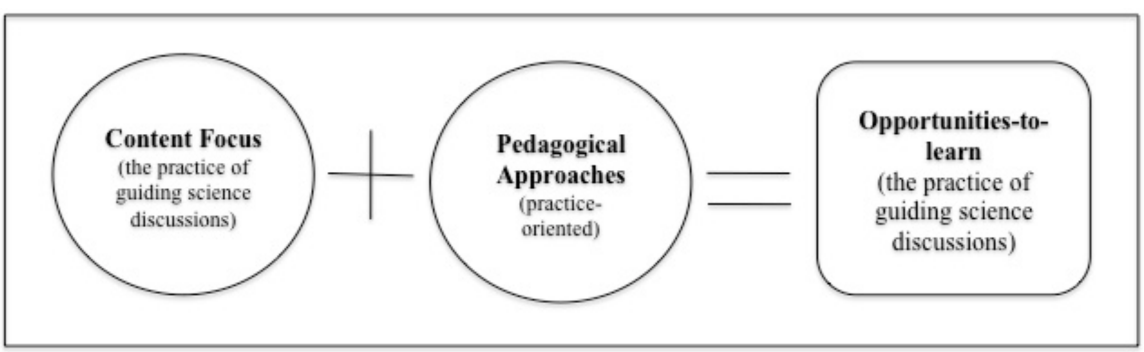

Figure 2.4. Opportunities-to-learn the practice of guiding science discussions are defined in this study as a combination of a content focus and a set of pedagogical approaches.

The following two research questions focused my data analysis and the presentation of the findings:

1. What was the content of guiding science classroom discussions that surfaced during practice-oriented course activities and
2. In what ways did the pedagogical approaches make this content of guiding science discussions available to interns to learn?

In Chapter 3, I will introduce the data collection and analysis procedures I used to explore these research questions.

CHAPTER 3
METHODOLOGY

Study Context

This study was funded by the Teacher Education Initiative (TEI), which is a large effort to redesign how teachers are prepared for practice at the University of Michigan School of Education. By helping to design and study a practice-oriented science methods course, this work contributes to the TEI's goal of "…making professional practice the centerpiece of teacher education" and their work on designing settings that allow for activities that will support prospective teachers, or interns, in develop teaching practice.

The Elementary Science Methods Course

The Elementary Masters of Arts with Certification program or ELMAC, is a full-time, masters-level teacher education program that includes coursework and a yearlong classroom internship with a cooperating teacher in a local elementary classroom. In 2010, when this study took place, a cohort of 43[3] interns were enrolled in the program, which lasted from June 2009 to mid-June 2010. ED 528, or Workshop on the Teaching of Science, was the only formal science methods course offered in the ELMAC curriculum (see Appendix B for syllabus). All interns were required to take the course, and it consisted of eight course meetings ranging from three to six hours during the

[3] I am only studying 42 interns, as one intern chose not to participate.

months of January and February. Prior to taking ED 528, the interns completed the courses listed in Table 3.1.

Table 3.1
Timeline and Course Schedule for ELMAC program (2009-2010)

Summer 2009	EDUC 401: Developmental Reading and Writing Instruction in the Elementary School MATH 485: Mathematics for Elementary School Teachers EDUC 510: Teaching and Learning
Fall 2009	EDUC 403: Individualizing Reading and Writing Instruction in Elementary Classrooms EDUC 649: Foundational Perspectives on Educational Reform EDUC 518: Workshop on Teaching Mathematics EDUC 593: Educational Linguistics EDUC 431: Teaching of Social Studies in the Elementary School EDUC 650: Reflective Teaching Experience
Winter 2010	EDUC 431: Teaching of Social Studies in the Elementary School EDUC 403: Individualizing Reading and Writing Instruction in Elementary Classrooms EDUC 650: Reflective Teaching Experience EDUC 510: Teaching and Learning **EDUC 528: Workshop on the Teaching of Science**

ED 528 was designed to be more practice-oriented. Drawing on the explanation of practice-oriented teacher education in Chapter 1, the course was different from previous iterations in two main ways (Table 3.2). First, older iterations of the course focused on providing interns with examples of inquiry-based science lessons and having the interns analyze them for different features of good science teaching. The interns also learned about content standards and had opportunities to write lesson plans that included investigations and explanation-building activities. Several readings and articles about students as learners in the science classroom and teaching science through inquiry were used. Discussions about images of scientists and the field of science occurred.

Table 3.2
Practice-oriented redesign of ED 528

Characteristic of practice-oriented teacher education	Redesigned Feature	Previous Iterations of the course
Focuses on the practices that make up the work of teaching	Designed to focus on interns developing the practice of guiding science discussions and all associated teaching moves at different grain sizes (e.g., asking questions, phrasing responses to misconceptions, etc.)	Focused generally on science teaching with an emphasis on knowing what teaching science through inquiry means, designing lesson plans and units using standards, becoming familiar with curricular materials.
Combining pedagogies of enactment and investigation	-Designed to engage interns in pedagogies of investigation in the university methods classroom and pedagogies of enactment in both the formal methods classroom and local elementary schools. -All interns were working with one of two curricular units. Course activities focused on preparing interns for and helping them learn from their teaching experiences. -Interns enacted three science classroom discussions individually with a small group of students	-Focused mainly on pedagogies of investigation; studying and adapting lesson plans, examining a range of curricular resources. -Had opportunities to teach a few science lessons in a group of four; co-planning with a cooperating teacher. No focused preparation in class -Designed a set of science lessons to enact in their fieldwork placement after the science methods course.

The redesigned ED 528 focused on the practice of guiding science discussions and all the related teaching moves. The focus was more on "how" to guide discussions, as opposed to only studying what a classroom discussion is and why a teacher would use a discussion.

The second change was that older iterations of the course focused mainly on using pedagogies of investigations; that is, interns studied science teaching instead of having many opportunities to practice doing it. In one previous iteration of the course, interns had opportunities to work in a group of four interns to teach a few short lessons in a real classroom. Groups taught different lessons and were constrained by the expectations of the cooperating teacher. However, it did provide them with an opportunity to try science teaching since many interns did not get to teach science in their fieldwork placements. Previous iterations of the course involved a final assignment involving the design of a set of science lessons the interns intended on enacting in their fieldwork placement after the methods course concluded. Beyond instructor feedback on the lesson plan, there were no extended opportunities to practice for these teaching experiences in the methods course. The redesigned ED 528 incorporated pedagogies of enactment that took place in both the traditional methods classroom setting and in elementary classroom settings, where cooperating teachers agreed to allow interns to guide discussions that aligned with the work happening in the methods course. A general outline of how the time was used across the eight course meetings is presented in Appendix C.

Study Participants

ELMAC Interns. 42 of the 43 ELMAC interns (7 males, 35 females) agreed to participate in this study while taking ED 528; they were notified about the goals of the research and the ways it would influence their experience in the course through a letter on the first day of class (see Appendix F). For some courses, the ELMAC interns were separated into two cohorts of 20-22 interns each. To create the teaching groups of four interns that would be assigned to a third or fourth grade classroom in the course, the teacher educator randomly selected two interns from each cohort. Because I could not observe all 42 interns during their teaching experiences in the elementary classrooms, I also used purposefully sampling to select a focal teaching group to gather more in-depth information about the interns' experiences in the course.

I selected my focal group of four interns by employing a combination of a maximum variation sampling strategy and a criterion sampling strategy (Miles & Huberman, 1994, p. 28; Patton, 2002, p. 238). Based on background surveys that the interns completed before the first day of class, I classified interns' experiences with science teaching in four categories; 1) they had no experience teaching science, 2) they had taught a science topic using a textbook or story, 3) they had taught science-related activities, and 4) they had taught more than one lesson in a science unit. I wanted to choose a teaching group that had the most variation in science teaching experience so I could see a range of ways they interacted with the practice-oriented course activities. I also wanted to select a teaching group that met the following criteria:

1. Because science teacher content knowledge is often a stumbling point for prospective teachers when learning to teach science, I wanted to choose a group that was teaching the 3rd grade rock and minerals unit, as they brought up confusion about the science content much less than those in the moon phases unit.
2. All four interns in the teaching group had to have good class attendance and be readily available to participate in pre-teaching and post-teaching interviews; in some ways, this criterion is like "convenience" sampling, as I needed to pick a group that would be easy to follow and contact outside of class.
3. I chose groups that were actively engaged and thoughtful during course sessions. I added this third criterion after observing the teaching groups planning their launches on the second day of class. I noticed that some groups were off-task and

taking the task lightly, while others were using the time to carefully think about their teaching. If my goal was to describe the ways interns experienced opportunities-to-learn in the course, I wanted to be sure they were going to be willing to engage in those opportunities.

The group that was selected had a range of science teaching experiences (see Table 3.3) and met the three criteria discussed above.

Table 3.3
Variation in Focal Group Science Teaching Experiences

Intern[4]	Category of Science Teaching Experience	How they responded on background survey
John	Taught science topic using textbook or story	"…the closest experience to teaching science I have had so far was leading a reading about volcanoes from the students reading book"
Melanie	None	"I have not had any science teaching experiences yet."
Haley	Taught more than one lesson in a unit	"…we shared responsibility for teaching the first science unit. It was about decomposers and things related that topic."
Vanessa	Have taught science-related activities	"…the only brief science lesson in which I helped students create a human spine out of gummy fruit rings, wagon wheel pasta, and pipe cleaners."

Teacher Educator. In ED 528, Meg was the main instructor of the course, and Shelly provided teaching support. Meg taught a version of ED 528 more than four times, and taught similar courses for over fifteen years. She earned her M.A. and Ph.D. in elementary science education, was an author of a middle school reform-based textbook series, and a developer of professional development experiences in science, math and technology education. She summarized her reasons for trying to make ED 528 more practice-oriented:

[4] Interns have been assigned pseudonyms to keep their identities anonymous.

> "Teaching science in the elementary school is filled with challenges. By increasing the practice components in ED 528, I hoped to create opportunities for the interns to identify quality instructional practices in their own teaching, rehearse these practices with peers, and then implement them in a safe, controlled, environment. " (Meg, personal communication)

Teaching Support. Shelly had over four years of teaching experience as a fifth and sixth grade teacher in all subject areas, and was a field instructor for some of the interns. She also helped with aspects of the mathematics methods course for ELMAC and other workshops throughout the program, so she was a consistent part of the interns' experiences in the program and was able to draw their attention to connections among the different methods courses.

The Role of the Researcher

At the time of the study, I was a fourth-year doctoral candidate in Science Education at the University of Michigan. I had observed the ELMAC science methods course twice: in the winter semesters of 2007 and 2008. In the 2007 experience, I observed a different teacher educator and participated in some of the course activities as a student. When I observed Meg teaching the course in 2008, I participated more in the planning sessions before and after each class session. I also joined the Science Teaching and Learning Team, which worked as a part of the Teacher Education Initiative to define what teachers do when teaching science. After taking courses entitled, "The Practice of Teaching," and "The Practice of Teacher Education," I was very interested in thinking about practice-oriented approaches to the science methods course. Meg agreed to redesign ED 528 in 2010, and to move the course to alternative settings where interns could work on practice.

I met with Meg almost every week since February 2009 to design the course activities and partnership with Garden City Schools. With Meg's experience teaching prospective teachers, and my developing knowledge of practice-based education literature, we were able to create a set of experiences that focused on the high-leverage practice of guiding science discussions (see Chapter 2). We also met before and after each class meeting to think of ways to adapt the course activities to the interns' needs as they began to develop their science teaching practice. During class meetings, I acted as an observer and focused on collecting data (e.g., moving video cameras, using Flip-cams to record smaller-group discussions, taking field-notes). When interns worked in small-groups, I often sat near my focal group or circulated to observe how all the interns were thinking about the class activities. Because the interns were teaching in three different schools, Meg, Shelly and I acted as representatives of the course in the schools while the interns were teaching there. Therefore, I did engage in discussions about "how it went" and "how they felt" about their teaching informally with interns on our way to or from the school; I had more formal conversations before and after their teaching with my focal group (see data sources). I did not participate in the assessment of any students for their final grades.

Partnership with Garden City Schools

Acknowledging that what interns learn about science teaching in methods courses often conflicts with what their cooperating teachers expect in their year-long teaching internships, Meg and I chose to find ways to give ELMAC interns experiences in real classrooms where they would not face resistance against trying the reform-based approaches to teaching that were being introduced throughout the course. The superintendent of Garden City Public Schools was enthusiastic about building a partnership with ED 528 at the University of Michigan. She recruited eleven elementary teachers in third and fourth grade to invite four interns into their classrooms. Garden City was a good match for our needs because the district was already using inquiry-based curricular materials called the Full Option Science System or FOSS. Therefore, the Garden City elementary teachers were excited to have four prospective teachers there during the units to provide additional opportunities for student learning about rocks and minerals (third grade) or moon phases (fourth grade). The Garden City elementary teachers were oriented to the goals of science discussions as presented in ED 528, and asked to only step-in when there was a larger classroom management issue that interns could not handle. Thus, because the teaching tasks were structured by Meg and agreed to be supported by the cooperating teachers, we hoped to have better coherence among course activities than the usual coursework versus fieldwork dichotomy.

Because ED 528 only met eight times, it was necessary to minimize travel time to and from Garden City. Therefore, the superintendent at Garden City provided a large classroom space at their local community center to hold ED 528 class meetings on days when the interns were also going to make visits to the elementary classrooms. This space was large, and had a smaller room attached for breakout groups. Due to the proximity of this location to the elementary schools where interns practiced science discussions, preparation for and debriefing of their teaching experiences were often the main activities in this setting.

Resources used in ED 528

In ED 528, the interns worked closely with three curricular units that focused on teaching content through scientific inquiry. The first was a unit from the Project-Based Inquiry Science (PBIS) series called "Good Friends and Germs" (see Appendix D for outline of activities in the unit). The goal of PBIS was summarized in the teacher's guide that interns referred to throughout the course: "In project-based inquiry learning, students investigate scientific content and learn science practices in the context of attempting to address challenges in or answer questions about the world around them" (PBIS teacher's guide, p.xiv). Meg modeled how to teach several discussions and investigations from the PBIS unit, and also used it as a template for discussing the parts of science teaching that interns would encounter (e.g., using scientific models, scientific text, assessment, role of vocabulary, etc.).

The other curricular examples were from the Full Option Science System or FOSS, which was the program being used in the Garden City elementary schools. Therefore, interns were using the same curricula while planning in the methods class that teachers were already used to teaching in the school district. Interns read through both units, but those assigned to third grade classrooms taught the Earth Materials unit and those in fourth grade classrooms taught the sun, moon and stars unit (see Appendix E for outline of activities in the unit). Interns only taught a small part of the unit during ED 528, and modified the FOSS curricula to include more opportunities for discussion. The earth materials unit involved having students investigate "mock rocks," which are models of real rocks, to determine that rocks are made up of more than one ingredient, and those ingredients are called minerals. The sun, moon and stars unit was referred to as the "moon phases" unit, because the interns only guided discussions about the phases of the moon and how they occur in predictable ways. In this unit, students used a physical model to practice modeling the phases of the moon and to explain why they happen.

Figure 3.1 illustrates the overall design of the science methods course. Course activities took place in a formal setting (i.e., university science methods classroom, or community center classroom in Garden City school district). Course activities also took place in third and fourth classrooms where groups of four interns were assigned to guide discussions with small groups of students. The course was situated in the practice of teaching with the hope that by focusing on actually engaging in teaching during the methods course, interns would take a beginning repertoire of teaching practices with them to their year-long internship and beyond.

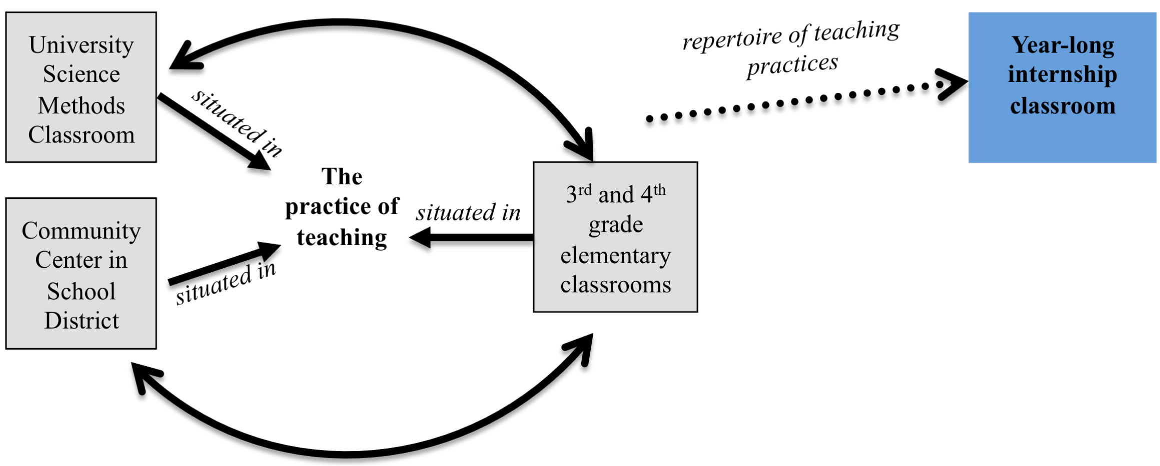

Figure 3.1 Design of settings for course activities to make ED 528 more practice-oriented.

Study Design

In this study, I collected data from each course session to find out what content of guiding science discussions emerged and what pedagogical approaches were used to teach the content to interns. Table 3.4 summarizes the research questions and purposes for each data source. Data sources used to identify the content of guiding science discussions included video records of course sessions, researcher's fieldnotes during each class, and take-home messages after each class. Cochran-Smith and Zeichner pointed out that the perspectives of university-based researchers predominate in teacher education, and the perspectives, questions, and voices of prospective teachers are rarely included (2005, p. 16); this study attempts to address this issue by providing evidence for the content of the course and the way pedagogical approaches made the content available from both the researcher's perspective and the prospective teachers' perspectives.

Table 3.4
Summary of Data Collected to Address Research Questions

Research Questions	Data Collected	Purpose of Analysis
1: What was the content of guiding science classroom discussions that surfaced during practice-oriented course activities	Video recordings of all 8 course sessions (30 hours of class time)	To capture the content that "comes up" about guiding science discussion across ED 528 activities (excluding experiences in elementary classrooms); analysis provides the researcher's perspective
	Fieldnotes (N=8)	
	Take-home messages after eight course sessions (N=256)	To capture the ways interns talk about the content they encountered in class; analysis provides the interns' perspective
2: In what ways did the pedagogical approaches make this content of guiding science discussions available to interns to learn?	Video recordings of all 8 course sessions (30 hours of class time)	To capture what the class activities, instructional discourse, in-class tasks used to help interns learn to guide classroom discussions; analysis provides the researcher's perspective
	Video recordings of focal groups' enactments of science discussions (~12 hours)	
	Video recordings of small-group planning of science discussions (9 recordings)	
	Take-home messages after eight course sessions (N=256)	To capture how interns are describing their experiences in

	Audio records of pre and post interviews with focal group before and after each enactment of science discussion (7 pre, 8 post)	course activities and how those experiences did or did not contribute to their learning how to guide science discussions; analysis provides the interns' perspective

Data Collection

Data collection took place in January and February 2010 during the implementation of a redesigned, practice-oriented ED 528. Table 3.5 summarizes what data was collected during each course session.

Table 3.5
Summary of data collected at each course session.

Session #	Field-notes	Class video recording	Focal group planning video	Take-home message prompts	Focal group teaching enactment video	Focal group pre-enactment interview	Focal group post enactment interview
1	x	x		x (n=41)			
2	x	x	x	x (n=41)			
3	x	x	x	x (n=41)	x (n=4)		
4	x	x	x	x (n=41)	x (n=4)	x (n=3)	x (n=4)
5	x	x		x (n=37)			
6	x	x	x	x (n=38)	x (n=2)	x (n=2)	x (n=2)
7	x	x	x	x (n=21)			
8	x	x		x (n=37)	x (n=2)	x (n=2)	x (n=2)

x=indicates that type of data was collected
Note: I put the number of take-home messages received, as interns did not always complete this assignment. I also put the number of enactment videos (4 if all 4 interns taught that day, 2 if only two interns taught that day). The missing pre-enactment interview was due to time constraints on the interns' schedule.

Video records. When Meg was addressing all the interns as a group, the video-camera was usually focused on her, and she wore a wireless microphone so the questions she asked, comments she made, and explanations she provided could be recorded. While intern comments were captured on the video recordings, it was not always easy to identify which intern was speaking, as they did not wear microphones and the camera usually stayed focused on Meg. Therefore, when providing excerpts of transcripts throughout this dissertation, I will simply label interns by the order they speak instead of identifying them. The goal of describing the content being "brought up" in class is still met, and since an analysis of individual interns' progress or ideas over time is not the goal of this study, there is no need to track each intern's contributions individually. Video records of focal group interns' enactments of science discussions were recorded by the interns themselves using Flip-cams. I downloaded their video files after each enactment onto an external hard drive so I had a copy to analyze, and they had a copy to reflect on their teaching.

Fieldnotes. During each course session, I typed fieldnotes describing particular exchanges between Meg and students or particular comments by students that would be worth analyzing further. Also, if Meg was writing ideas on the boards or having side-conversations with students that were unlikely to be captured well on the videocamera, I would take notes about them in the fieldnotes. In a few instances, technical difficulties led to Meg's microphone not recording properly or the videocamera turning off unexpectedly; in these cases, fieldnotes were very helpful in making sense of the almost inaudible dialogue in the video.

Take-home messages. After each course session, interns were asked to reflect on their experiences in the course activities and on their experiences guiding science discussions in the elementary school classrooms. To be able to provide evidence of whether or not the opportunities-to-learn that the researcher identified were also those that the interns experienced, the take-home message prompts tried to elicit interns' developing understandings: “Please identify and describe the aspects of leading a science class discussion with elementary students that you worked on today (in formal class and teaching)” or “What are some key take-home points you took away from today’s course experiences?” We tried to design the prompts to not ask about specific activities (e.g., “how did watching the video help you think about language use in discussions?) because we wanted to see what the interns would bring up as most salient for their learning. There is not a complete set of 42 take-home messages for each course session because some students forgot to complete the assignment each time.

Audio records of pre and post teaching interviews. Interviews were conducted with the interns in my focal group before and after the course activity of enacting science discussions with small groups of elementary students. Due to limited time before and after class, these interviews were usually conducted using speakerphone and using recording software to tape the interview. In these interviews, I asked more specific questions about what aspects of science teaching they hoped to work on in their enactment and then whether or not they felt they met their goals. These interviews helped to provide more detailed information about how the four focal group interns were translating messages from the methods course into their teaching enactments.

Data Analysis

I took the following set of steps to analyze the data: 1) reduced raw data by transcribing video and audio interviews and formatting data for software; 2) completed several iterations of coding at the sentence or paragraph unit of analysis based on guiding questions for each research question; and 3) added, removed, or revised codes and identified emerging patterns and themes (Miles & Huberman, 1994).

Data reduction. Video records, field-notes, and take-home messages were analyzed to identify what content came up in ED 528 about the practice of guiding science discussions. Video editing software (iMovie) was used to edit videos into shorter clips that did not include long periods of off-task discussion or discussion of logistics (e.g., where to get lunch near the elementary schools). Next, the videos were transcribed using NVIVO 8, a qualitative data analysis software package. Take-home messages were downloaded from the online survey program where interns could submit their responses, and were converted into tables so all intern responses to each question could be analyzed at once in NVIVO 8.

Coding. Based on my experiences with the design and observation of science methods courses, and the literature base on pedagogical approaches in teacher education and the role of discourse in science teaching, a "start-list" (see Appendix G) of codes were applied to groups of sentences that shared a similar "meaning unit" (Miles & Huberman, 1994, p. 58). Codes were added, deleted, combined, and renamed during several iterations of coding that were driven by the start-list and conceptual framework for the study. For example, codes such as "learning how to make scientific texts provide differentiated instruction," were deleted because they were beyond the scope of "learning the practice of guiding science discussions." Other codes, such as "modeling how to elicit student thinking as a science teacher," were divided into two codes: "modeling the role of the science teacher" as a pedagogical approach code and "eliciting student thinking" as a content code. I noticed that several of my codes required splitting, as I was combining content and pedagogical approaches instead of coding them separately to address the research questions. This level of coding was not helpful, as it did not allow me to address content (research question 1) and pedagogical approaches (research question 2) deeply; however it did help me explore the range of ideas in the data, which was an important initial step before developing interpretations (Corbin & Strauss, 2007, p. 64).

I chose to code my data again with the use of specific criteria to make sure I was analyzing the data to address my research questions. I used the following criteria when reviewing video transcripts, take-home messages, and field-notes to determine if a code for the content of guiding science discussions (research question 1) should be applied to a meaning unit[5]:

- Is the practice of guiding discussions explicitly mentioned?
- Are the "content" topics mentioned in preparation for an upcoming enactment of a discussion in the elementary schools, or in response to an enacted discussion in the elementary schools?
- Is this something interns need to know to be able to plan for, enact, and reflect on the practice of guiding science discussions?

I used the following criteria when reviewing video transcripts, take-home messages, and audio records to determine if a code for pedagogical approaches (research question 2) should be applied to a meaning unit:

- Is this activity or discourse between Meg and the interns or task the interns are being asked to do helping to prepare interns to enact science discussions?
- Is this activity, discourse, or task bringing "practice" to the forefront?

[5] A meaning unit is defined in this study as a set of sentences or paragraphs conveying a similar idea (Miles and Huberman, 1994)

- Is this an identifiable strategy for teaching interns that is different from just "telling them" what they should do?
- Are interns being encouraged to "work on" developing their teaching practice?

Codes that shared related meanings were then grouped into pattern codes, and larger themes were identified (Miles and Huberman, 1994).

Data not analyzed. The following content was presented in the course but was not included in the coding of content for this study, as these ideas did not meet the criteria I used to identify content associated with the practice of guiding science discussions[6].

- Designing assessments and end-of-unit projects
- Using scientific texts
- Differentiated instruction opportunities within PBIS curricula
- Scaffolding the writing of a scientific explanation (however, pressing for evidence and explanations more generally during discussion was included)
- Discussing biographies of scientists (to have examples of underrepresented groups as scientists to share with students)

Standards for Quality

"Qualitative analyses can be evocative, illuminating, masterful---and wrong. The story, well told as it is, does not fit the data" (Miles & Huberman, 1994, p. 262)

Following the tactics for data quality outlined in Miles and Huberman (1994), I attended carefully to validity and reliability in ways that were appropriate for qualitative data.

[6] However, these topics were still important parts of the methods course. For example, it was important to have interns share biographies of scientists of different racial, gender, or ethnic groups so they could breakdown their students' stereotypes of what a scientist looks like.

Bias and Triangulation

Unlike many studies in teacher education, where teacher educators study their own courses (Clift & Brady, 2005, p. 333), as a researcher observing the enactment of ED 528, I was not burdened with the responsibilities of participant, researcher, and teacher educator in the study. However, I must acknowledge that because I had a role in the planning of this new practice-oriented format for the course, I did have an interest in seeing the redesigned course elements successfully provide opportunities-to-learn for prospective teachers. Corbin and Strauss summarized the nature of bias while analyzing qualitative data:

> Though some analysts claim to be able to "bracket" their beliefs and perspectives when analyzing data, we have found this impossible. Bias and assumptions are often so deeply ingrained and cultural in nature that analysts often are unaware of their influence during analysis. We find it more helpful to acknowledge our biases and experiences and consciously use experience to enhance the analytic process (2007, p. 85)

There were many times when coding for "pedagogical approaches" that I had to ask myself if the interactions were really making the practice available to interns to learn, or if I was just searching for it in the depths of Meg's dialogue. At these times, I would return to the take-home messages and interview data to listen to what the interns were saying about the same experience. Triangulating across data sources (video records and take-home messages) that provided the researcher and participants' perspectives was necessary to continually confront any biases that emerged throughout my analysis. In other words, if I identified a particular pedagogical approach for supporting intern learning, I checked to make sure that the interns also spoke about the approach as helping them, and that I was not just assuming it created an OTL.

Weighting the Evidence

The idea of weighting evidence suggests that some data are better than other data, based on how the data were collected, when they were collected, or who they were collected from and why. For example, some interns were better at articulating what they were learning and how they were opportunities to learn those things in their written take-home messages. Whether or not they felt the take-home message was an appropriate task also influenced the level of effort they put in their responses. Therefore, I may cite well-articulated examples of how a particular pedagogical approach (e.g., walk-throughs of lesson plans) was important to develop an interns' practice of guiding science discussions; however, there may be some interns that did not find it useful but did not take the time to explain why in their take-home message. Therefore, the search for disconfirming evidence could be inaccurate. I tried to not quote the same intern repeatedly, or interns who were teaching only one unit, so I could capture the range of responses in order to make my assertions.

Using the methods described in this chapter, I set out to uncover the opportunities-to-learn the practice of guiding science discussions in ED 528. In the next chapter, I share how several iterations of coding led to my identification of the content of guiding science discussions that surfaced across course activities.

CHAPTER 4
THE CONTENT OF GUIDING SCIENCE DISCUSSIONS

Teacher education programs need to follow the example of other professional schools. They need a shared vision of what a teacher must know and be able to do to promote student learning. And there needs to be agreement on the curriculum that future teachers must complete to learn these things. (Levine, 2006)

This chapter addresses the first research question: *What was the content of guiding science classroom discussions that surfaced during practice-oriented course activities?* One way to determine the content of a teacher education methods course is to examine how the course syllabus describes the "content"; that is, the listed topics and assignments are used as a proxy for the "content" of teaching that will be covered (Smith & Gess-Newsome, 2004). Instead of discussing the content for ED 528 that was planned before the course began, I will unpack the detailed content about guiding science discussions that surfaced as Meg responded to interns' ideas or questions during course meetings.

I coded the content that surfaced about guiding science discussions across the eight course sessions by using the criteria introduced in Chapter 3 (see Appendix H for raw codes). When reporting my findings, I will focus on the content that was made available to the whole class of 43 interns or to the whole group of interns working on a particular unit (e.g., all the interns teaching moon phases). Content that surfaced during individual debriefings with Meg were not included, as they did not necessarily represent the shared content experience of all those that took the course.

The result of coding "what is being taught about guiding science discussions," across all eight course sessions of the practice-oriented science methods course was the identification of a set of teacher actions that were named throughout the course and associated rationales that provided interns with the supports on which to use those actions. That is, the teacher actions offered concrete things the interns could say and do when acting on particular rationales. In Figure 4.1, I illustrate the relationship of these teacher actions to the practice of guiding science discussions, and to the overall practice of teaching which is made up of the shared practices teachers do as professionals (see Chapter 1).

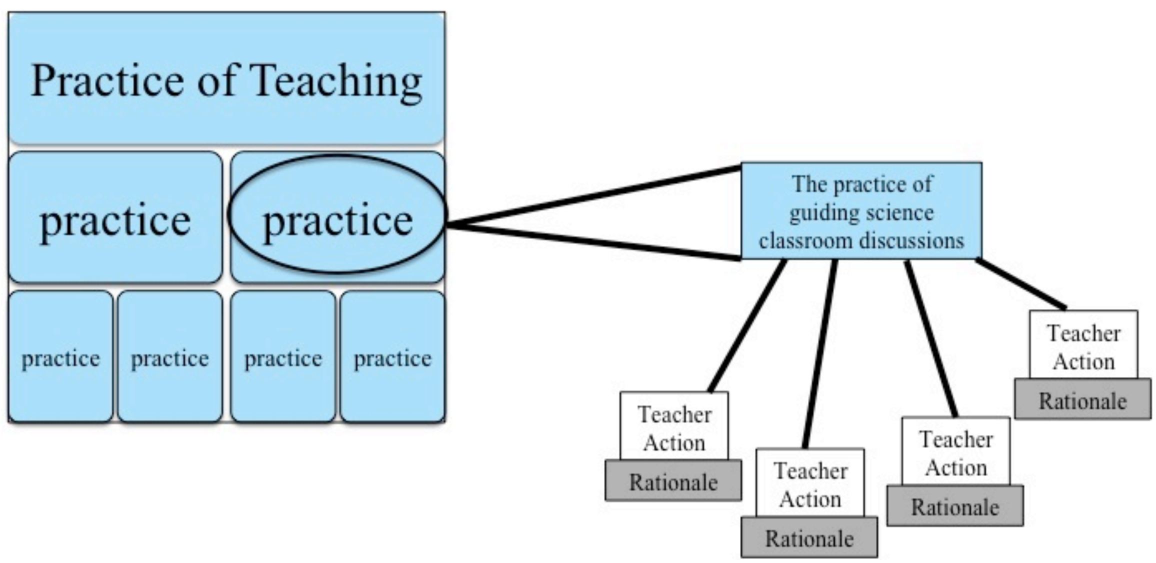

Figure 4.1. The practice of guiding science discussions is made up of several teacher actions that are linked to rationales.

The teacher actions and associated rationales were then grouped into the following five content themes that represented the content of guiding science discussions in ED 528 (see Figure 4.2):

- foregrounding student ideas and questions
- steering discussion towards intended learning goals
- supporting students to do the cognitive work
- enacting teacher role of facilitator
- creating a classroom culture for science discussion

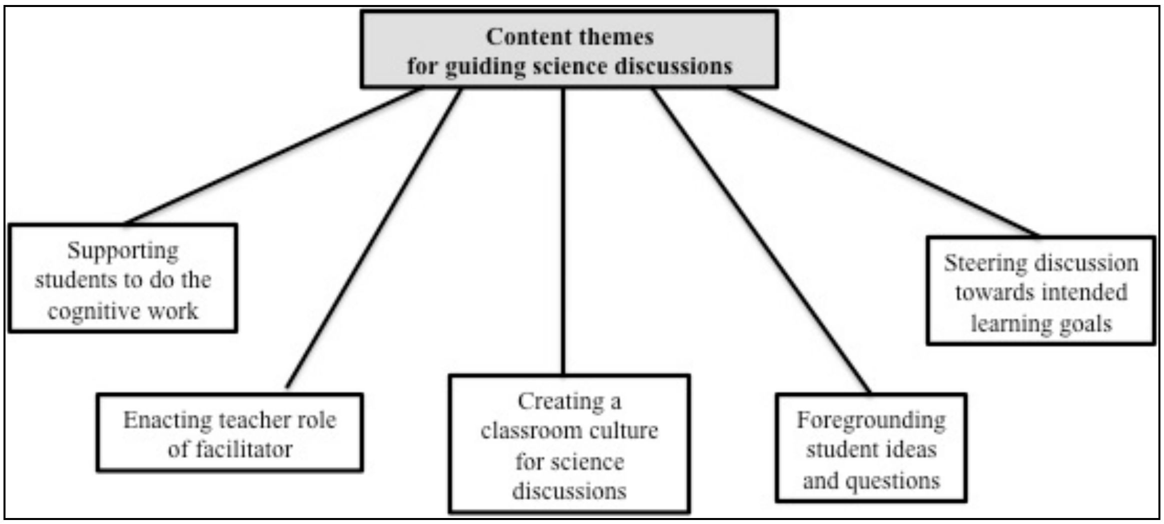

Figure 4.2. Five content themes in ED 528.

Each content theme reflects codes that reflect the underlying rationale that Meg provided for particular aspects of guiding science discussions, as well as codes that named teacher actions, or what teachers should do while enacting science discussions (see Appendix I for examples of how raw codes were grouped into themes).

Figure 4.3 represents the frequency of codes for each content theme in each of the eight course sessions making up ED 528. Because the content of the course evolved as interns engaged in more opportunities-to-learn the practice of guiding science discussions, the frequency of various themes across course sessions reflected both what Meg felt was important as a teacher educator, but also, what content the interns needed the most as they encountered their initial experiences enacting this practic

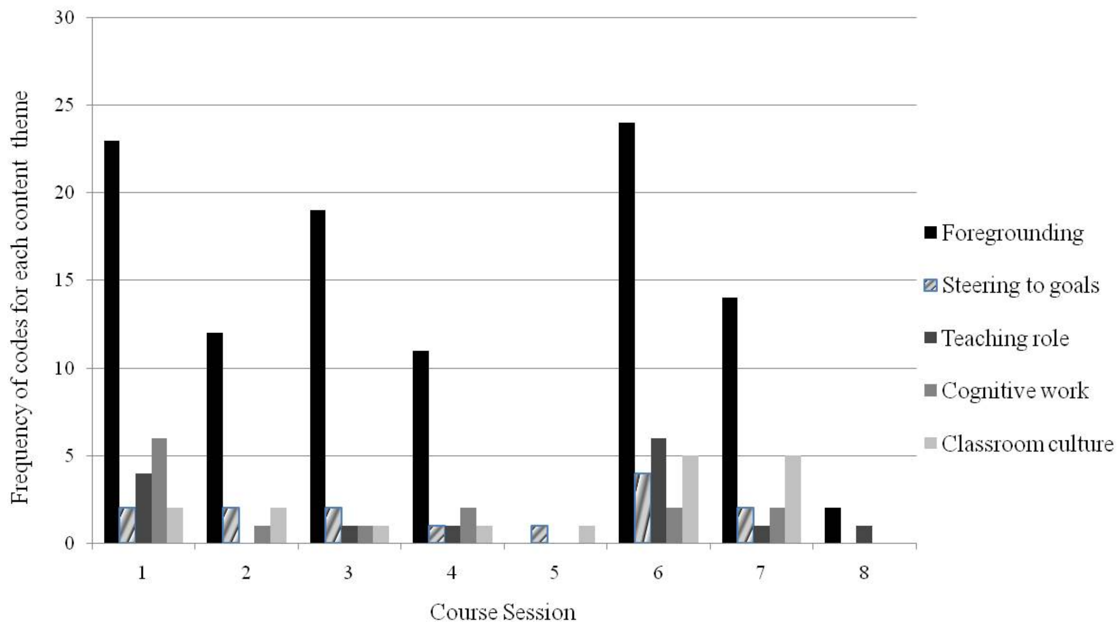

Figure 4.3. Frequency of codes for each content theme across eight course sessions.

The content theme of *foregrounding student ideas and questions* appeared in seven of the eight course sessions and had the highest frequency in the course (n=105)[7]. The content themes of *steering discussion towards learning goals* (n=14) and *creating a classroom culture that supports science discussions* (n=17) appeared in all but the last course session. The content themes of *enacting teacher role of facilitator* (n=14) and *having students do the cognitive work* (n=14) appeared in six of the eight course sessions. I will now introduce the rationale, teacher actions, and examples associated with each content theme (see Table 4.1 for an overview of the examples in this chapter).

[7] The "n" value reflects the total frequency at which codes that made up the particular content theme appeared throughout the entire course. For example, the content theme of *foregrounding* was the combination of seven raw codes (see Appendix I). Codes from that set of seven codes appeared 105 times across all eight course sessions. For details of how raw codes were initially applied and grouped to themes, see Chapter 3, Methodology.

Table 4.1
Content themes and associated examples across ED 528

Foregrounding student ideas and questions	Examples 1-3
Steering discussion towards intended learning goals	Examples 4-5
Supporting students to do the cognitive work	Examples 6-8
Enacting the teacher role of facilitator	Examples 9-10
Creating a classroom culture that supports science discussions	Examples 11-13

Foregrounding student ideas and questions

The content theme of keeping student ideas and questions at the forefront of science discussions appeared the most in ED 528. As they used various pedagogical approaches (these approaches are elaborated in Chapter 5), Meg and Shelly conveyed the rationale supporting the actions that made up this content theme (see Table 4.2). The rationale included the notion that students were active learners, and teachers needed to guide their thinking as they moved from their initial ideas about science concepts to more scientifically accurate ones. Furthermore, to revisit and refine their ideas as they developed better understandings, students needed ways to record and communicate their ideas for themselves, their peers, and the teacher. Meg explained that eliciting prior knowledge helped the intern or classroom teachers gather information about what the students already thought about the concepts in the unit.

Meg and the interns discussed several teacher actions that related to this content theme. The following examples illustrate the ways the teacher actions and the rationale underlying them surfaced throughout particular course activities and interactions among Meg, Shelly, and interns in ED 528.

Table 4.2
Rationale and actions for content theme: foregrounding student ideas and questions

<table>
<tr><td colspan="3">Rationale: Students are active learners who need to be guided to move from their less developed ideas of scientific concepts to more developed understandings.</td></tr>
<tr><th>Teacher Actions</th><th>Example No./Title</th><th>Example Summary</th></tr>
<tr><td rowspan="3">• elicit students' ideas (prior knowledge, possible misconceptions)
• encourage students to ask questions
• give students ownership (use their names to credit them for contributions)
• capitalize on student ideas to move discussion forward
• Pick a question from student list to investigate
• Record student contributions in classroom to refer back to
• Always revisit inaccurate student ideas (can't teach 2+2=5!)</td><td>Example 1: Eliciting students' ideas and questions</td><td>• Meg modeled how she gathered students' initial ideas about germs and helped them come up with questions to investigate during the unit</td></tr>
<tr><td>Example 2: Giving students ownership of their ideas during discussion</td><td>• Meg and the interns discuss how the classroom teacher gave Mitchell ownership for an observation that sparked further discussion among his classmates</td></tr>
<tr><td>Example 3: Using student questions to lead to class investigations</td><td>• Intern shares how her student suggested breaking apart a rock. Shelly suggests capitalizing on this by giving the student credit for the next investigation.</td></tr>
</table>

Example 1[8]: Eliciting students' ideas and questions

In order to keep student contributions at the forefront during classroom discussions, Meg encouraged interns to elicit students' ideas and questions about the question or topic that was the focus of the discussion. In the following example from Session 1, Meg acted like an elementary science teacher guiding a science discussion,

[8] Each example may be made up of excerpts from one or more transcripts across course sessions. They all relate to the same idea captured by the example title.

while the interns were acting like elementary students engaging in the discussion. Meg introduced the big question for the PBIS unit she was going to have the interns experience as students (see Appendix D). The question from the PBIS curriculum was, "How can I prevent my good friends from getting sick?" Meg asked the interns, acting as elementary students, to share their initial ideas about the big question. Some of the interns' initial ideas are presented below:

1[9] Intern A: I think I know that getting a moderate amount of exercise is good for your immune system…

2 Intern B: Don't cough in someone's face.

3 Intern C: Don't share cups or Chapstick, or other things that touch your mouth.

4 Intern D: When you wash you hands, wash them long enough like by singing the ABC's or some other song. (Session 1, part 2, 1:03)[10]

As interns proposed their ideas about preventing their friends from getting sick, Meg and Shelly typed the interns' responses and projected them on the screen for the class to see. Later, Meg and the interns discussed how the teacher action of recording student contributions acknowledged and valued student talk in the classroom. It also created a class record so the whole class could actively investigate and revisit those ideas as they gathered more information and engaged in more investigations throughout the unit.

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[9] During dialogue among multiple speakers in an example, each speaker's turn will be numbered so particular comments can be referred to in the text. Numbering will begin again at the start of each example. When presenting dialogue from selected transcripts for each example, I will identify the interns with the letters A, B, C and so on in order as they speak. These letters will not be used to track particular interns throughout the examples; therefore, they will begin again with A at the start of each dialogue.

[10] The timestamp indicates which course session the transcript is from, the part of the recording (the recordings were divided into parts for easier viewing and coding), and the time when that particular excerpt from the transcript began.

After the interns proposed a long list of questions they had about germs, getting sick, and preventing being sick, Meg asked them to think of questions they had after hearing each others' ideas. In the following dialogue, Meg modeled how teachers could give ownership to students for their questions during a discussion:

5 Intern A: We talked a lot about temperature, being cold and being wet and cold. Or like drastic changes in temperature like going from very cold to hot…

6 Meg: Okay, so let's take what Lauren[11] said about the temperature, and let's see if we can turn that into one of these questions that we would like to investigate. Because it feels to me like it's got good question potential. So how would you word a question about being cold or changes in temperature that we could investigate?

7 Intern B: We have is it merely exposure to cold weather or is it [inaudible]...

8 Meg: Okay, is that a good start for a question about the cold? So that's a pretty good question, something about temperature, air temperature. Do you think maybe we should put air temperature on there because some people call fever, temperature?

9 Intern C: Sure.

10 Meg: ...so it seems like maybe air temperature should go in there. Ok, very good, good start? So now we have two questions. Can you be exposed to something and not get sick...that question came from...Sarah! And now we have Lindsay's start of a question which is is it merely exposure to air temperature or is it being ill-prepared? Allright, who's next? (Session 1, Part 3, 2:41)

Again, the interns' questions were recorded publicly. When interns brought up concerns about this teaching action of gathering all of students' ideas, both accurate and inaccurate, and displaying them in the classroom, Meg responded by using the phrase, "2+2 does not equal 5!" This phrase acted as an analogy to emphasize that the rationale behind foregrounding student ideas and questions was to help both the students and teachers become aware of students' current thinking. It was then the role of the teacher

[11] Pseudonyms used when interns or Meg are calling someone by name.

to provide students with experiences with phenomena, investigation, models or simulations to help them gather evidence to develop more accurate scientific ideas or to address their questions. Therefore, by simply listing student ideas and questions without evaluating them as right or wrong during the first discussions in a unit, teachers were not teaching the wrong thing (e.g., 2+2=5), but instead, were gaining information that would help orchestrate future discussions and choose future class activities. Meg also highlighted the importance of collecting students questions that could be used later. In Line 10, she specifically named the interns with the questions they contributed so that their classmates knew that student ideas were valued and were an important part of the discussion.

Example 2: Giving students ownership of their ideas during discussion

In Session 7, Meg showed interns a video-clip of an experienced elementary teacher and a student teacher guiding a discussion together on magnets[12]. The discussion captured by the video took place after the elementary students had opportunities to explore magnets at different stations where they tried using magnets to pick up objects of different sizes and explored the relative strength of magnets of different shapes. Figure 4.4 includes the transcript from an excerpt of the video, where the third graders were asked to share their observations during the explorations they had completed about magnets and magnetism:

[12] Source for the magnets video online: http://www.scasd.org/2497125727105938/lib/2497125727105938/Magnet_Science_Talk_II.mov

Speaker	Video-clip transcript
Student Teacher:	We did four different experiments to find out [about magnets], and Mitchell, do you have something you want to share?
Mitchell:	I had it, I had the rod magnet and I had a couple paper clips and I put them on the one magnet, the rod magnet, and they all clipped together and made a train, and then when I took them off the magnet, they were all hanging together.
Student Teacher:	Without the magnet...they stayed together? [Mitchell nods yes]
Experienced Teacher:	Mitchell noticed, that the first thing he did was, he did this, and he did this, and he did this, right [she adds paper clips to the end of the paper-clip hanging from the rod magnet), and then what happened, Mitchell? Come and show us.
Mitchell:	I took this off [removes the first paperclip from the rod magnet] and it went like that [he holds up the chain of paper-clips that is still together even though the rod magnet was removed].
Students:	Wow!
Students:	Cool!

Figure 4.4. Dialogue in video-clip of magnet discussion.

Meg asked interns to consider the following questions when watching the video-clips of the science discussion: "How does the classroom teacher get the students involved in this science discussion? What are the things that she does?" The interns brought up several observations about the questions used and comments made by the teacher in the video. For example, one intern observed that in addition to having the student, Mitchell, explain what he observed, the experienced teacher also brought out the materials (magnet and paperclips) to allow him to show his peers what he did and what he saw. In this way, Mitchell was contributing the ideas that guided the discussion, not the teacher alone.

1 Intern A: ...she asked him to show it...

2 Meg: So, she could have taken over there. She must have seen what Mitchell had done. She could have taken over and she started right? She put the magnet up. She put the paper clips on. But then she let him have that “whoa” thing [students expressing their excitement about Mitchell’s observation]. Where she could have taken [the paperclips] off. [And she could have said] this is what Mitchell did. But she didn’t do that, she made a different choice with it to let him take it off and [let him say] this is what I found out. He had some ownership of that and by extrapolation the kids [in the class] then have ownership of that. One of us [the students] figured this out. [That is] much cooler than a demonstration by the teacher where she just pulls it off [and says] look it, this is what Mitchell saw and then it’s hers [her idea]. (Session 7, part 2, 3:10)

The interns also noticed that in the video-clip, after the students were excited about Mitchell's finding, a few more students tried to explain what he found and contributed their ideas without much teacher facilitation. The video was a good example of how the teacher took the role of facilitator (see Examples 9-10) in the conversation instead of just telling the students what Mitchell observed. She allowed Mitchell to share his idea and that invited others to comment as well. Interns were able to see how young students, such as the third graders in the video, were capable of talking to each other about science concepts in a classroom discussion:

3 Intern A: There was also a lot more discussion after Mitchell did the thing with the paper clips. There were 3 or 4 kids that had something to say about that. And the teacher was like, what do you think, what do you think? They were like wow this is what’s happening. I didn’t hear anything in between. I just noticed a big chunk of the minute or two that the kids were just talking to each other and it was different than you know….

4 Meg: Where she wasn’t really involved in the conversation and they could handle it. They are really little.

5 Intern A: Yeah, I was impressed with that. And it wasn’t silly talk. They were talking magnets. (Session 7, part 2, 5:28)

In sum, the video helped to illustrate that teachers can facilitate classroom discussions to help students think about and begin to develop understandings about scientific concepts like magnetism. These discussions can revolve around student observations and explanations, as the teacher works to help the students make sense of the concepts together.

The content theme of foregrounding student ideas and questions also involved what teachers can do with the student ideas and questions once they have elicited them during a discussion. In the next example, excerpts from the course illustrate how interns learned about selecting particular student questions to prompt classroom investigations.

Example 3: Using student questions to lead to class investigations

Meg and the interns discussed how instead of having all the ideas for what to talk about during discussions coming from the teacher, foregrounding students' ideas and questions allowed teachers to capitalize on particular student contributions that could help move the discussion forward. In this way, the purpose of the classroom discussion was less about what the teacher wanted to discuss and more about what students were wondering. For example, after collecting their initial ideas and questions about germs, getting sick, and spreading disease, Meg chose one of their questions that were projected on the screen to prompt the next activity:

> So we have this set of really interesting questions [produced by the interns in the role of elementary students], and the one that I would like to start with is, this one over here [points to one on the list recorded in the classroom], which is, can you be exposed to something without, and not get sick? So we're going to do a little, a short activity, that might help us to think about that question, an investigation that can kinda move us towards finding an answer to that. (Session 1, part 4, 0:37)

Similarly, in Session 3, Shelly helped interns think about the teaching actions to keep student ideas at the forefront in a discussion where interns were sharing student contributions they heard while teaching their launch discussion for the moon phases unit. One intern shared that a student in her group suggested breaking apart the rock to see what was inside. Since the next investigation in the unit involved breaking apart a mock rock (i.e., a model rock that was easier to break) to see what was inside, Shelly suggested that the intern give ownership to that student for suggesting the next activity they would do in class. Shelly suggested using the student's name and moving the discussion forward with the student's idea; for example, the intern could say: "Robert thinks we should break apart the rock to see what's inside. Should we do that? How could we do that, and what materials would we need?" In this way, the reason for doing the investigation the teacher wanted students to do anyway came from one of the students, instead of from the teacher, and had a purpose for the students (i.e., to explore what was inside the rock) instead of the sole purpose of following the directions of the teacher.

Steering discussion towards intended learning goals

The content theme of steering discussion towards intended learning goals highlighted an important aspect of science teaching: students are expected to engage in scientific practices and learn key scientific concepts agreed upon by national and local standards. While discussions offer opportunities for interactions among teachers and students, teachers need to find ways to steer the discussion in ways that focus those interactions on the scientific concepts that students need to be exploring. Table 4.3 introduces the rationale and teacher actions associated with this content theme.

Meg summarized this content theme when she used phrases like, “always know where you are going,” and “you are steering the car,” to remind interns that teachers must always keep learning goals in sight during science discussions. While student ideas and questions should be used to move discussions forward, the teacher should be helping students connect ideas or build on particular ideas to help them reach the learning goals.

Table 4.3
Rationale and actions for content theme: steering discussion towards intended learning goals

<table>
<tr><td colspan="3">Rationale: Teachers must prepare for science classroom discussions so they can purposefully guide students to make sense of their ideas and reach the intended learning goals.</td></tr>
<tr><td>Teacher Actions</td><td>Example No./Title</td><td>Example Summary</td></tr>
<tr><td rowspan="2">• Cycle back to the big question
• Listen carefully to student responses and how their ideas build towards learning goals
Plan carefully for discussions…
• Anticipate student misconceptions
• Generate lists of questions to guide thinking based on type of discussion (launch, data discussion, etc.)
• Consult standards and unit learning goals to select appropriate big question
• Build on earlier discussions
• Prepare for range of content that may come up
• Adapt curriculum materials to engage students in scientific practices</td><td>Example 4: Responding to student ideas in the present to revisit in the future</td><td>• Meg and the interns discuss how to respond to ideas that are introduced too early by students but will be needed later to reach learning goals.</td></tr>
<tr><td>Example 5: Planning for the twists and turns of a classroom discussion</td><td>• Meg introduces the phrase, “no winging it” to emphasize the importance of planning in a discussion</td></tr>
</table>

For example, Meg stated:

> What you’re doing is moving out of the way so kids can talk to each other. You are constantly listening; you’re constantly negotiating whether the conversation is going where you need it to go. Hear my words, the way *you* need it to go. You’re

> ultimately responsible for those goals and how you're going to direct it so that it [the discussion] gets to that place…(Session 6, part 1, 34:12)

In Example 4, Meg helped interns think about how to handle situations where students bring up vocabulary words too early in a discussion or unit, before they have the experiences to make sense of the words.

Example 4: Responding to student ideas in the present to revisit in the future

In the following dialogue, Meg asked interns to consider a possible scenario where a student brings up vocabulary terms like "bacteria" and "viruses" during the first or launch discussion in the PBIS unit when most students would not be prepared to make sense of the definitions. She encouraged interns to make their decision about how to respond to the student's use of that vocabulary based on what they knew about the learning goals for the unit and where they were eventually headed. On one hand, they did not want to dismiss the student's contribution (related to foregrounding student ideas), however, they also did not want to confuse other students with vocabulary words before they had completed investigations, readings, and activities to prepare them for those words and their meanings.

1 Meg: ...what do you suppose if somebody had raised their hand and said, [ ] she knows, and she is going to answer the question, what do you think about preventing your friends from getting sick, and she is going to say, colds are caused by viruses. What do you suppose in a launch I should do with that if I'm the teacher or when you are the teacher you should do with that statement?

2 Intern A: Not evaluate it or affirm it anyway. Just treat it like any of the other things...

3 Meg: So practice. What would you say?

4 Intern A: Alright. Let's put that down [write it on the board].

5 Meg: So I'm going to say, "colds are caused by viruses." Paula, what would you say?

6 Intern B: [She would say] So, what's a suggestion you would have, how can you prevent your friends from getting sick?

7 Meg: Okay, so [the student says,] colds are caused by bacteria. So what might you say?

8 Intern B: I would say, "ok, thanks for that information, but what would you do with that information to prevent your friends from getting sick?" Cause that's my question.

9 Meg: Okay, so we could sort of redirect. Would you write down colds are caused by bacteria or colds are caused by viruses? (Session 2, part 2, 0:32)

In the preceding dialogue, interns offered ways to avoid discussing the vocabulary words that the student introduced by trying to get the student to focus on answering the big question (Lines 6 and 8). After several interns offered other ways of handling the student's contribution, Meg informed interns that she would suggest putting the terms up on the board to revisit later, because she knew that eventually students would learn those words in the unit:

> …the goal of the unit is to answer the big question--in this case, how do you prevent your friends from getting sick? So eventually, one of the things you need to know is what are bacteria and what is a virus? You don't know that yet, because we haven't gotten that far in the unit. And there are two reasons [for writing the words on the board for later]: In order to really answer the question, how do you prevent good friends from getting sick, you would need to know, what's the mechanism that causes illness? So that's one reason. Second reason, in middle school state standards, all across the country, knowing what a bacteria is and knowing what a virus is and knowing what the difference is between the two is a standard. (Session 2, part 2, 6:38)

Meg acknowledged that the interns did not have a sense of the entire PBIS unit to know whether or not those terms would be important later, however, she introduced the idea that by knowing the end goal, a teacher could either respond directly and engage students in discussing or expanding on vocabulary immediately, or could decide to collect the idea to revisit later, knowing that it would eventually contribute to the learning goals of the unit and associated standards. In this case, Meg suggested simply recording the idea for a later discussion instead of prompting students to try to explain or define the words:

> So in this case, I'm telling you, I would put it up there, because I know as the teacher where my unit is heading…so in fact, it's a good thing if one of the students use the words virus or bacteria. However, I wouldn't give them that word at this point…it's kind of good knowledge [for the teacher] to know that they know those words, but the definitions of those words, not so important at the moment. (Session 2, part 2, 7:44)

By reminding the interns about the big question and standards, Meg brought up the idea that guiding science discussions involved a lot of work in the pre-active, planning phase of teaching, so teachers could carefully prepare how students would be guided towards intended learning goals (see example 5).

Example 5: Planning for the twists and turns of a classroom discussion

Throughout the course, Meg reminded interns that they might struggle to steer a discussion towards intended learning goals unless they had prepared carefully:

> We do not wing it! There is no winging it. So having a big question and saying we are going to discuss it is not a lesson plan, because the only reason you can

> have a really good discussion is that you are well-prepared…(Session 2, part 5, 24:17)

Meg also reminded interns to find ways to cycle back to the big question, so student always knew why they were engaging in a discussion. She also suggested anticipating what third and fourth grade students might say in response to the questions the interns planned on asking. Planning also required interns to become familiar with the range of content topics that students could bring up in a discussion. For example, in the moon phases unit, simply knowing how to model the moon phases and what the phases were called would not be enough preparation for interns to be able to respond to the range of scientific ideas that could come up during a discussion of moon phases. For example, while reflecting on his launch discussion enactment, one intern shared:

> …they [the students] kept talking about spinning and orbiting, and they got up and actually physically did it. And I thought they were talking about the moon, but they had just jumped from what we were talking about to the reasons why we don't see it [the moon] during the day is what they were trying to describe, and eventually they were talking about the earth, the axis and its tilt, and the spin, and I was relieved, so I explained that a bit. Then we talked about the moon orbiting, not spinning. They knew that it orbited (I37, Session 3, part 2, 13:15)

The intern's comments illustrate how the students started bringing up topics related to the earth, moon, orbits, tilt, and spinning that were beyond the narrow topic of moon phases. He even admitted feeling "relieved" when the students started talking about the tilt of the earth, something he felt he could explain. Anticipating these issues and preparing how to talk about the range of content would be important actions for teachers to take before teaching in order to better steer the discussion towards the learning goals. Meg also encouraged interns to take notes and share what they learned about students' developing ideas with their teaching group after each teaching experience. That way, they could build on earlier discussions to guide students towards the learning goals in future discussions.

Supporting students to do the cognitive work

The third content theme, supporting students to do the cognitive work, was supported by the rationale that students are active participants in their learning and they should be supported in making sense of their initial ideas experiences in class. This is different than the teacher doing all the thinking, defining, and supplying of answers for them. That is, students should be pushed to explain their ideas and to build deeper understanding rather than just memorizing information from a teacher-led lecture. Meg summarized the rationale for having students do the cognitive work:

> What we are trying to do in these discussions, what we want your role to be, is to help students do the cognitive, academic work in the classroom, and move it off of you, and onto them. You are the teacher, that doesn't mean you can think for them. They have to think for themselves. Your job is to help them do that thinking. One way to move that work back to the kids is through the questions that you ask them. And really good questions make kids think…we would like you to think about how are we going to ask questions to the students to move some of the academic work over to them and not keep it to yourself. (Session 4, part 2, 1:48)

There were two main types of teacher actions associated with having students do the cognitive work: asking questions and engaging students in scientific practices (see Table 4.4). Examples 6 and 7 will provide examples of the ways questions could be used to ask students to do more of the cognitive work, and Example 8 describes the ways science practices pushed students to think deeper about scientific concepts.

Table 4.4
Rationale and actions for content theme: having students do the cognitive work

<table>
<tr><td colspan="3">Rationale: Students learn by being asked to actively think about their initial ideas and evaluate them using evidence and experiences versus passively receiving information from the teacher.</td></tr>
<tr><td>Teacher Actions</td><td>Example No./Title</td><td>Example Summary</td></tr>
<tr><td rowspan="2">Using questions:
• Ask open-ended questions (not yes/no questions)
• Ask questions that prompt students to come up with data collection procedures, investigations, definitions: don’t tell them.
• Don’t ask, “does everyone understand?”
• Ask questions that push student thinking
• Respond to inaccurate ideas with questions that will guide students to modify their understanding</td><td>Example 6: Using questions to have students come up with investigation plans</td><td>• Shelly led interns to think of ways to put the cognitive work on the students by asking them how they think they can break a mock rock apart further.</td></tr>
<tr><td>Example 7: Moving beyond memorizing the moon phases</td><td>• Meg provided examples of questions that would push students to explain their understanding of moon phases</td></tr>
<tr><td>Engage students in scientific practices that allow for cognitive work specific to science:
• Encourage them to ask questions about their observations
• Ask students to provide evidence
• support them to create explanations using scientific reasoning</td><td>Example 8: The cognitive work of learning science through inquiry</td><td>• Meg and interns describe the ways data analysis, evidence, and explanations place more cognitive work on students in science class</td></tr>
</table>

Example 6: Using questions to have students come up with investigation plans

Meg and Shelly brought up different ways of phrasing questions so students were being encouraged to think deeply instead of responding in more superficial ways, like giving yes or no answers with no explanation of their thinking. In Session 3, Shelly helped interns plan the upcoming mock rock[13] investigation. First, she and the interns discussed how the elementary students would break apart their mock rocks using a nail to discover that rocks are made of several materials that they could sort into piles. For example, students would sort the rock pieces into piles of different color gravel pieces and oyster shells. The remaining mixture of the mock rocks would look like a grey grainy mixture, and students would place that grey mixture in vials with water to explore if other components of the mock rock separated out into the water. Instead of telling students, "next, we are going to add water to the remaining part of your mock rocks to see if we can break it down further to find more parts of a rock," Shelly asked interns to brainstorm ways to have students plan the subsequent investigation procedure:

1 Shelly: …it would be tempting to ask [the following question] this afternoon, but I think we can make it better so the kids can do more intellectual work: you just talked about what makes up the mock rock, and the question is "Does anyone know how we can take this apart with water?" So here are all the parts of the mock rock, we talked about it, and the question is, "does anyone know how we can take this apart with water?" How can we make that better? Because it gets right to the point, and no discussion really needed...so what kind of question or couple of questions could you ask instead…

2 Intern A: If we just talk about what we did this morning, we broke the model rock down using a pick, is there anyway we could break this rock down any further?

3 Shelly: So what if they don't bring up water, that's a great question, but they don't bring up water, where do you go next? So that THEY are doing the [cognitive]

[13] A mock rock was intended to be a model of a real rock for elementary students to break apart and investigate in an effort to learn that rocks are made of different materials. The mock rocks were made of flour, red and green gravel pieces, sand, and oyster shells. See Appendix E for more details about the activities using the mock rock.

work.

4 Intern B: What if we mix it with water?

5 Shelly: So at a time you might just need to throw it out, but is there something else we can ask if we want them to keep thinking...

6 Intern C: Could you add anything to it, they were thinking of taking it apart, but just asking if they could add anything.

7 Intern D: Maybe lead them to water without saying it--like what can you think of in nature that breaks rocks apart? [ ]

9 Meg: So the goal for your group for the afternoon is to have a discussion about the model and pushing the mock rocks to the next place. Don't hold all that mental work for yourself--move it back to the students--make them think--and one way to do that is through the questions…(Session 3, part 3, 8:58)

In Line 2, Intern A offered a good, open-ended question, "is there anyway we could break this rock down any further?" Shelly asked interns to think of other questions they could use if the students did not come up with water as a response. In Line 4, the intern offered a direct question that could have been answered with a simple, "yes, let's do that." In a way, the question simply asked students to confirm an idea the teacher seemed to lead them to think was correct. In Line 7, an intern suggested giving students a hint by asking them to think of something in nature that might break apart rocks. With more questions around this idea of nature, it was likely the students would eventually suggest water. In sum, this interaction illustrated the difference between saying, "okay, now I want you to put the remaining rock materials into a vial with water so we can see if anything else is in there," and saying, "can you think of a way we can break this down any further?" In the former question, the teacher decided the next step based on *her understanding* of what will break the rock; in the latter, the students were pushed to do the thinking based on their prior knowledge about possible ways to investigate the rock materials further. The interns that were teaching the moon phases unit were led by Meg to also think about ways to ask thought-provoking questions while guiding discussions for their unit (see Example 7).

Example 7: Moving beyond memorizing the moon phases

The main activity in the FOSS moon phases unit was the modeling of each moon phase (see Appendix E) using a light source (the sun), the student or teacher's eyes (view from earth) and a ball on a stick (the moon). Meg encouraged interns to think of questions that would require more thinking by the students beyond just memorizing how to use the model to show each phase. For example, instead of simply saying, "can you show me how you would model full moon?" Meg suggested asking, "could you lay out the sun, earth and moon in a different way [order] so that you would see a full moon?" (Session 3, 31:10). To answer this question, students would need to be comfortable with a range of ideas. For example, one intern suggested that the sun go between the earth and moon. Meg used the model to show this arrangement, and several interns noted right away that this was not accurate:

1 Intern A: No, that's impossible!

2 Intern B: there is no way.

3 Intern C: You can't have the sun come between the earth and the moon because the sun is far away from the earth, and the moon is closer to the earth.

4 Meg: Right, because the earth and the moon always move together. The sun doesn't come between the earth and the moon. (Session 3, part 1, 33:45)

Once the interns established that the arrangement of the sun, earth, and moon had to be the same each time for a full moon, Meg provided another example of a question that would push students to do more cognitive thinking: "When, would you see a full moon in the sky? If it has to be in this order: the sun, the earth, and the moon—when would you see it in the sky?" This question required students to think about when they would be facing away from the sun, which would be at night[14]. Thus, students had to draw on their understanding of the earth and moon always moving together so the sun could not come between them (Line 4), and the idea that the only time the moon can be fully lit is when the sun, earth, and moon are aligned in that particular order. Students would also need to understand that the full moon can only be seen at night in order to respond to the question, "could you lay out the sun, earth and moon in a different way [order] so that you would see a full moon?"

This question called on students to negotiate among three main science ideas that Meg identified: 1) the earth and moon always move together so the sun can never come between them; 2) the only time the moon is fully lit is when the sun, earth, and moon are aligned in that particular order; 3) the full moon can only be seen during the night. Moving among these content ideas to determine that there is no other arrangement to make full moon requires far more cognitive work than simply memorizing how to show full moon with the model. Meg provided an analogy of the crème brulee dessert to help interns understand how questions can push student thinking:

> This [basic naming the phases or modeling the phases] is called the crème brulee understanding. It's like custard with sugar burned on the top and you put your spoon in and it goes crunch. What we understand [by modeling the phase correctly] is the crème brulee part but as soon as get past that little thin coating of

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[14] At night, when the Earth is between the moon and the Sun, the side of the moon which reflects the sunlight is facing the part of the Earth that is facing away from the Sun. Therefore, while sometimes people see an "almost full moon" during the day, it is not possible to see a complete full moon during the day; full moon only appears at night.

> understanding, the rest of it is just mush, because we are not really sure. (Meg, Session 3, 31:48)

With this analogy, Meg hoped interns would include questions in their lesson plans for the next classroom discussion that would push students, as they used the model, to move beyond their superficial understandings of moon phases and think deeper about the patterns caused by the particular position of objects in the solar system.

Example 8: The cognitive work of learning science through inquiry

Meg also emphasized the cognitive work that was specific to learning science through inquiry: asking questions, analyzing data, choosing evidence to support explanations. Throughout the course, they discussed the importance of having students engaging in scientific practices, such as collecting and analyzing data during from an investigation and having students provide evidence for their ideas in class. For example, when interns brought up the idea of using a controversial topic or a debate during discussions to get students interested in the big question for the unit, Meg acknowledged that students enjoyed debating, but it was the role of the teacher to help students get used to providing evidence for their claims. She reminded the interns, "…they [students] love to debate, but in science, it's not to just debate, it's not okay to just throw your idea out there, you have to support your idea with evidence…in science, we require that you work from evidence" (Session 1, part 4.5, 53:25).

For the last discussion, Meg asked interns to return to their big questions for each unit and to ask students to use evidence, whether it was from the mock rock investigation or the modeling of the moon phases, to help explain their answer to the big question (Session 7, part 6, 18:42). One intern summarized what they learned in the methods course about asking students to do more of the cognitive work by explaining their answers versus just providing them:

> I think it's so important (in all subjects) to have students explain why they think something is the way it is and to have evidence for their answers. I see in my placement classroom now that there are students who will answer, and say, "Just because" when you ask them why they think that. So few teachers are asking questions just to hear the right answer, but not probing deeper into students' thinking. So, I think it's extremely important to focus on explanations in all subjects. (Melanie, THM7[15])

Another intern provided an example of how asking for evidence required students to think deeper and to provide more than just their opinion:

> In my classroom, I think that scientific explanations will serve as a method of engaging students in deeper thinking about scientific processes as well as preparing them to discuss their ideas in a more structured way. The purpose will be to encourage students to share their ideas with one another and to prepare them to support those ideas with scientific evidence…A student with an interest in saving the whales, for example, might make a claim that whales need to be saved because he likes them. That same student, after practicing and developing techniques for scientific explanations, might make a more convincing claim and provide data that supports that claim. (Vanessa, THM 7)

[15] When a quote from an intern's take-home message is presented, it will be cited with the intern number that was randomly given to each intern (e.g., 13 for Intern 13) or with the pseudonym if it is a focal intern (e.g., Haley, Melanie, John, and Vanessa). So, THM7 stands for take-home message after course session 7).

As Meg, Shelly, and the interns talked about asking open-ended questions, engaging students in complex thinking about scientific concepts, and encouraging them to provide evidence for their explanations about how the world works, the content theme of having students do the cognitive work was reinforced. The ways interns tried phrasing questions to put the cognitive work on students, or asked students for evidence will be presented in more detail in Chapter 5, when examples from their enactments of discussions are shared.

Enacting the teacher role of facilitator

Related to the idea of having students participate in the cognitive work, is the content theme of enacting the teacher role of facilitator (see Table 4.5). The rationale for this theme is that teaching and learning science through inquiry requires new ways of envisioning the role of teacher and the role of students. Throughout the course, Meg reminded the interns that teaching science through inquiry required moving away from more traditional approaches to teaching, where student-teacher interactions often involved the teacher "telling" students what was right or wrong and the students passively memorizing the information. Meg used the analogy of a tire for the roles of teachers and students: she suggested that in more traditional views of teaching, the students were on the outside rim of the tire, and all their comments were directed towards the teacher, who was at the center of the wheel. Meg suggested that interns try joining the students on the rim, so they can facilitate the discussion of ideas and questions among the students by listening and guiding when necessary.

In order to change the interactions among teachers and students, some teacher actions included providing more opportunities for students to share and discuss ideas instead of only trying to give the teacher the right answer, along with efforts to orient students' ideas to each other so there could be more student-student interaction. I will explore these actions in the following examples.

Table 4.5
Rationale and actions for content theme: Enacting the teacher role of facilitator

<table>
<tr><td colspan="3">Rationale: Teaching and learning science through inquiry requires students to actively engage in their learning by asking questions and revising their ideas using evidence. Traditional student-teacher roles of receiver and teller should be replaced with roles of learner and facilitator, respectively.</td></tr>
<tr><td>Teacher Actions</td><td>Example No./Title</td><td>Example Summary</td></tr>
<tr><td rowspan="2">• provide more opportunities for discussion by adapting curricular materials
• use "tell us" vs. "tell me"
• orient students to each others' ideas
• act as facilitator, not teller</td><td>Example 9: Less telling, more active learning during classroom discussion</td><td>• Meg and the interns discuss the differences between telling students to memorize definitions versus guiding their learning the concepts behind definitions.</td></tr>
<tr><td>Example 10: Encouraging talk among students</td><td>• Meg models how to orient student responses to each other instead of directing all responses to the teacher.</td></tr>
</table>

Example 9: Less telling, more active learning during classroom discussion

Throughout ED 528, Meg tried to use the PBIS unit as an example of how a curricular unit can include many opportunities for students to discuss their ideas instead of sitting through a series of lectures led by the teacher. She summarized that facilitating student learning takes much longer than just telling students if they are right or wrong, but it includes more students in the discussion and helps students build deeper understandings:

> …the goal is to really try to pull in all different kinds of learners in school…if this is how it had happened: Somebody says, "I *know* that every single time I feel cold, I get a cold." And I said, "You're absolutely right. That's how it works."

> Now what? Discussion over. Killed it. Absolutely no more discussion. I've made it very clear that my knowledge [the teacher's] is the knowledge that is preferred in this classroom. Or maybe it's the knowledge that is presented in the book, as the book knowledge, and that your ideas [students' ideas] don't matter anymore. All we are trying to do is get kids started thinking about this stuff [in the launch discussion], and then over the unit, we can take apart their initial ideas, build up those that are accurate, and rework those that are not accurate. But it's a long-term process. (Session 1, part 5, 43:15)

Meg and the interns also had an extensive discussion about the use of vocabulary, as some interns had witnessed their cooperating teachers starting off the FOSS units by having the students copy vocabulary words and definitions from the units into their notebooks. The interns reported that as the students copied the definitions from the book, they were simply following directions, not learning content:

1 Intern A: …our group kind of had an interesting thing happen today at our little meeting…so, when we get there, the kids are writing the definitions first day, that's exactly what they told us not to do last week, so, kind of funny. So one of the definitions, for moon, is earth's natural satellite. Ask any fourth grader what that [satellite] means, and they looked at me like they had no clue. So I said, okay, let's look up satellite. [The dictionary said] An object, such as the moon, that orbits another object, such as a planet. Okay? So [I asked the student] what does orbit mean? On the next definition, [the dictionary said] to move or travel around an object in a curved path. Earth orbits the sun, the moon orbits the Earth. So, it is kind of confusing for a 4th grader to grasp, I had to go through 3 definitions [with the student] to [help him] figure out what a satellite is, what orbit means, and so then we tried to figure out the moon. So that was I think a teaching moment of what *not* to do…

2 Intern B: One of the words was planet, and one of the kids wrote plant. They were just transcribing.

3 Intern C: Well I asked them, I asked a boy, well tell me, what's a planet, and he pointed to the globe and he said, "that's a planet." And I said well describe it, he goes, "it's blue and green and it's a circle"…(Session 2, part 5, 39:12)

In this discussion, the interns shared their observations of what was happening in their assigned elementary classroom, and it offered an opportunity for Meg to discuss the role of vocabulary in science discussions and throughout a unit. As they wrote definitions, some students were not prepared to make sense of the definitions they were writing (Line 1). As Intern B pointed out in Line 2, some students were simply writing each word without thinking about what they were writing or what it meant. When asked to share his own idea of what the word "planet" meant, the student pointed to an example of a planet and could describe its shape generally (Line 3). Meg prompted the interns to take this scenario as motivation for thinking of ways to ask good questions to give students a purpose for learning (i.e., there was no motivating purpose for memorizing the vocabulary terms) and to begin with student ideas during a discussion. Instead of taking the role of "teller," and providing definitions, she encouraged them to take the role of "facilitator." This shift suggested they would first engage students by giving them experiences with phenomena or models to think about scientific concepts first, and then would guide them to understand terms and definitions through classroom discussion. In this way, students would be supported to take a more active role in their learning, where they could discuss their developing understandings of the terms with peers instead of copying terms and definitions without context or purpose. Overall, taking on the role of teacher as a facilitator was challenging for many interns, as it was often different from the more traditional teacher-student roles they experienced when they were students in school. One intern described her struggle enacting the actions aligned with this content theme:

> I was not completely successful teaching today. I am finding it extremely challenging to teach this unit. I have no experience teaching science and it is difficult for me to not tell the students the answers! I think I should get better at predicting students' responses because when they ask a question that I did not anticipate, I blank out. I also need much more practice with my questioning skills in order to get at understanding. In some cases, I feel that if I were to just tell the students the answer, they would get it much more easily, so I'm torn between the two methods of teaching. I honestly think there needs to be a balance of both...(Intern 32, THM 6)

Example 10: Encouraging talk among students

During a discussion about being careful with the language used during classroom discussions, Shelly and Meg pushed interns to think about ways to include more students in the dialogue, and how to help students direct their responses to each other instead of only the teacher. For example, they suggested teacher actions like saying, "tell us," so the students felt that they were addressing their classmates and the teacher, instead of saying, “tell me,” which implies that the student’s response is only for the teacher who is asking the question. Also, Meg asked the interns to comment on each other’s ideas that they had collected as a class (see Example 1 for how she elicited those ideas initially):

1 Meg: What else on here [the class list of ideas about preventing friends from getting sick] made you say, hmm, I’m not so sure about that?

2 Intern A: Hand sanitizers and washing hands all the time…you need to have exposure [to germs].

3 Meg: Well, so it sounds to me that you are taking Rob’s position a little bit?

4 Intern A: [inaudible]…need exposure over a lifetime…[inaudible, but he explains more about the need for exposure to germs]

5 Meg: What do you all think about Ian [Intern A] and Rob's ideas?

6 Intern B: I agree, so I actually know someone who, they called it environmental allergies because his house was so clean growing up, he never built up an immune system, so he was allergic to everything...

7 Intern C: Building off of that, when I was visiting family in Georgia, my little cousin has eczema all over her skin, and breaks out in rashes, and really bad runny nose with allergies because her mom is a fanatic about cleaning everything with Lysol, and she's never allowed to go outside with other kids, it's weird, she is isolated from everything, so I think there is something to be said about a little bit of exposure to germs…(Session 1, part 2, 1:10)

In these exchanges, Meg modeled how a teacher would take on the role of facilitator, and would help orient students to their peers' ideas, thereby guiding students to respond to each other as well as to the teacher. In Line 3, Meg oriented Intern A towards a classmate's response that aligned with Intern A's ideas, hoping those students would see the similarities in their viewpoints. She then asked their peers what they thought about those ideas. In Line 6, an intern agreed with her classmates' views and provided an additional example to further support that view. This prompted Intern C to also join the conversation at Line 7, with a personal experience that aligned with her classmates' ideas. Meg, acting as the facilitator, then prompted the interns to share another idea about getting sick:

8 Meg: What else is on this list that you are maybe not so sure about or [that you] maybe really believe in…

9 Intern D: I'm kind of wondering about the [idea of] washing hands before going to the bathroom.

10 Intern E: I know, I read about this somewhere. It makes sense, because you are touching open orifices, and your hands will probably already have germs on them, so it's good to wash before.

11 Intern D: Yeah, and I totally see that, I just think that there is something about washing your hands too much, [inaudible] building up immunity…

12 Meg: …So if you follow Rob and Intern A's and Intern D's and Intern E's ideas about, you know, maybe we're getting a little too neurotic…so I've heard about these parties where they take somebody who has H1N1, and people actually go their house, in order to be exposed to the flu…have you heard about this? (Session 1, part 2, 3:13)

In Line 9, Intern D referred to a classmate's idea that was projected on the class list. The student who wrote the idea, Intern E, spoke up to respond to Intern D's interest in her comment. She began to provide reasoning for why she felt washing hands before going to the bathroom was important in Line 10. Intern D acknowledged that people have germs on their hands even when they go into a bathroom, however, she started to suggest that people could also wash their hands too much (Line 11). Noticing that there were emerging differences in the interns responses, Meg decided to build on the idea of building immunity by presenting the idea of "parties" that she heard about on the news, where people purposefully gather at the home of someone who has the flu (Line 12). Meg knew that the next activity in the unit involved a simulation that introduced ideas like exposure, being a carrier of a disease but not being infected, and how communicable diseases are transmitted. Therefore, by bringing up the "parties" in Line 12, she was able to take the role of facilitator and direct interns towards ideas that would set-up the upcoming simulation activity well. Several content themes surfaced during the interactions in Lines 1-12: Meg was foregrounding student ideas, orienting students to each others' ideas by acting as the facilitator, and steering the discussion towards intended learning goals.

Meg explained that when enacting the role of facilitator during discussions, a teacher does not continue through her lesson plan at her own pace; instead, she constantly listens and responds to her students' developing understandings and determines the best ways to help students move from their ideas and questions to the learning goals the teacher is responsible for supporting her students to meet. Meg encouraged interns to always check if they were taking too much of a "teller" role during a discussion:

> So when you're in the middle of this [a discussion], I want you to hear the words in your head, am I taking all the all the control here? How can I give it back to the kids? How can I step back? (Session 6, part 1, 47:19)

Creating a classroom culture that supports science discussions

As they began guiding science discussions in Garden City classrooms, many interns brought up how difficult it was to guide science discussions since the students seemed to expect the teacher to do most of the talking: "I feel like when we got there on the first day, we all came away from it saying, wow, these kids have not been taught how to have a discussion" (Intern 7, Session 4, part 4). The interns noticed that many of the students they were working with were used to completing worksheets without understanding the purpose, answering questions for the teacher, and rarely directing comments and questions about their scientific understandings to each other.

Thus, Meg provided a rationale for creating a classroom culture that supports science discussions: students could not be expected to suddenly share ideas with each other, ask each other questions, and build understandings together unless they were used to a classroom culture that supported them in participating as students in those ways. Based on this rationale, Meg and the interns discussed how to purposefully create a physical and social environment where students could participate comfortably in discussions about science concepts (see Table 4.6).

Table 4.6
Rationale and actions for content theme: creating a classroom culture for science discussions

Rationale: Students cannot be expected to participate actively in discussions without the establishment of a classroom culture that supports that type of interaction		
Teacher Actions	**Example No./Title**	**Example Summary**
• Make it possible for all students to participate (vary small-group and large-group opportunities to talk) • Engage students in scientific practices during discussion (using evidence, providing explanations) • Set-up seating for discussion (e.g., groups, circle on floor) • Establish and share rules and expectations for talking to each other, disagreeing, sharing ideas • Have a space for recording student ideas (e.g., project board)	Example 11: Identifying features of classroom culture	• The interns share struggles in guiding discussions in classrooms where students are not used to agreeing and disagreeing with each other in productive ways
	Example 12: Meg and the interns discuss the classroom culture in a video-clip	• The interns identify characteristics of the classroom culture that had to be in place to support the magnet discussion among third graders in a video-clip
	Example 13: Interns share their early attempts at modifying the classroom culture	• While debriefing their teaching experiences, one group shares how they tried modeling what a “good listener” looks like and ways to “politely disagree” during discussion

Example 11: Identifying aspects of classroom culture

Meg introduced interns to several ways of establishing a classroom culture that allows for science discussions. Teacher actions included creating a space that was set-up to encourage students to talk to each other. For example, the arrangement of seating, in rows versus groups, could encourage or discourage students from talking to each other. Meg asked interns to observe the physical set-up of their assigned elementary classrooms on their first visit:

> …the culture of the classroom is partially defined by the way they are seated, so pay attention to that today. Do they seem to work together in small groups, or are they seated in that way, are they in rows, in a "U" all the stuff about collaboration, and what they are used to is somewhat set by how she has the desks set-up. Is there a carpet where they all meet, is there a time where the whole class will sit together and talk to each other, is there a "front" of the classroom?" (Session 2, part1, 2:01).

When she was modeling the role of an elementary science teacher in Session 1, Meg alternated between having the interns, acting as elementary students, share their ideas in small-groups and with the whole class. One intern summarized the importance of having these opportunities in the launch discussion where students are first thinking about their ideas about a particular scientific concept:

1 Intern A: [A launch should] provide an opportunity at least once in the launch for every student to contribute…

2 Meg: Does that mean that everybody has to talk out to the group?

3 Intern A: …I would picture that as talking in small groups, or maybe in pairs, but I think it's important for each students to get a chance to feel like they had something to say about this [the big question].

Meg also encouraged interns to create a classroom culture where students were aware that the different activities and discussions they were participating in were similar to the work of scientists. This could help to breakdown some of the stereotypes about scientists that the students might have adopted from the media; for example, images of scientists sitting in labs, wearing white coats, and working with chemicals. Meg suggested pointing out the scientific practices that students were engaging in so they knew what activities made up the science classroom culture:

> Meg: So we want to say, "we're going to make a model of the sun, moon, and earth and how it makes full moon. Scientists use models a lot because we can't go to the moon or we can't move the moon ourselves to see how that happens, so we have to use a model to show that." You all with the rocks said, "we're all going to use the mock rock because we can't break different kinds of rocks apart, we need rocks that are easily broken by us. So the model is a really important tool that scientists use….So modeling is a good scientific practice….(Session 6, part 2, 32:50)

Meg pointed out that when students are learning science through inquiry, they need to be supported in a classroom culture where they can ask questions, conduct investigations, provide evidence, and engage in scientific discourse. She related it to history class because interns were bringing up connections about creating classroom cultures across subject-areas:

> …we are going to have a classroom culture, just like Natalie said, that we are going to do these things. We are not going to read about history, we are not going to read about science, we are going to investigate history, and we are going to investigate science, and be investigators and be questioners…(Session 6, part 2, 39:47)

In sum, Meg and the interns discussed these three aspects of classroom culture that can support science discussions: physical set-up of seating, creating many opportunities for students to share their ideas, and making students' participation in scientific practices explicit (e.g., providing evidence, comparing explanations).

Example 12: Meg and the interns discuss the classroom culture in a video-clip

After watching the video-clip of Mitchell explaining his observation of a bar magnet (see Example 2), interns expressed how impressed they were with how the young third graders responded to each other's ideas and felt comfortable sharing their thinking with the group. Meg explained, "…in these classrooms, they really work on the whole science talk culture throughout the school year. And if you watch [the video-clip] carefully, you'll see that this is already March….they had green beads and they all had shamrock nametags on. So it's been a long time that they set up that culture," (Class 7, part 2, 5:28). Meg pointed out that, in the video-clip, the discussion took place on the floor, so students could easily see each other and speak to the group and teacher. The interns also brought up an easel that they observed in the classroom where student "wonderings" or questions were posted; Meg explained that it was a part of the classroom culture (in the video-clip) to return to the list of "wonderings" as a class after engaging in an investigation or activity that would provide them with more information to respond to their wonderings. The interns also noticed that students were wearing white dress shirts that acted as the students' lab coats. They connected this observation to a previous discussion they had with Meg in Session 6 about stereotypes that can be created by particular aspects of a science classroom (e.g., wearing a white lab coat, having images of the scientific method on the wall, telling students they should put their "science hats" on, etc.). In these types of discussions between Meg and interns, the importance of carefully creating a classroom culture that represented science accurately but appropriately for the school setting, and also supported students in engaging in science versus only reading about it was woven throughout almost all the course sessions (i.e., seven of the eight sessions).

Example 13: Interns share their early attempts at modifying the classroom culture

Because interns were unable to set up the culture of the Garden City classrooms earlier in the school year, they had to do their best to set up some aspects of culture on their visits. Interns often shared their techniques. For example, one group of interns tried to model "politely disagreeing" and being "good listeners" of peers' ideas:

1 Intern A: …today we modeled how to politely disagree…[next time] we will bring up how to respond to someone.

2 Intern B: When they [the elementary students] were all talking over each other, I would say "I'm not sure that everyone heard that, can you repeat it?" So that would quiet the group down. Or, "let's make sure everyone is listening before we start to talk," or things like that.

3 Intern C: We also asked, "what does a good listener look like?" and tried to model that… (Session 4, part 4, 22:42)

In identifying the challenges they were facing, the interns were able to realize how important setting up the culture ahead of time was as a science teacher; for example, one intern reflected:

> "…it takes time to build a culture of trust where students feel they can say what they want and even venture ideas even when they aren't sure they are "right" or not…I could see in the eyes of the students that they were desperately seeking affirmation from me about their word and thoughts from the unit and [I] feel the necessity of being the one that helps create an environment where students CAN

talk at will and share ideas…the important thing is that they are ASKING without fear of failure" (Haley, THM4).

In sum, interns began to recognize that the way students were used to sitting, completing tasks, and sharing their ideas all influenced what was possible in terms of the interactions and learning that could happen.

Careful and purposeful use of language in science discussions

The role of language was emphasized repeatedly throughout the course; it was intertwined in discussions of all five content themes. That is, codes for the careful and purposeful use of language were often found overlapping or in close proximity to several instances of the other content codes (see Figure 4.5).

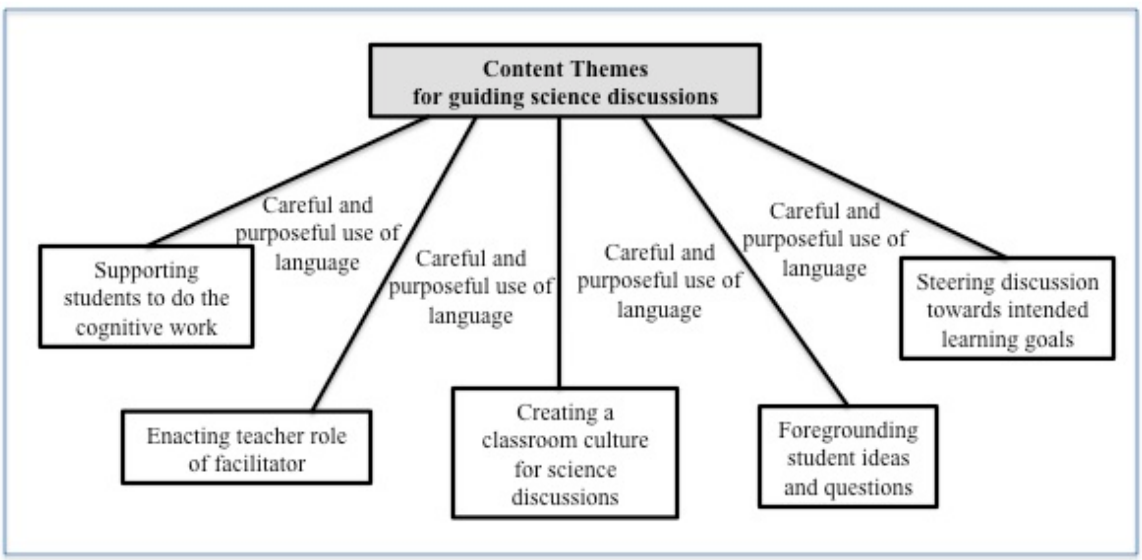

Figure 4.5. The role of careful and purposeful use of language across all five content themes in ED 528.

Attending to language when foregrounding student ideas and questions

In the foregrounding student ideas and questions content theme, the teaching action of moving forward in a discussion with a student idea was introduced. Meg noted the importance of word choice when moving forward with student ideas, as casually using everyday terms could add to students' existing misconceptions.

Example 14. Talking about moon phases. For example, when discussing moon phases, Meg pointed out that students often talk about their observations of the moon "changing shape;" however, they need to understand that the moon always stays the same shape (i.e., a sphere), and only looks different because of the relative position of the sun, moon, and earth. Meg cautioned interns to select their words carefully:

> In the phases of the moon this [attending to language] is really important because it's the *apparent* [italics added] change in the shape or it seems to look different, in fact the shape changes not at all, the moon is always a sphere, it is always like a ball in the sky, half of it always has light shining on it, and half of it always doesn't have light shining on it, even though we don't always see the same amount of light. So, the sun, moon, and stars people have to be really careful about your language because you just will feed in to what they [the elementary students] already think they know. (Session 2, part 5, 29:00)

In a related example, Meg warned interns that elementary students often use the idea of the earth creating shadows on the moon to explain phases. Again, she pushed interns to be careful about how they discussed light and shadows during their discussions:

> What causes the phases of the moon? The angle I'm looking at the moon, and the order in which all the solar system objects are aligned, right? The words we use to help students understand it is going to be very important. Now here comes the tricky part, several of you mentioned stuff about the kids talking about shadows. How are you going to help students use this model to understand that it's not

about shadows...about the shadow of the earth on the moon creating the phases of the moon? (Class 3, part 2, 51:00)

Attending to language when steering discussion toward intended learning goals

Planning how they would steer students towards learning goals also required careful attention to language. Meg asked interns to consider what words in a unit may be unfamiliar or confusing to students.

Example 15. Using the term "mock rock." For example, as interns were taking turns acting out their lesson plans, Vanessa practiced introducing the "mock rock." When asking her teaching group, who were acting as students, what they thought "mock" might mean, she was surprised when an intern brought up the idea of "mock" as making fun of someone:

1 Vanessa: We're not going to use a real rock, we're going to use a mock rock. A mock rock is made up of different materials than what a rock is made out of....Okay, so, mock actually means something that looks or acts like something else...

2 Haley: Or you could ask them...[Haley suggested that Vanessa ask the students to share what they think mock means instead of telling them]

3 Vanessa: Oh I could ask, "so what do you think mock might mean?"

4 John: Like you make fun of someone. Like you mock someone.

Vanessa then attempted to respond to John's unexpected definition. She realized she was thrown off by this alternative definition of the term, and asked her peers for help to come up with how to handle it in Line 5. In Line 6, Haley offered an analogy to the multiple definitions of the term "mineral" that they had discussed before.

5 Vanessa: [laughs] Ya that is one definition of mock, we're thinking of mock in a different form though, this is something, um [Vanessa stopped

being in the role of teacher and addressed her peers], how do I handle that? Like if somebody says, that is true, mocking something...

6 Haley: Yeah, yeah, no, you did a good job, you say, some words have more than one definition and just like when you talk about minerals--some kid said in your body, makes you healthy, and like you are totally right, but there is more than one reference for it, and that's a different one than what we are focusing on today.

7 Vanessa: So think about in terms of rocks, what do you think mock could mean?

8 Haley: Well you just said, we're going to be working with something that is different than actual rocks, I think you said something like that already, so you're like, "so yeah, MOCK, we already said it would be something different, so what do you think mock might mean in relation to that," because you had already given them something to go off of...

9 Vanessa: Right, talk about it, so you know it can't be rocks mocking each other [laughs]

10 Haley: Right. (Class 4, walk-through, 5:15)

The interns had many experiences in course sessions to think about the language they were using and possible ways those terms could be stumbling points in their discussions. Sometimes Meg and Shelly would bring up the terms, such as the ideas about moon phases (Example 14), and other times the interns would begin noticing possible terms on their own, such as "mock" (Example 15).

Attending to language when creating a classroom culture for science discussions

In creating a classroom culture, Meg emphasized the importance of using language that invited all students to participate in discussions. However, the way they were asked to join the conversation mattered. For example, if a teacher noticed that a student was not paying attention, inviting them into the discussion as a disciplinary move did not create a culture where discussion was a means to developing understanding. For example, "Robert, what did Jen just say?" would not guide student thinking, it would merely embarrass Robert for not listening. Meg suggested repeating what Jen said, and asking Robert if he agreed or could add anything to her idea; in this way, the teacher would use language that invited him into the discussion to learn.

Attending to language so students do the cognitive work

Meg reminded interns that the way they phrased questions and responses to student contributions influenced how much cognitive work the students were doing. Carefully selected language could prompt students to think beyond just getting the answer, and towards providing an explanation with their reasoning. For example, in Session 2, Meg had interns think about ways to slightly change the wording of questions to prompt more thinking from students. For example, she asked interns what the difference would be between “is it a rock” which could be answered with a yes or no response, or “what is a rock,” which might require students to be able to explain the characteristics of rocks, how they are formed, and how they are different from other earth materials (Session 2, part 5, 2:21). Another example was thinking about how some questions lead to recognizing and labeling versus explaining why. Meg asked interns to think carefully about their goals for their discussions. She presented the two options she saw across lesson plans: “students will be able to recognize and label the phases of the moon,” or “explain why there are different phases of the moon” (Session 2, part 5, 32:20). By reflecting on these phrasing options that Meg brought up, interns recognized that the former could be satisfied with superficial memorization, whereas the latter required deeper understanding in order to explain why moon phases occurred. The interns worked to revise the language they used in their lesson plans later in that session.

Attending to language to enact teacher role of facilitator

As illustrated in Example 10, Meg and the interns discussed several ways to choose language that would help to breakdown more traditional teacher-student interactions. For example, using phrases like "tell us," instead of "tell me," helped to invite students to share their ideas with the whole class instead of just with the teacher. They also discussed using phrases that oriented students to each other's ideas, such as, "do you want to add to what Jen said," or "do you agree with what George said", or "do you want to share another idea with the group?"

Because language influenced all aspects of the content of guiding science discussions, it was added to the representation of the content themes in ED 528 (see Figure 4.4).

Relationships among content themes

When coding for the content of guiding science discussions, several transcript paragraphs included overlapping codes that represented dialogue about more than one content theme. The co-occurrence of codes related to particular content themes suggested a relationship among them. Because my analysis could only count the instances where codes overlapped directly, and not the instances where codes were in close proximity, I was unable to examine all the possible relationships among content themes. Instead, I will provide some preliminary evidence for relationships among content themes by looking closely at portions of two course session transcripts, to help describe how content themes connected during the dialogue of course activities.

Connections among content themes in a discussion of a video-clip

During a nine-minute discussion between Meg and the interns about the video they watched of an elementary science discussion (see Example 2), preliminary evidence for possible connections among content themes were identified. Figure 4.6[16] illustrates the way codes overlapped and occurred close to each other in the discussion over time.

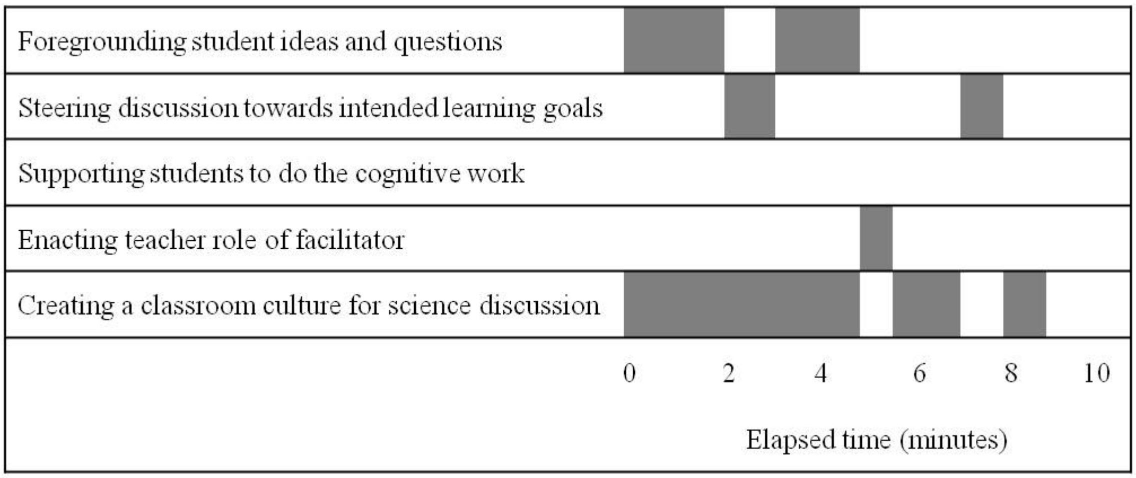

Figure 4.6. Relationships among content themes during discussion of a video-clip.

First, Meg and the interns discussed the "wonderings" chart they observed in the video-clip as an example of how the teacher brought students ideas to the forefront in her classroom. The students in the video-clip were used to sharing their ideas on these charts and knew that they would be asked to refer back to their ideas and questions in the discussion. Thus, watching the video allowed the interns to discuss how the classroom culture allowed the teacher to foreground and steer the discussion with student ideas. This connection between both content themes was represented by the overlapping grey portions between 0-2 minutes in Figure 4.6.

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[16] The time-line representations in Figure 4.6 and 4.7 are based on representations found in the work of Alan H. Schoenfeld, in his book *Mathematical Problem Solving* (1985).

Next, Meg and the interns discussed the choices the teacher made to go ahead with some student ideas versus others so that she could steer the discussion towards learning goals. For example, Meg suggested that at a particular moment the teacher in the video-clip had to decide whether to continue with Mitchell's idea or to follow-up on a student idea that "…was going to drag them far, far away from the goal that she had for the discussion…" (Class 1, part 1, 2:10). The teacher chose to give Mitchell ownership for his idea (see Example 2) and credited him for his observation; in this way, she took the role of facilitator by foregrounding student ideas.

Connections among content themes when discussing how to address student misconceptions about modeling moon phases

In Session 6, Meg guided interns to think through the possible responses they would have to a pair of students who were struggling to model the phases of the moon. At each step, Meg pushed interns to think about why they would make the next move. Figure 4.7 illustrates the content themes that were discussed across this set of interactions that spanned a period of less than three minutes.

During these interactions, Meg suggested that two hypothetical students were modeling "new moon" when they were asked to use a model to represent "full moon." Interns suggested having the students think about how they could revise their model after the teacher helped them understand the location of the light source in the model. In this way, the interns were asking the students to do the cognitive work instead of simply telling them how to correct their model. An intern then suggested inviting other students to help the students revise their answer and modeling. By doing this, more student ideas could be brought to the forefront. Meg pointed out that this was a great way for her to step back, and allow the students to do the work. She helped to steer them to the aspects of the model they had to think about (e.g., the light source and position of the earth, sun, and moon), however, she then provided time for students to discuss the ideas with each other and engage in the cognitive work to revise their model themselves. The content themes of enacting the teacher role of facilitator, foregrounding student ideas and questions, and steering discussion towards learning were represented when the interns were considering ways to respond to student misconceptions.

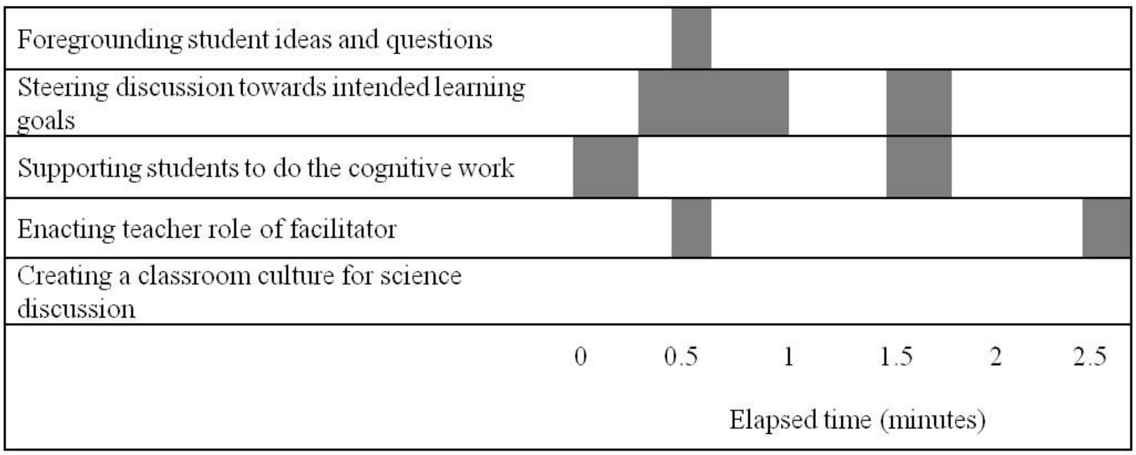

Figure 4.7. Connections among content themes in discussion of moon phases model.

In summary, there is preliminary evidence for connections among content themes that can be explored further in later work that is designed to more carefully code for and count these relationships. By enacting the role of facilitator, student ideas and questions can be brought to the forefront. Reciprocally, as student ideas are brought to the forefront, there may be less focus on the teacher being the center of the discussion or the only person that students can respond to in a discussion. As students' ideas are made public and students are discussing them together, they are able to do more of the cognitive work. For example, Meg told interns:

> But you [the elementary students] have to do the learning. So if I don't put it up [their accurate and inaccurate ideas] and make it public, it's still there…but hopefully if we have made it public, then we can go back and use our investigations, use the evidence for our investigations, remind students, [and say] remember when you thought this, how is what we just did different from what you thought before? (Session 1, part 5, 32:45).

In her comments above, Meg discussed the importance of foregrounding student ideas, even if they were inaccurate, so that students could revisit their ideas later. Codes for the content themes of foregrounding student ideas and questions and having students do the cognitive work overlapped in this part of the transcript from Session 1.

As the teacher takes the role of facilitator, she guides student thinking towards intended learning goals, instead of telling them the answers (enacting role of facilitator). While foregrounding, student accurate *and* inaccurate student ideas can be made public; therefore, the teacher must carefully steer the discussion towards learning goals by revisiting student misconceptions in discussions throughout the unit so students can gradually refine their understanding.

This connection was illustrated in Example 4, when Meg and the interns discussed what to do when foregrounding student ideas led to a student bringing up content or vocabulary terms before students were ready to understand the concepts behind the terms. In Example 4, she told interns that she would write students ideas about bacteria and viruses up on the board, because she knew she could later steer students towards their meaning. In this way, she could capitalize on the student's idea about the terms from the earlier discussion to steer the discussion towards defining them in a later discussion. Thus, she was helping interns see the connections between the content themes of foregrounding student ideas and steering the discussion towards the intended learning goals.

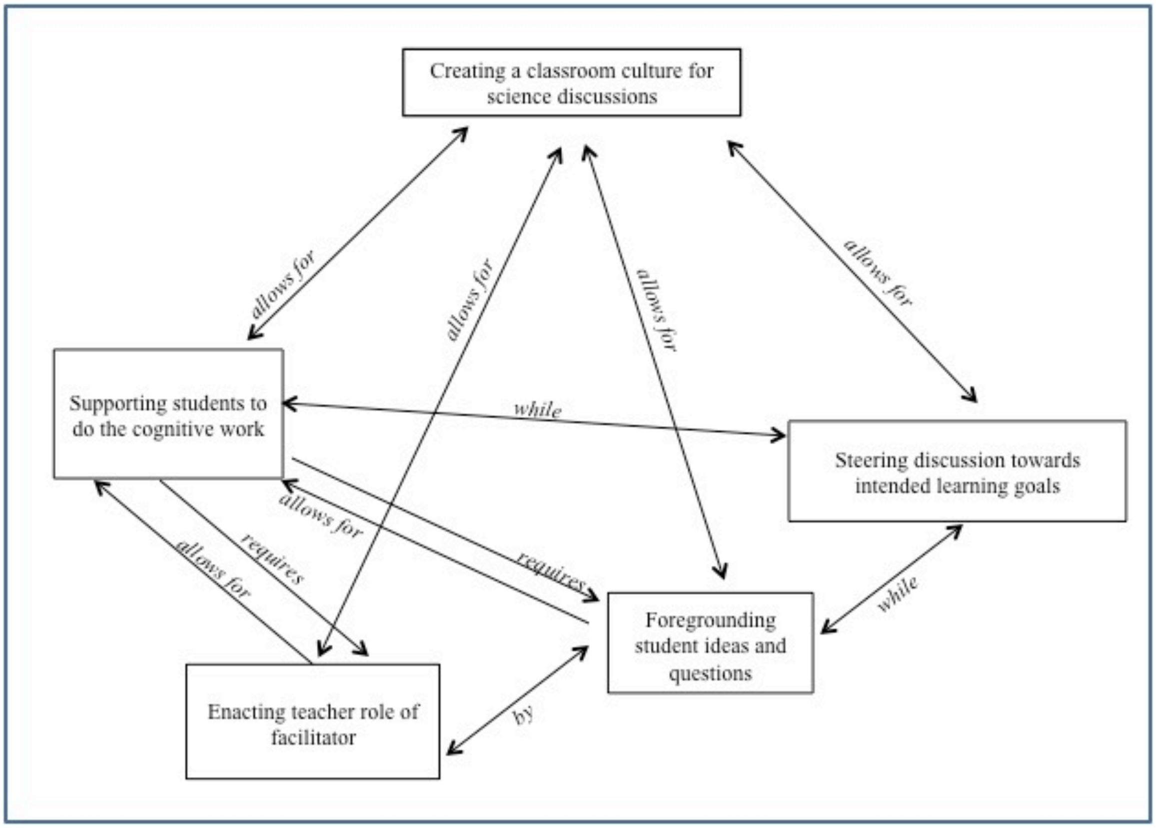

Figure 4.8. Preliminary evidence suggestions relationships among themes that make up the content of guiding science discussions in ED 528.

Finally, several discussions among the interns and Meg highlighted the relationship between classroom culture and the five content themes. Overall, the type of classroom culture that is established will either allow for or make it more difficult to enact the other content themes of guiding a science classroom discussion. Figure 4.8 illustrates the range of possible content theme connections that were suggested by overlapping codes.[17] The arrows and words along the arrows describe the ways the ideas

[17] Instances of overlapping codes only occurred between one to three times for the connections depicted in Figure 4.7. It is likely that with more precise, line-by-line coding strategies more connections would be

in each content theme are related by doing the work of closely analyzing how they are discussed in transcripts (see Figure 4.6 and 4.7).

Summary of Content Themes

In summary, five content themes emerged as a result of coding across all eight course sessions in ED 528: foregrounding student ideas and questions, steering discussion towards intended learning goals, supporting students to do the cognitive work, enacting the teaching role of facilitator, and creating a classroom culture for science discussions. In his take-home message, an intern summarized the content of guiding science classroom discussions that he experienced up to Session 6:

> ...during formal class I made a great list of quality questions and questions to avoid. I understand that creating a discussion has to do with the students, NOT the teacher. Discussions are not meant to be, a teacher asks a question and a student answers. Discussions are meant for students to be actively engaged and respond to other students' thoughts. The role of the teacher is to steer the students in right direction, but 90% of the discussion has to do with student responses. If we are asking close-ended questions, such as "Does everyone understand?" then we are not doing a good job of steering the discussion. (I25, THM6)

The intern's comments reflected his developing ideas about the importance of student contributions in a classroom discussion.

Each content theme included an underlying rationale that Meg explicitly or implicitly provided in course activities and a set of teacher actions that interns could

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found. Since coding in ways to reveal these connections was not an intended purpose of analysis, it was difficult to provide accurate frequencies of codes that occurred in proximity to each other without recoding the entire dataset using a more fine grain of analysis. The lines and words describing connections in Figure 4.7 capture the relationships based on the limited examples of overlapping codes, and can be explored further in other reports of this work.

begin to enact in their teaching. The careful and purposeful use of language was woven throughout all five content themes. That is, teaching involves using particular language to elicit student ideas and to encourage students to talk to each other instead of just the teacher, to guide the discussion towards learning goals, and to phrase questions that push student thinking. Finally, preliminary evidence was presented for possible relationships among the content themes, as Meg would often discuss two content themes simultaneously or discuss how one relates to another. For example, after foregrounding student ideas, a teacher may choose to capitalize on a particular student contribution to steer the discussion towards learning goals.

In Chapter 5, I will identify and provide examples of the ways Meg and Shelly made the five content themes and their connections available to interns to learn.

CHAPTER 5
PEDAGOGICAL APPROACHES TO MAKE THE CONTENT OF GUIDING SCIENCE DISCUSSIONS AVAILABLE TO INTERNS

Chapter 4 introduced the content of guiding science classroom discussions in terms of the rationales and actions associated with each of five content themes. Having defined *what* was being taught in ED 528 about the practice of guiding science discussions, I will now explore *how* the practice was taught in ways that prepared interns to start enacting it. This chapter will address the second research question: *in what ways did the pedagogical approaches enacted in ED 528 make the content of guiding science discussions available to interns to learn?*

Identifying Pedagogical Approaches used in ED 528

Pedagogical approaches in ED 528 were identified through several iterations of coding. First, I coded the pedagogical approaches used across the eight course sessions by using a start-list of possible pedagogical approaches (see Appendix G for start-list codes). This first-level coding led to over sixty codes. After several iterations of coding, codes were grouped into seven pattern codes that described distinct pedagogical approaches used in the course (see Appendix J for details of moving from raw codes to themes). The seven categories fell into three *pedagogical approach themes* that captured similar ways of helping interns learn the practice of guiding science discussions (see Table 5.1).

Table 5.1
The seven pattern codes and three main pedagogical approach themes identified across course activities in ED 528.

Pattern codes for pedagogical approaches	Pedagogical approach themes
Modeling the role of elementary science teacher	**Creating images of inquiry-based elementary science discussions**
Showing videos of experienced and prospective teachers guiding discussions	
Targeted rehearsals of teacher talk	**Providing focused teaching experiences**
Peer walk-throughs of lesson plan	
Small-group teaching enactments in real elementary classrooms	
Joint problem-solving while planning science discussions	**Guiding analysis of science discussions**
Structured debriefing of science discussions	

Overview of the three pedagogical approach themes

Images of inquiry-based elementary science discussions were created for interns through *modeling* and *showing videos*. Throughout the course, Meg modeled the role of an elementary teacher during an inquiry-based science discussion, while the interns participated in the discussions in the role of elementary students. She modeled many aspects of guiding a discussion such as how to elicit students' prior knowledge, how to orient students' ideas to one another, how to use questions to guide thinking, how to press students to provide evidence for their statements, and how to guide students to ask questions that can be investigated in class. Interns also watched videos of experienced teachers and fellow interns guiding science discussions. This allowed them to have images of what to strive for and to see emerging aspects of the practice in their peers' attempts. Few interns had experienced inquiry-based science discussions as elementary students or had opportunities to observe experienced teachers enact these types of discussions. Therefore, seeing Meg model science discussions and videos of experienced and prospective teachers attempting to enact science discussions, provided images for interns to see what teachers may say and do when guiding an inquiry-based classroom discussion in science.

Focused teaching experiences provided opportunities for the interns to practice teaching moves with and without elementary students present. *Targeted rehearsals* were led by Meg and Shelly and involved the whole class brainstorming and practicing particular aspects of discussions, such as phrasing questions, or deciding how to respond to inaccurate student ideas. *Peer walk-throughs* of lesson plans, involved interns working with their peers to talk through and sometimes act out parts of their lesson plans to catch possible issues that might arise while teaching. *Small-group teaching enactments* allowed interns to practice guiding science discussions with small groups of elementary students, so they would be able to focus on listening and responding to student ideas without feeling overwhelmed with the responsibilities of teaching a whole class.

Because interns were just learning the practice of guiding science discussions, they needed to be guided carefully while planning for and debriefing practice. The interns were led through *joint problem-solving during planning* so they could begin to anticipate the logistical stumbling points (e.g., using materials or technology during the discussion) and conceptual misconceptions (e.g., inaccurate ideas students may share or terms that might be confusing) that could arise. So much occurred during teaching enactments with elementary students: from management issues to unexpected student comments and difficulties. *Structured debriefing* in the form of course activities and take-home message prompts helped interns constructively analyze the ways their teaching was or was not aligning with the images inquiry-based science discussions presented in the methods course.

In the remainder of this chapter, I will present each pedagogical approach theme (see Figure 5.1) individually and will use extended examples from ED 528 course activities to illustrate the pedagogical approaches making up each theme.

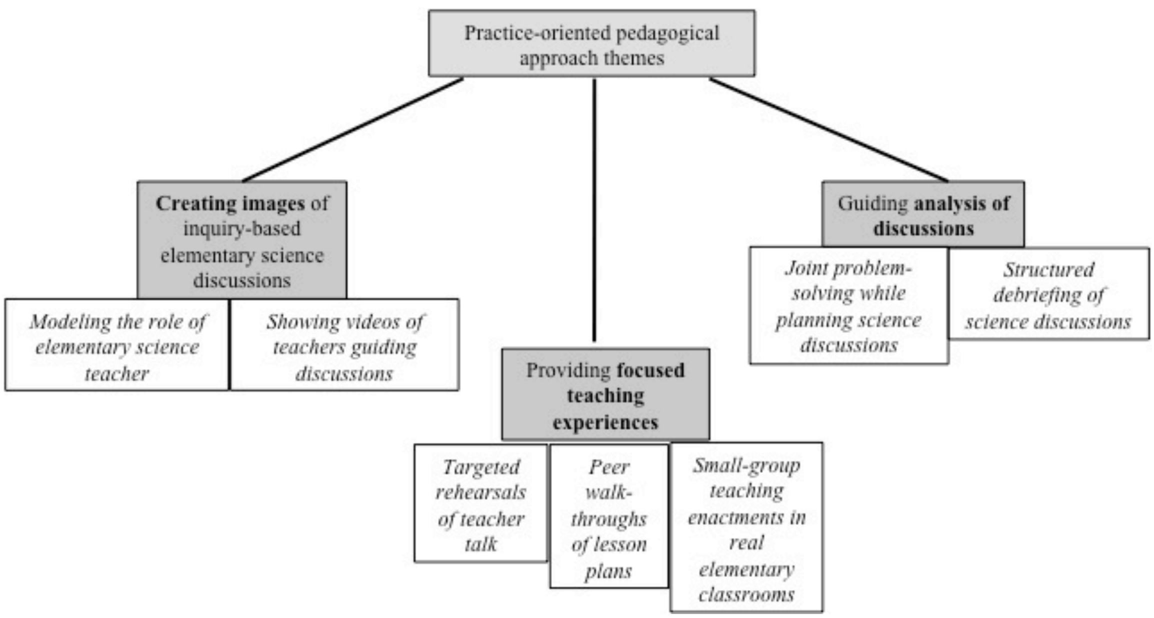

Figure 5.1. Nine pedagogical approaches were grouped into three pedagogical approach themes that made the content of guiding science discussions available to interns.

Images of Inquiry-Based Elementary Science Discussions

The following examples[18] outlined in Table 5.2, illustrate how pedagogical approaches such as modeling the role of teacher and showing videos of teaching

[18] Some of the transcript excerpts will be repeated from the last chapter, so the numbering of examples will refer back to and continue from Chapter 4.

characterize the pedagogical approach theme of using **images of inquiry-based elementary science discussions**.

Table 5.2
Examples of how creating images of inquiry-based elementary science discussions made the content of guiding science discussions available to interns

Images of inquiry-based elementary science discussions made the content of guiding science discussions available to interns…	**Example #**
By modeling the role of the elementary teacher during science discussions	1, 14, 16
By showing videos of experienced and prospective teachers guiding discussions	2, 17

Creating images by modeling the role of the elementary science teacher

While modeling was used throughout the course, Meg modeled the role of an elementary teacher extensively on the first day of ED 528. For the first half (approximately 3 hours) of the class meeting, she led the interns through the "launch" or opening activities of the PBIS unit (see Appendix D) and asked the interns to participate as elementary student learners. The first example of modeling was already introduced as Example 1 in Chapter 4.

Example 1: Eliciting student contributions during discussion. Meg elicited intern thinking about the big question for the unit: "how can you prevent good friends from getting sick?" In Example 1, Meg modeled giving students ownership and moving forward with their ideas. For example, Meg said: "…let's take what Lauren said about the temperature, and let's see if we can turn that into one of these questions that we would like to investigate," (Line 6).

In her actions leading to the dialogue in Example 1, Meg modeled several aspects of a science discussion that are important for the launch of an activity. First, she made sure all student contributions were recorded publicly, so students knew their ideas and questions would prompt further questions and investigations. In other words, the teacher's plans for the lesson were not the only driving force, the students' ideas and questions guided the discussion. Also, she directly credited students for the questions they contributed to the class instead of proposing the questions as her own. In these ways, modeling created images of several content themes (see Chapter 4).

The interns cited the modeling by Meg as a good way to experience the types of science discussions they would be enacting themselves in the future. In their take-home messages, interns were asked to compare what they experienced during the modeling to what they experienced in their own elementary classrooms or in their yearlong internship classrooms. Several interns described how the modeled classroom discussions gave the interns an image of how to give students ownership over their learning. For example, one intern shared how the prior knowledge and ideas the interns, acting as elementary students, brought with them to the classroom were valued and used as a starting-point for further exploration:

> I think the most different thing about class this morning was that we as students were expected to brainstorm what we already knew about a topic and then extend that thinking to develop our own questions about what we wanted to know more about. This question-generating process prompted us to use higher-order thinking and it also made us have more ownership of the content being discussed. (I22, THM1)

Another intern recognized that during the discussion, the interns' responses were valued and displayed for all students to view and discuss. In this way, the teacher was not telling students what they needed to know; instead, both students and teachers were actively involved in the discussion:

> ...Meg actually typed our responses and questions into her Power Point, acknowledging our thinking as important and interesting. I don't remember being allowed to ask so many questions without the teacher giving direct answers in elementary school either, which may've made us as young students less curious about science. (I23, THM1)

In addition to providing interns with images of how to encourage students to ask questions to investigate so they were motivated to explore the answers in class, Meg also modeled how to move away from "cookbook" lab activities, and give more responsibility to students for planning appropriate data collection and analysis for answering scientific questions. When guiding a discussion in Example 16, Meg modeled how to prompt the interns, acting as elementary students, to decide what data they needed to collect during an in-class simulation so they could answer a question about how disease spreads.

Example 16: Modeling how to discuss an in-class simulation and data collection plan. The interns engaged in a simulation to address a question that one of their classmates asked during an earlier discussion: "Can I be exposed to something and still not get sick?" Interns walked around the room with a beaker of unknown liquid. They poured some of the liquid from their own beaker into five classmates' beakers. After time was called, the interns observed that the liquid in some beakers was clear and some had turned pink. Pink water indicated the intern was "infected" with a communicable disease in the simulation. Meg asked the interns to brainstorm ways to identify the original carrier of the disease (i.e., the person who had the liquid with a chemical that made others' water pink). After struggling to remember who they had shared water with and in what order, the interns realized they had not collected the appropriate data to determine the original carrier. Meg guided a discussion where the interns were asked to design a data collection protocol that would allow them to gather systematic evidence to identify the initial carrier. The following dialogue occurred:

1 Meg: ...what I would like to do is use those extra cups, and come up with a plan of how we would collect good data so that as the goal at the end of doing this again with you all, we would be able to identify who is the one with the cup that's making everybody sick. So what would good data look like? What would data that could help us answer the question, whose the initial carrier, need to have? So if Karen and all the rest of our pink friends were going to give us really good data, what would that data have to have?

2 Intern A: The order of interactions.

3 Meg: Okay, so we have to have the order [writes it on the board], what else, it's the most obvious thing...

4 Intern B: All the people.

5 Meg: All the people, we have to have their names. So you have to have their names and you have to have the order. And how many interactions are you going have to have?

6 Intern B: Five.

7 Meg: Five. Okay, so now your task becomes more complicated. We're going to do this [collect data] again. But you can't just hope to remember all the people and all the order, you have to make notes. (Class 1, Part 4, 9:00)

Interns suggested they should do a better job of tracking the order of their interactions (Line 2) and the names of the people they interacted with (Line 4). They ran the simulation again with their data collection plan. This activity created an image of data collection different from the typical step-by-step lab protocols that are often used in science classrooms, where students are told what data to collect and how to collect them without knowing the reasoning for the steps or without being pushed to think about the procedure. After the data was collected, Meg prompted the interns to suggest a way to analyze the data so it could provide evidence for who was the initial carrier. The following excerpt illustrates how student contributions were used to make sense of the data:

8 Meg: Alright, this is a big group, a lot of pink, now we have to figure out who had the vial that made everybody sick? Where should we start?

9 Intern A: I think we should eliminate all those who everybody that they talked to isn't pink...so only people stand who everyone's pink...

10 Meg: Okay, this is what I think I am hearing Kristina say, you should, if you're standing, you should look at all the people on your list, and if you have someone on your list who is NOT pink, you should sit down. (Class 1, Part 4, 8:43)

The interns used the suggestion in Line 9 and continued to follow their peers' suggestions until the carrier was identified. In their take-home messages, interns brought up how the simulation activity introduced complicated science content in ways that actively engaged them with the concepts, instead of just being told the definition of a carrier by the teacher or listening to a lecture about how disease can spread:

> I was really interested in both of the hands-on activities, the passing of the little guy, as well as the water "disease" transfer. The activities were able to illustrate concepts that if were just explained verbally, might not sink in with most students. (I14, THM1)

Another intern highlighted the students' participation in deciding the steps of making sense of the simulation activity:

> I also don't remember doing interactive activities that often, such as the virus spreading simulation that we enacted today. It was very different that the students

were allowed to decide what steps to take to identify the virus carrier, instead of the teacher explaining the correct process. (I30, THM1)

By modeling how a teacher can guide her students to develop a data collection protocol and then can encourage them to discuss the collected data as a class to form explanations, Meg contributed to the interns' images of what learning science through inquiry entails. Specifically, they observed how a teacher can teach content (e.g., what is a carrier in a communicable disease) while engaging students in thinking and reasoning skills (e.g., data analysis and selecting evidence) that are at the core of scientific inquiry (National Research Council, 1996). Instead of just being told the answers by the teacher, the interns, acting as elementary students, engaged in hands-on simulations that allowed them to really understand the ideas. This created images of students asking questions and working with data to explain phenomena in the world around them. Meg also modeled how a teacher could encourage students to talk to each other during a discussion in the next example.

Example 10: Encouraging talk among students. In Example 10 from Chapter 4, Meg modeled how to orient students to each other's ideas and how to encourage students to talk to each other instead of always responding to the teacher. For example, in Line 3, she stated: "…it sounds to me that you are taking Rob's position a little bit?" In Line 5, she asked the whole class to comment on classmates' contributions in the discussion: "What do you all think about Ian [Intern A] and Rob's ideas?" Two interns, acting as elementary students, then commented on Ian and Rob's ideas and continued the conversation without the teacher calling on them. Meg's modeling during this discussion illustrated ways to act as a facilitator of students' ideas so they could talk to each other instead of simply being told information from the teacher. In this way, they created images for interns of student-teacher interactions that might be different from the more "teacher as teller" approaches they might have experienced more frequently in their school experiences.

In addition to having images that were created by participating in discussions as students and watching Meg model science teaching live in their methods sessions, the interns also experienced images by watching videos of classroom discussions.

Creating images by watching videos of experienced and prospective teachers guiding discussions

In order to provide interns with images of what a fully enacted discussion may look like with real elementary students instead of with their peers during modeling, Meg selected a video-clip of a third grade science discussion about the behavior of magnets. In Example 2 from Chapter 4, interns watched and discussed a video-clip (see Figure 4.4 for the dialogue during the video-clip).

Example 2: Giving students ownership of their ideas during discussion.

Meg asked interns to consider the following questions when watching the video-clips of the science discussion: "How does the classroom teacher get the students involved in this science discussion? What are the things that she does?" The interns brought up several observations about the questions used and comments made by the teachers during the video. For example, they observed how the teacher gave Mitchell ownership for his idea by providing him with the materials (magnet and paperclips) to share his finding with his classmates. Also, after Mitchell shared his finding, other students tried to explain why he may have observed the paperclips staying linked even after the magnet was removed. The interns also observed several features of the classroom in the video (e.g., seating arrangement, "wonderings" board) and the use of language that created a classroom culture for guiding discussions (see Example 12). By watching the video, the interns had an image of how young elementary students, in third grade, were able to engage in discussion about science content (i.e., magnets). In this way, the video created an image of what is possible if teachers create a classroom culture that supports students talking to each other about their developing ideas about content.

Example 17: Viewing peers' videos of discussions as images. Another way videos were used to provide images of the practice of guiding classroom discussions was by encouraging interns to share videos of their teaching experiences with each other after completing a video analysis assignment. The assignment required interns to choose a short video clip from their launch discussion, where they had gathered students' prior knowledge and questions about the unit they were starting. Next, the interns had to select another video clip from a later discussion with the students that connected to something that occurred in the launch. For example, if interns noticed that students thought that rocks were all made of one thing in the launch, they could pick a video clip from the next lesson where students started to discover that there are actually several different components to a rock.

Meg asked interns to share their video selections with their peers in their own teaching group[19] and with those in other teaching groups who were teaching the other FOSS unit (moon phases or earth materials). When watching videos of the members of their own teaching group, interns were able to carefully consider how students were

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[19] Teaching groups were three or four interns that were assigned to guide discussions in the same elementary school classroom during ED 528 (see Chapter 3 for details).

thinking about the content and see the ways their peers responded to different content understandings as they guided the students towards the learning goals. When watching video clips from peers teaching a different unit, the interns were able to focus less on science content, and spend more time identifying the general strengths and weaknesses in the ways their peers phrased questions or responded to student ideas that were surfacing during the discussion.

In their take-home messages, interns identified how sharing and discussing videos of each other's developing skills at guiding discussions helped them think about how they could improve themselves, but also helped them find comfort seeing that others were struggling with similar issues when developing this difficult teaching practice. For one intern, watching the videos gave her the opportunity to hear different student responses to similar questions that she used in her launch, thereby exposing her to a range of elementary student ideas about moon phases:

> What I was most surprised about were all of the diverse responses that the students in the different groups had. Some students had some clear ideas and others were very confused. It was beneficial to hear how other students responded to the questions that we all came up with. It gave me better insight as to what the other students were thinking. (I25, THM5)

Another intern found that watching the video clips helped her better appreciate the importance of starting with students' prior knowledge, and having them actively take part in the sense-making process so they move from initial ideas that may be inaccurate to more accurate understandings over time:

> Watching the students, in the launches especially, it was really interesting how students were so *sure* rocks couldn't break until a rock actually broke. They were *sure* the Sun was *between* the Earth and the Moon until they were sure it wasn't. So interesting to watch the students process and try to use information and make sense of it all. In knowing that, it was just reconfirmed to me again that the students *do* have some kind of understanding. It may not be the correct understanding but it IS a formal place to begin the journey to accurate understanding. They [the students] are always coming from somewhere in their ideas. It's never really just a blank slate more like just a hidden one you have to tap. (Haley, THM5)

Another intern was able to observe the ways language was used as her peer explained a model to elementary students:

> The most interesting thing I learned while watching my peer's videos was some of the language that was used. I especially liked Kacey's [a fellow intern's] language about how with a model, we are taking what is outside to the inside and she did a little discussion about the similarities and differences between the model and the real world. I think this was done well. (I4, THM5)

Finally, several interns mentioned that seeing others struggle through similar stumbling blocks was reassuring but also a great opportunity for the interns to reflect on what they did and said differently, and how that impacted the outcome of their lesson:

> I was somewhat relieved to see that most of my peers struggled with similar issues to those my group did. It ended up being really interesting because we were able to discuss little differences in the way we went about our lessons and

> the effects that they had on the success of our lesson. We were also able to express some of our opinions in regards to the pros and cons of using certain models. (I41, THM5)

In this way, the videos provided common images of teaching that interns could use to address common challenges together:

> I learned that many of the same things that were challenging for me were also challenging for the other groups and other members of my group. It was really helpful to talk through these things and come to some interesting conclusions. (I39, THM5)

It is important to point out that just because images of reform-based teaching were presented through modeling or videos, this did not mean the interns would always interpret the images in the ways that were intended. Therefore, Meg never simply modeled a set of inquiry-based teaching practices or showed videos in class and left the interns to make sense of the interactions on their own. For example, the interns spent several hours debriefing Meg's modeling to reflect on what decisions Meg made as the teacher and what implications those choices had for the interns acting as elementary students (see debriefing examples 26-27).

Focused Teaching Experiences

The following examples (see Table 5.3) illustrate how pedagogical approaches such as engaging interns in targeted rehearsals of teacher talk, providing time for peer walk-throughs of lesson plans, and creating opportunities for teaching enactments with small-groups of elementary students are all grouped under the theme of using **focused**

teaching experiences to make the content of guiding science discussions available to interns.

Table 5.3
Summary of ways focused teaching experiences made the content of guiding science discussions available to interns

Focused teaching experiences made the content of guiding science discussions available to interns...	Example #
Through targeted rehearsals of teacher talk	Examples 18-19
Through peer walk-throughs of lesson plans for discussions	Examples 20-22
Through small-group teaching enactments in real elementary classrooms	Examples 15, 23-25

Providing focused teaching experiences through targeted rehearsals of teacher talk

During targeted rehearsals, Meg presented scenarios that allowed the interns to practice how they would interact with students during a science discussion. She chose specific challenges that could arise during discussions, and asked the interns to work together to consider how they would respond to students. As interns offered ideas, Meg provided feedback and asked interns to continue to strengthen their responses.

Example 18: Targeted rehearsal of how to phrase better questions in discussions. During targeted rehearsals, Meg and Shelly focused on phrasing questions to invite interns to do the cognitive work and to breakdown traditional teacher-student interactions. After observing the interns' teaching experiences in the elementary schools, Meg and Shelly brought up questions that they observed the interns using in their teaching experiences and had interns rehearse ways to improve them:

1 Meg: This is the most common question I think early novice teachers, such as yourselves, ask in classrooms. It is also unfortunately a common question for experienced teachers to ask in the classroom. And that question is, "Does everyone understand?" So how could you restate "Does everyone understand"

into a question for your unit that you are doing right now, that moves some of that thinking back to the kids?

2 Intern A: Maybe who can summarize what we just talked about?

3 Meg: Okay, so Erin's idea is "who can summarize what we just talked about?" I really like that she started with "who can." When you start questions like that then it assumes that you expect an answer. The alternative to that is, "can anyone" -- the difference in those two questions sounds like words, but can anyone summarize what she just said, what's the answer to that?

4 Interns (in unison): Yes or No.

5 Meg: Yes or no, it also allows kids to just sit there. *Who can* [italics added], really gets kids thinking about, well maybe one of us better answer. Go ahead.
Intern B: I'd like to add to that, "let's all think about how we would answer that, get everyone's brain churning." (Session 4, part 2, 1:48)

Intern reflections after class and after teaching provided evidence for the ways targeted rehearsals created opportunities-to-learn the range of teacher talk that could include all students in a discussion, breakdown traditional teacher-student roles, and put the cognitive work on the students (see content themes in Chapter 4). One intern wrote the following reflection about what she took away from class:

> We discussed ways to continue sharpening "teacher language" that is inclusive of the students and focuses on them and their ideas and not on the teacher and his or her desires. The biggest way we worked on it was to focus on NOT using yes or no questions in our discussions and asking questions that were not "I" or "me" focusing on pleasing the teacher but more on the search for information and understanding of content with all students and the teacher included but not specifically FOR the teacher for the teacher's sake. This was a guiding focus in class and in the classroom as I used language to share with and solicit ideas from the students. (I8, THM 6)

In her next experience teaching a discussion, Intern 8 attempted to draw on the ways they had practiced using language in the methods course during her teaching experience in the elementary classroom. In her post-teaching reflection, she described this effort:

> I know I used both the "I" and the "we" at different times in the discussion. I tried to remember to keep the "we" in the front of my mind but sometimes it gets lost. When the students were drawing what was in their evaporation dish, I told them I needed them to be as detailed as they could with their drawings and descriptions so I could see and understand better what they were thinking. I could have said something like, "being detailed in drawings and descriptions is important for many reasons...for you to remember what you think and have a record and to have an account to share with others about your thoughts. (Intern 8, THM 6)

Her description of how she was able to take the ideas from the methods class, apply them while teaching, and make sense of her teaching afterwards, illustrates one way a focus on a practice like guiding science discussions paired with practice-based pedagogical approaches helped interns bridge the gap between theory and practice, and university coursework and fieldwork.

Example 19: Targeted rehearsal of responding to student misconceptions while using moon phases model. In a rehearsal that began in response to an interns' question about how to come up with follow-up questions, Meg presented a scenario in which a pair of students were modeling moon phases (some of the content themes in this course activity were depicted in Figure 4.7). She asked the interns to rehearse how to respond if the students modeled the moon phase incorrectly. In the scenario, two hypothetical students, that Meg called Sam and Bridgette, were trying to explain why they labeled a particular phase as "full moon" in their journals. They were supposed to use model materials (ball on stick was the moon, light source was the sun, student's head was the earth) to explain the phase. Meg told interns to think about what they would do next if the students were actually modeling new moon when they thought they were modeling full moon. The following dialogue between the interns and Meg allowed the interns to practice many aspects of addressing student ideas during discussion:

1 Meg: ...Let's say, *this* [italics added] is what the kids modeled [she turns around to face the light source from the windows so she is modeling new moon instead of full moon]… what phase of the moon is this? …this is new moon. You wouldn't see anything because the lit half of the moon is actually away from you. So this is new moon. Okay? So let's say they [Sam and Bridgette] model it this way. Now what do I do? (Session 6, part 1, 40:15)

The interns rehearsed possible ways of phrasing a follow-up question to the students' inaccurate use of the model:

2 Intern A: Why do you think that?

3 Intern B: Can you explain what you are doing?

4 Meg: "No I can't cause I don't know". So where are you going next? (Session 6, part 1, 41:33)

Meg responded to the interns' suggestions by pointing out that if students are confused by the model and have the inaccurate answer, they may not be able to provide a good explanation for why they are modeling it in a particular way. Therefore, she responded to the interns' suggestion of asking, "why do you think that" or "can you explain what you are doing," with "no I can't cause I don't know!" (Line 4). This pushed interns to think of how they would respond when they received a dead-end response from students who were confused or frustrated. Another intern offered another possible question they could ask the student to help the students explain what they were modeling:

5 Intern A: Where is the light of the sun? Describing this model, show me in the model where the light of the sun is shining on the moon?” and then they can start, when they see that [that they are using the model incorrectly] they can start self correcting.

6 Meg: Okay. So, Zach said, “show me where the light from the sun is.” Something like that? Tweak it just a little bit.

7 Intern B: Tell us...

8 Intern C: Tell the group... (Session 6, part 1, 41:45)

The interns drew on their earlier discussion about phrasing questions to encourage students to talk to each other and suggested changing "tell me" to “tell *us.”* In this way, they were inviting a response that was not just for the teacher.

> Meg: Okay. Or, tell us, please describe...first thing you need to do to debunk this model problem is where is the sun? We need to ask a question, where is the sun? This is really hard because what you don’t want to do is make it so that there is total embarrassment because they totally messed it up and they’re like four weeks into this. But again, you have to drive the car. You’re the navigator here so we’ve got to get to the right answers. Alright? (Session 6, part 1, 42:12)

Meg pushed the interns to think about how to address Sam and Bridgette’s confusion about modeling full moon, and how to guide both the class and Sam and Bridgette’s thinking towards an accurate understanding. At the same time, she reminds interns to guide their thinking without embarrassing the students (Sam and Bridgette) for sharing their thinking. This scenario presented a difficult aspect of guiding science classroom discussions, as it was tempting to simply say, "no, that is incorrect," and to reveal the "correct" answer. Meg continued to model how she could explain the new moon to the students and then asked the interns to rehearse what to do next:

9 Meg: This would be the new moon, right? When the sun is shining and all the light is reflecting, now hear me explaining it back in scientific words. I'm trying to help them with the rehearsal of what the scientific words will sound like. When the sun is shining on this side of the moon, all the light bounces back that way away from us. So Sam and Bridgette are actually showing us the new moon. Alright? Now how do Sam and Bridgette feel right now? Do they feel okay?

10 Intern B: You could always ask them, would you like to revise your model?

11 Meg: So, very good, Ali, so: "Sam and Bridgette, if this is the new moon that you showed us, what would you have to do to change it up to show the full moon?" So maybe now that we've helped them see, "oh wait we messed up, we can fix it". (Session, part 1, 42:57)

An intern suggested asking the students to revise their model now that they were aware that they were actually modeling the new moon instead of the full moon (Line 10). Meg pushed interns further to consider how to move the discussion along if the students still did not know how to fix their model:

12 Meg: [What if] we're still stumped? What would I do next? I'm the driver of the car. I need to get this to the right place. What would I do next? Sam and Bridgette are stumped.

13 Intern A: Ask for any other students that could help them.

14 Meg: So get another set of students up there. I'm stepping back out of the picture, right? I've led them to the place where understanding this is not right, now I'm going to step back a little bit and see if they can figure out if they can fix it. I'm not saying, so this is how you need to fix it...Maybe we can ask for support, some input from the other group, from the rest of the group. What else could you do?

15 Intern B: Could you ask them what side of the moon the sun needs to shine on?

16 Meg: Good idea. If we [Sam and Bridgette] still are stumped, [the teacher could ask], "what side of the moon does the sun need to shine on so that you would see the full moon?" Well, it needs to shine on the side we're looking at. So how would we see that side? It needs to fully shine on that side. We're sort of scaffolding these ideas through the questions. Okay? (Session 6, part 1, 44:50)

Interns suggested asking classmates to help Sam and Bridgette if they were still struggling to model the full moon (Line 13). Meg emphasized that this teaching move allowed her to step back and allow the students to do the thinking (Line 14). She was still not providing the students with the right answer because she wanted them to be able to take the ideas about new moon that they had discussed and try to model full moon themselves. In Line 15, an intern suggested that asking the students to think about where the light would shine might help them realize that they were positioning the sun, earth and moon in the incorrect order.

In this targeted rehearsal, hypothetical students, Sam and Bridgette, used the moon phase model inaccurately to illustrate the full moon. In developing the scenario and responding to interns' ideas with possible student responses, Meg created several opportunities for the interns to rehearse follow-up decisions they might need to make in response to student ideas during a science discussion. Some of the teacher actions they worked on with this scenario included phrasing questions to gain information about student thinking, thinking of ways to prompt students to explain their understanding so misconceptions could be surfaced, and using language so no student felt ashamed for contributing their ideas to their peers.

Providing focused teaching experiences through peer walk-throughs of lesson plans for classroom discussions

During peer walk-throughs, teaching groups discussed their lesson plans for classroom discussions and anticipated any possible stumbling points that could arise. They alternated between discussing their plans and taking turns acting as teachers or students in their small teaching groups.

Example 20. Peer walk-through of mock rock lesson. The goal of the second discussion the interns guided was to connect students' initial ideas from the launch discussion to the investigation the students were going to complete that day: breaking apart a mock rock to model what they would find if they broke apart a real rock. As a group of interns were walking through their lesson plan for this mock rock lesson, Intern A was acting as the teacher and the other interns were responding as students or pausing the walk-through to discuss possible changes.

While reading from his lesson plan, Intern A was stopped by his peers, as they felt that they should think about a way to have the students think about the procedure for breaking apart the mock rocks instead of providing it for the students. The interns were drawing on ideas from course discussions about giving ownership of learning to students, having the students do the cognitive work, as well as the images of Meg modeling how to have students come up with a data collection plan:

1 Intern A: Today we are going to use these models of rocks, these mock rocks, as a way of exploring and observing things about rocks. So what we are going to do is you are going to be split into pairs, and each pair is going to get one of these mock rocks. And you're going to have to break it in half so you each have a piece to work on. And you're going to take it apart. And how scientists examine rocks, is they have picks, you might have seen a pick before...

2 Intern B: Can I pause? [breaks from acting as student and initiates discussion among interns] Do we want to ask them, I mean, it's up to you, do we want to ask them for ways of how to figure out....

3 Intern A: Oh first? Ways of finding out what?

4 Intern B: Ways of finding out more about rocks...

5 Intern C: Instead of giving them the procedure, trying to get them to come up with the procedure. Because someone will say "scratch it," I mean…it's a personal thing...

The teaching group suggested putting the cognitive work on the students by asking them to come up with a way to investigate more about the mock rock. This was similar to when Meg modeled asking the interns to come up for a procedure for collecting data in their water sharing simulation (see Example 16). Intern A tried to use the group's suggestion as he continued acting as the teacher while talking through lesson plan:

6 Intern A: Yeah, I mean I could ask [he switches back to acting like the teacher], "so does anyone have any ideas about how we could find out more about these mock rocks? What could we do to find out?"

7 Intern C: Rub them together.

8 Intern A: Okay, rub them together. How would that help us figure out more about them?

9 Intern C: It could tell us how tough they are or how weak they are...

10 Intern A: You could see if they fell apart when you rubbed them together. Any other ideas, or what does someone think of Intern C's idea? (Session 4, Part 1, 2:25)

The interns continued walking through the lesson, and Intern A continued to elicit student ideas about a possible way to find out more about mock rocks. He also tried to orient students to each other's ideas as well (Line 10). By engaging in walk-throughs, interns were able to talk through their questions and responses to possible student contributions while having the ability to stop and improve their lesson plans as needed. Even without the guidance of Meg or Shelly like that provided in targeted rehearsals, the interns were able to draw on each other's ideas for connecting what they were learning in the methods course to their preparation for teaching.

Example 21: Peer walk-through with "fishing-for-a-response" questioning.

During their walk-through, the focal group practiced questions they would ask to help students make sense of what they found when they broke apart their mock rocks.

The goal was for students to observe that rocks were made of different things, and later they would learn that those parts that make-up rocks are called minerals. However, this term was not introduced yet. The following example from a walk-through illustrates how the group noticed that while Haley was practicing the questions, she was “fishing" for a particular student answer instead of letting the student responses guide the next question. Her teaching group members helped her consider alternative ways to guide students to the idea she was fishing for without waiting for the students to come up with the exact idea. In the following example, Haley is acting as the teacher and her peers are acting as elementary students:

1 Haley: If you were going to think, someone has never heard of a rock before, and they asked you, "what's a rock," and you had to help them understand, based on your investigation with the mock rock, what kind of words might you use?" You're the teacher now trying to help someone understand.

2 John: It's hard but you can break it up.

3 Haley: Okay. What could we add?

4 Melanie: It's made of different things.

5 Haley: Okay, it's hard and you can break it apart and it's made of different things. What might some of those things be?

6 Melanie: Sand

7 Haley: …Okay, so what do you think if we said, rocks are things that, uh, can be broken apart and are made of many...different things. If we want to use a different word besides *things*, because things is used a lot, if we want to be more scientific in our words, what other word can we use besides things? Made up of many different....

8 Vanessa: parts...

9 Haley: Yeah, parts okay...

10 John: types of rocks...

11 Haley: Types of rocks, but if we are defining a rock, would it be hard to use the word rock if we are trying to explain a rock.

12 John: Yeah, I guess so...

13 Haley: So maybe we could think of a different word...if something is made of a lot of parts, what do we call those parts?

14 Vanessa: Pieces.

15 John: Made of stuff like sand and red...(Session 4, part 2, 4:10)

At this point, Vanessa stops the walk-through because she notices that the discussion is not moving along and Haley seems to be searching for a particular student response that her questions are not leading the students to provide. Vanessa brings up the idea of a frog and toad question that she learned about in a previous class:

16 Vanessa: Wait—so out of student role for a moment...what are you trying to get to when you say "part"...

17 Haley: I'm wondering if they can say ingredient, I probably won't spend so much time on it.

18 Vanessa: Yeah, I feel like that could be one of those frog and toad questions...

19 Haley: Frog and toad?

20 Vanessa: Did they [referring to another teacher educator] use the example with you when a teacher is looking for a specific answer and asking a question that sounds open-ended...

21 Haley: Yeah, that's good. I'd say, pieces, or maybe we could be even more specific and say, the things that make up a rock, like ingredients, or maybe they'll say ingredients, I don't know...

Haley was hoping for her teaching group interns, who were acting as elementary students, to use the word "ingredients" to describe the components of a rock. Vanessa suggested that she move on instead of waiting for that particular term. John suggested why that particular term may or may not be worth using:

22 John: But I don't think that “ingredients” is that important, that critical of a word, it can be “pieces”.

23 Haley: No, I think it can too, except ingredients has a different role than piece or part because it says that...

24 Vanessa: It makes it up…

25 Haley: ..it makes it up. Instead of a piece, is like it's broken apart so there are pieces.

Haley justified the reason for hoping to use the word ingredient. She felt that ingredient would imply that there are different things that make up a rock, which students would later learn were called minerals. Pieces, on the other hand, just implied a part that broke off of a rock, not necessarily something that is different from a rock, or is a component that makes up a rock. Vanessa suggested providing the term when the students get close enough to the idea of an ingredient, instead of spending time waiting for students to come up with the term:

26 Vanessa: Maybe if they get to the point where they are saying something that makes it up, you can say, that's called an ingredient...

27 Haley: Yeah, so re-phrase...

28 Vanessa: Or you can say, think about when you're working with a recipe, have you ever made cookies...

29 Haley: I was debating in my head whether to say that or not...

30 Vanessa: I think that would be a good way for them to think about it...you don't have to say the rock is like a cookie, you can just say, for example, if you are making a cookie, you have lots of ingredients in a recipe and those all come together to make a cookie...

31 Haley: That was exactly what I was thinking and I was fishing around... (Session 4, part 2, 6:26)

Together, the teaching group helped Haley guide students towards the idea of a rock being made of different ingredients without spending too much time "fishing" for the students to say the exact word she was thinking. They decided that the term was not as important as the concept behind it, and that she should use an analogy to help students understand the concept more than spending time on having them produce a particular term (Line 30).

Example 22: Peer walk-through debating use of cookies as analogy in discussion. During another walk-through of a discussion of students' findings from the mock rock investigation, the interns brainstormed other ways to make the content ideas accessible to the students. First, they discussed whether it was appropriate or not to compare rocks to chocolate chip cookies by considered what ideas that analogy may bring up for students:

1 John: Maybe we could ask them, instead of using these mock rocks, could I use chocolate chip cookies to simulate a rock?

2 Haley: Do we want to use chocolate chip cookies?

3 John: We can use any kind of cookie...

4 Vanessa: That might get them off track...

5 Haley: Do we want to talk about cookies is my question.

6 John: It might be engaging, I don't know. It's just an idea.

7 Haley: What's the answer?

8 John: Ya, because there are different ingredients--there are chocolate chips, flour, sugar, salt

9 Haley: Some you can see, some you cannot.

10 Vanessa: You can't eat rocks! [imitating a student voice]

11 Haley: Yeah, but that's not really the point. They are not exactly the same thing, but idea of parts.

When debating whether or not to use the analogy of cookies when explaining rocks and minerals, Haley asked her fellow teaching group members to think about how the cookie is like a rock (Line 7). John described the similarities, in that cookies are also made of different ingredients, just as rocks are made of different minerals (Line 8). Haley added that ingredients in cookies, some are visible to the naked eye and some are not. Similarly, some minerals parts of the mock rocks students were observing were visible to the naked eye, such as gravel pieces and sand, while others, such as salt crystals, only appeared after evaporating the water away from the leftover rock materials that did not separate out in water. Vanessa brought up a possible student concern with the analogy in Line 10, where she imitated a student pointing out that rocks were not edible, however, Haley felt that would not be an issue (Line 11). At the end of their discussion, the interns decided to use the analogy to provide another engaging way to help students makes sense of the idea of a rock beign made of many different parts called minerals.

12 Vanessa: I like it.

13 Haley: I mean the unit talks about cookies.

14 Vanessa: I mean if you are looking for a way to engage them and you feel like you're losing them, maybe that [the cookie analogy] would be another way to bring them back.

15 John: And that's like a different way, this kind of touches on the same idea as that one question that you had. (Class 4, morning, 6:28)

Overall, the walk-throughs supported interns in preparing for their enactments with real students. Specifically, the walk-throughs allowed interns to think through their lesson plans with peer support:

> I found leading a discussion difficult because you have to be able to think on your feet as well depending on what the students responses are. But, being prepared also helps with this part as you need to be able to anticipate what students are going to say. I found working with three other people helpful because they provided perspectives I had not thought of during my preparation (I19, THM4)

They also helped interns anticipate possible stumbling points in their plans:

> Rehearsing for a lesson can be exhausting and frustrating, but it ultimately can be the difference between a confident, well-run presentation and a disorganized, well-intentioned one (I40, THM4)

Finally, the walk-throughs offered opportunities for interns to practice the language they might use and different ways of talking about content that might be unfamiliar to them as well:

> Rehearsal [walk-through] is a really big help in preparing my words and anticipating student strategies for learning. Creating pointed questions and guidelines are important but there will ALWAYS be the unknown factor variables that come up and you need to decide before hand what kind of reaction you will have in regards to them. (Haley, THM4)

Both targeted rehearsals and peer walk-throughs provided opportunities for interns to practice guiding science discussions with the teacher educator or fellow peers taking the role of the students. In the following set of focused teaching experiences, the interns began interacting with elementary students in actual classrooms.

Small-group teaching enactments with elementary students

During small-group teaching enactments, the interns had opportunities to practice guiding science discussions in real elementary classroom settings. The interns guided discussions that helped third and fourth grade students make sense of the activities they were completing with their classroom teachers during one of two FOSS units (moon phases or rocks and minerals). Each intern taught the launch discussion for the unit with a group of 4-5 students. Then they took turns teaching half a class for the remaining four discussions (see Table 5.4).

Table 5.4
The five types of discussions and division of teaching responsibilities during small-group enactments.

Type of Discussion	Description	Who was teaching
Launch Discussion	The goal of the launch discussion was to elicit students' prior knowledge and introduce the big question for the unit (e.g., moon phases or rocks and minerals)	Each intern guided a small group of 4-5 students.
Discussion of questions to investigate	The goal of this discussion was to help students discuss their initial ideas and questions about the unit so they could prepare to collect data in an in-class investigation.	Interns 1 and 3 guided the discussion with half of the class (10-12 students). Their partners, interns 2 and 4 provided teaching support.
Discussion of data collected during investigation	The goal of this discussion was to help students make sense of the data they collected (e.g., what do the pieces of the rock tell you about what a rock is made of, or what does the model of moon phases tell you about why it looks like the moon is changing shape)	Interns 2 and 4 guided the discussion with half of the class (10-12 students). Their partners, interns 1 and 3 provided teaching support.
Discussion of data collected during an	The goal of this discussion was to help students start to re-visit and refine their ideas about the big unit question with	Interns 1 and 3 guided the discussion with half of the class (10-12

investigation	further discussion of new data collected (e.g., what does an investigation of crystals tell us about minerals? What is the relationship of rocks and minerals)	students). Their partners, interns 2 and 4 provided teaching support.
Discussion of students' explanations	The goal of this last discussion was to push students to provide evidence for their explanations that addressed the big question for the unit. (e.g., students explain how the position of the Earth, moon, and sun determines the phases of the moon or students explain the difference between rocks and minerals)	Interns 2 and 4 guided the discussion with half of the class (10-12 students). Their partners, interns 1 and 3 provided teaching support.

Note: In this table, the interns are labeled 1-4 to represent any four interns in a teaching group and how pairs, 1 and 3, and 2 and 4 would generally teach together and then switch with 3 and 4.

Example 23. Teaching enactment: eliciting student ideas in a launch discussion. The goal of the launch discussion was to introduce the students to the big question for the unit (e.g., what makes a rock a rock?), to elicit students' prior knowledge about the topic being studied, and to raise interest and questions for further investigation in later lessons. Additionally, the goal was to make students' ideas available for all to hear and think about so later investigations could help them refine those ideas to more accurate ones over time. In the following example from a launch discussion, Melanie provided students with a mystery sample of earth material and asked them to share whether or not they thought it was a rock. As discussed in the methods course, the launch was not the place to evaluate student ideas; instead, it was the time to collect student ideas and make their thinking public to each other and the teacher. Below is an example of Melanie's first attempts to translate the ideas about a launch from Sessions 1 and 2, to her teaching experience with a small-group of students during Session 3:

1 Melanie: Okay, I saw a lot of good work going on here. So look in tray A, it is a rock?

2 S1[20]: No.

3 S2: Yes.

4 Melanie: Why? Okay, the people that say yes for A, raise your hand. Okay, Becka, can you tell me why?

5 S1: Because it feels like a rock because it's hard.

6 Melanie: Feels like a rock...[Melanie is writing down student ideas on a piece of paper]

7 S2: But it could be a stone because stones are shiny.

8 S1: Well it doesn't look shiny, it looks dirty!

9 Melanie: Naya, why is it a rock?

10 S3: I think it's a rock because it's basically like sometimes rocks are like that and stone are something like that and crystals. And um...same thing as Bethenny, they are hard too..

11 Melanie : Hard, okay, Damion why do you think it is a rock?

12 S4: It's shiny. Look at it, it's shiny. (Melanie, Class 3 enactment, 8:33)

In the interactions above, Melanie repeated a student's idea as she recorded it, or repeated the idea and then called on another student (Lines 6, 11). In this early attempt at guiding a science discussion, she tried to elicit several students' contributions, but the dialogue still moved mainly from teacher to student; she did not try to have students build off of or comment on each other's ideas. In John's launch discussion, he made some initial attempts to orient student ideas to one another as he elicited student contributions:

13 John: Okay, so now, scientists, I need you to look up here, so what did you think, which one of these were rocks? Which ones do you think were rocks [referring to a bin of rocks and minerals that were labeled A-H]?

14 S1: E

[20] Elementary students in the Garden City classrooms will be labeled as S1, S2, S3 and so on, in the order that they speak in the transcript.

15 John: E is a rock, why do you think that E is a rock?

16 S2: It's shape.

17 John: Will you tell me more what's the shape of a rock?

18 S2: [inaudible; student mentions something about box shape]

19 John: Okay, what does everybody think about that, do you think that rocks are like a box shape or do you think they can be different shapes?

In Line 17, John asks the student explain his idea about the shape of the rock in more detail. He then asks the rest of the class to respond to their peer's contribution (Line 19). Two students offer their ideas about a rock's shape:

20 S3: They can be any shape.

21 S4: They can be different shapes but most rocks are round...plus,

22 John: Alright, we all need to listen to Daphne [S4] right now, she's talking...

23 S4: these might be rocks but (inaudible)...so these are like salt.
[several minutes later....]

24 John: And are rocks made of a bunch of stuff or just one thing?
25 S3: One thing.

26 S4: They can be made up of lots of stuff.

27 John: Okay, so Daphne [S4] says that rocks can be made of a lot of stuff, what do you think of that?

John tried to emphasize the culture of students listening to each other's ideas by asking the students to listen to Daphne's response in Line 22. He then decided to focus on Daphne's idea of rocks being made up of "lots of stuff" in Line 26, by asking students what they thought abou ther idea. In this way, he was trying to steer the disscussion towards the idea of rocks being made of more than one material.

28 S2: Salt, (inaudible), some of them are on the sidewalk...

29 John: Okay, so now we have a bunch of things that we think about rocks. And it's okay if you don't agree with everything on the list. (John, Class 3 enactment, 4:40 and 3:18)

Throughout this discussion, John used language like, “we all need to listen,” and “what does everybody think,” to try to include more students in the discussion and to breakdown dialogue between him and a single student only. He tried to ask follow-up questions to students to have them explain why they thought particular materials were rocks or not, and he also tried to have students listen to and comment on each other's ideas so the conversation included everyone in the small group. He also indicated that while he was writing all the ideas down, each student did not have to agree with everything on the list; in this way, he was valuing each individual child's contributions and not establishing the accuracy of any responses yet.

Managing student talk about science content during discussions was difficult, especially since the interns were visiting in the second semester of the school year and were not there at the start to set-up the appropriate classroom culture to support discussions. Interns discussed this tension in their take-home messages:

> One student started talking to his neighbor while one of the other students was talking. Sometimes I'm not sure whether to interrupt the student talking in order to re-focus the other students. I do not want to cut off one student's thought because others are misbehaving, but I also do not want the others to lose out on the discussion or take away from their classmates' concentration. (I4, THM3)

In addition to managing student talk, interns also had to be careful of their teacher talk, and be cautious of how much “telling” they were doing versus “guiding” during classroom discussions.

The idea of a launch that only collected prior knowledge and developing questions without just telling students the content they needed to know was also new and challenging for interns. They struggled to decide how much to "give away" and which ideas to make into questions for later investigations: "I was also uncertain about the way to follow up on responses because I didn't want to get too deep into content," (I36, THM3).

Example 24: Teaching enactment: bringing up vocabulary too early in a launch discussion. Many interns faced the tension of trying to explain too much in the launch discussion instead of gathering students' initial ideas and questions to use for later discussions. In the following example, John confused students by bringing up the name of a mineral, calcite, before the students had even learned what a rock or mineral was; the result was a confusing exchange between teacher and student:

1 John: ...What is a rock made of? What do you think Ben?

2 S1: Sometimes they are bumpy.

3 John: So to find out what a rock is, we need to figure out what it's made of. This is not a rock...this is calcite [John tells them directly even though students were not going to do an investigation to discover minerals like calcite until the fourth discussion].

4 S2: What is calcite?

5 John: That is calcite [points to the calcite sample].

6 S3: What's it made of?

7 John: It's made of calcite.

At this point in the interaction, John was flustered, as he was not prepared to explain what calcite was. The students were now curious, but had not learned enough about rocks and minerals to understand the term.

8 S1: I have no idea what that means.

9 S3: What's calcite?

10 John: That's calcite. It's what we call a mineral [in a lower tone]

11 S2: What's a mineral?

12 John: And that is what we are going to be investigating and finding out. What is a rock, what makes a rock a rock and what makes a mineral a mineral. (John, Session 3 enactment, 27:22)

John introduced the term calcite too early (Line 3), and then found himself facing several questions about what calcite meant, which led him to introduce the word "mineral," also much earlier than planned (Line 10). When he realized that the students had no preparation to learn these words, he tried to turn the students' curiosities into questions that they could investigate over the next weeks (Line 12). In this case, John gave in to the temptation to just tell students that the earth material was calcite and calcite is a mineral, and he had to quickly regroup to find a way to maintain students' interest without telling them everything they were going to find out over the next three teaching experiences. This experience provided a good opportunity for him to learn about the importance of making a list of questions ahead of time to help to push students thinking about ideas in the launch, so he would be able to prompt students to tell what they were observing instead of him feeling like he needed to tell them answers.

On their next visit after the launch discussion, students broke apart a model of a rock to separate its contents into different piles. The interns then guided a discussion that helped students use their observations from breaking apart the rocks to start trying to define rocks and minerals based on evidence from their investigation.

Example 25. Teaching enactment: using observations during investigation to define terms. After establishing the definition of rocks and minerals over several lines of dialogue, Haley asked the students to apply the definitions to the mock rock model, and hoped the students would be able to point out that a mock rock was like a rock because it was made of several different materials. However, she realized that the students were still confused about the terms when she tried to move past their surface level knowledge of the terms:

1 Haley: So then if we look back at our mock rock, this is a rock because...why? Our mock rock is a "mock rock" *rock* because...because? [no response]. We just said…

2 S: It's a mineral!

3 S2: It’s a mineral. [other students join in and say the term mineral]

4 Haley: Could this be a mineral? (pointing to the mock rock)
[Some students say yes and some say no at the same time]

5 Haley: Well if you say yes, you have to tell me why, if you say no, you have to tell me why. Does this represent a rock or mineral [holds up the mock rock]

6 S3: I think it has a rock and mineral in it.

7 Haley: Can you explain?

8 S3: That part would be a rock and that would be a mineral.

9 Haley: Can you show me which parts? So is this like a rock or like a mineral?

10 S: Like a rock.

11 S2: Like a mineral.

Haley tried to press students to provide evidence for their ideas (e.g., if the mock rock is a rock or mineral). Still eliciting mixed responses, she tried to have a student explain why she thought it was a rock so other students could comment on her idea:

12 Haley: If this mock rock was made up of one thing, would it look like this? [holds up the mock rock]

13 S2: No.

14 Haley: No, what would it look like, Ali [S3]?

15 S3 (Ali): It would be just grey, and then it would be called a mineral.

16 Haley: A mineral, why?

17 S3 (Ali): Because if it's a mineral then it's only made of one thing, but if it's a mock rock or rock then it has many different materials.

Now that Ali (S3) had contributed a good understanding of the terms (Line 17), Haley moved to the large poster on the board to write down the definitions for the students to see. However, the students were still struggling to explain the difference between rocks and minerals:

18 Haley: Okay, so if we wanted to make a definition of mineral, what would we say a mineral is? [writing]

19 S4: Um, it doesn't break, it doesn't have anything inside of it.

20 Haley: A mineral is nothing?

21 S4: No.

22 Haley: What is a mineral? Ali [S3] said something that might help if you want to ask her...to repeat, you guys can talk to each other, not just to me.

23 S3 (Ali): I don't remember what I said!

24 Haley: You don't?

25 S3 (Ali): No..umm..oh ya…

26 Haley: Do you want her to tell you?

27 S3 (Ali): A mineral, it, it like, it doesn't have stuff in it, it's one color it doesn't have anything in it if you break it open, but a mock rock has many different things in it.

28 Haley: Now that's a little bit different than what you said the first time. [Haley pauses to ask her partner to get a rock and mineral out of the box]. So a mineral is made up of how many things? A mineral is made of…

29 S5: Different ingredients

30 Haley: Is it different ingredients?

31 S6: Different materials

32 Haley: Is it different? So minerals are made with different materials?

33 S2: No, that's a rock.

34 S3: That's a rock.

35 Haley: That's a rock, well then what's a mineral, Naya? (Haley, Session 4 enactment, 23:00)

Even though Ali (S3) was able to articulate the difference between a rock and mineral, when Haley asked the group to help her write a definition, the students still had trouble re-phrasing what their peer had contributed. Also, when Haley tried to orient other students to Ali's (S3) answer by asking her to repeat it, Ali could not remember the way she had responded the first time, so her new response included the misconception that minerals do not have anything in them (Line 27). When Haley prompted students again by asking, "so a mineral is made of," one student responded "different ingredients," and then another student offered changing the term "ingredients" to "materials," instead of realizing that minerals were only made of one ingredient or material (Lines 29, 31). In the end, there still was no consensus about the difference between rocks and minerals.

Realizing that her line of questioning was not guiding students' thinking, Haley decided to move away from discussing the mock rock, and used a rock and mineral sample to illustrate the differences between them first. She asked students to look closely, touch, and compare the sizes of sandstone (a rock) and calcite (a mineral). She pointed out that both samples were similar sizes, and then asked how many things they thought were inside each. After several questions and responses, two students started to connect the idea that if a mock rock could be broken apart into different materials, so could sandstone, a real rock. Haley was not able to check all students' understanding of the definitions before the end of the allotted time, but she did push student thinking and surface several ideas that could be built upon in the next discussion.

In her post-enactment interview, Haley discussed her plans for the next discussion, where she would explicitly point out that the green and red material in the mock rock represented minerals, and that everything together represented a rock. While reflecting on the part of the discussion where some students seemed to still think the mock rock was a mineral, Haley acknowledged that connecting the mock rock to the definitions was confusing for the students:

> I was doing a comparison, okay they get that they have to compare a rock and mock rock, but they don't really see, it's not as clear as it is for me, the actual comparison, of the green thing could be like a mineral... I talked about it in my plan that I was going to do, but it [the discussion] just didn't go there. "This green thing represents a mineral, and the red thing represents a mineral, and they are all in there." I would have liked to say a little more like that. Kind of model and map a little bit more between rock and mineral, because the answer there showed me that they needed a little more guidance on the road to get from rock to mineral. (Haley, post-enactment interview 3)

This focused teaching experience illustrated many ways opportunities were created for Haley to work on the content of guiding science discussions. She used several questions and prompts she rehearsed, but found her students still struggling to understand the difference between rocks and minerals. Instead of giving up, defining the terms, and moving on, she continued to try to guide students towards making connections between their observations of the mock rock and the definition of a real rock. To support students in doing the cognitive work of identifying the differences between rocks and minerals, she showed the students the pieces of their mock rocks, and guided them to draw on their investigations to think about how to define a rock. Next, she showed students an intact mock rock and asked them to imagine if it would look different if it was only made of one material; in this way, the students could think about how rocks and minerals would be different inside. Finally, she showed the students an example of a real rock, sandstone, and a real mineral, calcite, from the launch activity, and had them touch and compare them visually to help prompt students to describe the differences between rocks and minerals. By the end of the discussion, all the students were still not completely convinced, but she had tried many approaches to elicit their thinking and push them to think about the differences on their own. Haley's struggles and multiple efforts to improve her practice illustrates the power of providing interns with a low-stakes environment for working through the many challenges they are faced with when responding to students and guiding them towards learning goals in a discussion.

Example 15. Using the term "mock rock".

Because the goal of the practice-oriented methods course was to better align opportunities to learn about and to try to enact science teaching, interns benefited greatly when the preparation they did in walk-throughs or targeted rehearsals in class contributed directly to experiences they had while teaching in the elementary schools. For example, during a walk-through, Vanessa practiced introducing the "mock rock" (see Example 15 in Chapter 4 for the dialogue). When asking her teaching group, who were acting as students, what they thought "mock" might mean, she was surprised when an intern brought up the idea of "mock" as making fun of someone. Together, the teaching group discussed explaining the two meanings to students and make clear which definition they were using when using the term "mock rock." When enacting her discussion in the elementary school shortly after this walk-through, Vanessa encountered the same scenario with the elementary students that her teaching group had discussed in the walk-through:

1 Vanessa: So, a couple of you say that rocks can break. And that's actually something that we are going to look at today with the activity that we are doing. So right here, you are probably wondering what these things are (pointing to plates with mock rocks on it), right? Do those look like rocks? So what these are, these are actually called mock rocks. And does anyone have an idea what mock might mean?

2 S: Clay.

3 S2: Mocking people…

4 Vanessa: That actually is a definition, that you're making fun of somebody, there is actually more than one definition. In this case, mock means something that looks like something else but it's not really that. So this is not really a rock, but it looks like one. (Session 4, teaching enactment, 2:55)

Vanessa reflected on the way the preparation she did during the walk-through in the methods course helped her better respond to student ideas about the word "mock" in her teaching experience at the elementary school:

> During the rehearsal, we asked: "What do you think "mock" might mean?" One of the group members responded as a student and said: "You know, like when you make fun of someone..." I had not anticipated this response, but we discussed

> what we might say if a student responded in that way: "That is one definition of "mock," but we're working with another one today." Interestingly enough, a student responded exactly the same way in my group. I was ready with a response after our rehearsal and was able to simultaneously recognize the contribution of that student's definition and move us closer to the more relevant one. The students eventually came to the conclusion that "mock" means "pretend" or "looks like something else." (Vanessa, THM4)

Whether they were practicing teaching with peers or in schools with elementary students, the interns had many opportunities to "try out" the practice of guiding science discussions. These structured teaching experiences offered opportunities that were different from experiences in their yearlong internship classrooms. For example, they had time to plan carefully in groups and with the support of their methods instructors in class, and also had time after class to debrief and make sense of their enactments so they could make adjustments in their next teaching experience: these opportunities are the focus of the next pedagogical approach theme.

Guiding Analysis of Discussions

The following examples (see Table 5.5) illustrate how pedagogical approaches such as joint planning and structured debriefing characterized the theme of **guiding analysis of discussions**. Images allowed interns to learn the practice of guiding science discussions by watching others enact the practice through modeling and videos, and focused teaching experiences allowed interns to learn the practice of guiding science discussions by trying to enact it themselves. Guided analysis allowed interns to breakdown the features of science classroom discussions in the pre-active and post-active phases of teaching.

Table 5.5
Summary of ways guided analysis makes the practice of guiding science discussions available

Guiding analysis of discussions made the content of guiding science discussions available to interns...	Example #
Through joint problem-solving while planning science discussions	Examples 26-27
Through debriefing connections between coursework and fieldwork	Examples 28-30

Joint problem-solving while planning for science discussions

Throughout the course, before interns worked on planning their discussions in their teaching groups and then engaged in walk-throughs, they often would be guided through the planning process with a teacher educator. By using this pedagogical approach, Meg and Shelly structured the planning process so interns would consider the rationale and learning goals behind each discussion. Also, they guided interns to anticipate possible issues that they could continue to think about in their teaching groups as they wrote their lesson plans.

Example 26: Joint planning: keeping learning goals in mind when planning to move from launch to investigation. After teaching their launch lessons, the interns broke into content groups (moon phases and earth materials) and discussed how they would prepare for the use of models in the two units (model of moon phases and model of a rock). Shelly asked interns to share the ideas students brought up during the launch so interns could hear the range of ideas that came up across their peers' teaching experiences. Then, she asked if the interns had prompted students to think about what they could do to find out what was in a rock, so the interns could use a student idea to introduce the next investigation in the unit:

1 Shelly: ...Did anyone [any interns] get to the point [in their launch discussion], as far as inquiry goes of starting to ask questions, maybe starting to think about what we could do to figure out if that makes a rock?

2 Intern A: Yeah, my group had a discussion about what could we do to figure out these are rocks, and one of the kids actually came up with the idea that, well, if we smashed them all up into tiny pieces, we could see. We [showed them] two rocks and one mineral, we had the quartz, and for that one he said it's not a rock, that if you smash it up it's all going to be the same type, just smaller pieces.

[laughter from the other interns, since this student already figured out what they were going to observe in the mock rock investigation].

3 Shelly: I'm going to pick on you a little bit, so let's say that happens, everyone knows what's coming up next, right--with the mock rocks...how are you going to use that?

4 Intern A: What would we do?

5 Shelly: Yeah.

6 Intern A: Well in a way, it's [the upcoming mock rock investigation] testing what he said so it's kind of like he made a prediction about what what we're going to be doing, so when we do this, we're going to be doing his experiment basically to see if the results match what he thinks.

7 Shelly: So you'd actually use the student's name, or say, you know, Robert came up with this..

8 Intern A: Yeah.

9 Shelly: So this is a really good example of what happens in inquiry. Because there is a misconception for science teachers that you just let these kids ask these questions and experiment away and really it all goes in all these directions, but really there is a very clear path, you have an essential question, you really are moving in a certain direction, and so that example is great where, "oh, you might break it up, do you think we should do that?" And suddenly it's the kids' ideas that are guiding the investigation, but really, you knew where it was going. So that would definitely be something to capitalize on. (Session 3, rock breakout discussion, 3:20)

Shelly pushed the intern to think about how she could give ownership to the student who mentioned breaking apart the rock in the launch discussion. She also reminded interns that just because student ideas and questions were important in inquiry did not mean that the discussions and activities could go in any direction. She discussed the role of the teacher is to find ways to capitalize on student ideas and questions in ways that continue to work towards the learning goals for the unit.

Example 27: Joint-planning by anticipating challenging content for elementary students. Once Meg guided interns to not be afraid to question the curriculum materials they were provided, and to think carefully about how students are being supported to learn, she had them go through the curriculum and plan each step they would take to support students in building and using the moon phases model. The FOSS unit had step-by-step instructions for how to show each phase of the model. Figure 6.1 is an illustration used in the teacher's guide for FOSS that showed the arm of the teacher and how much light she would be seeing on the ball (representing the moon) from different angles.

Meg guided the interns through using the suggested instructions in the teacher's guide so the interns could think about possible challenges they could face and modifications they would need to make:

1 Meg: But [to] make a lesson plan, you have to really understand it. So, who has the actual FOSS model directions? Gaby, you have it right there, the investigation 2, so I think I'm going to get the materials out, and we should actually walk through it, and try to figure out how it's going to work, what do we need?

2 Intern A: Um, stick, balls on straws, and a light source.

3 Meg: Okay, got a light source.

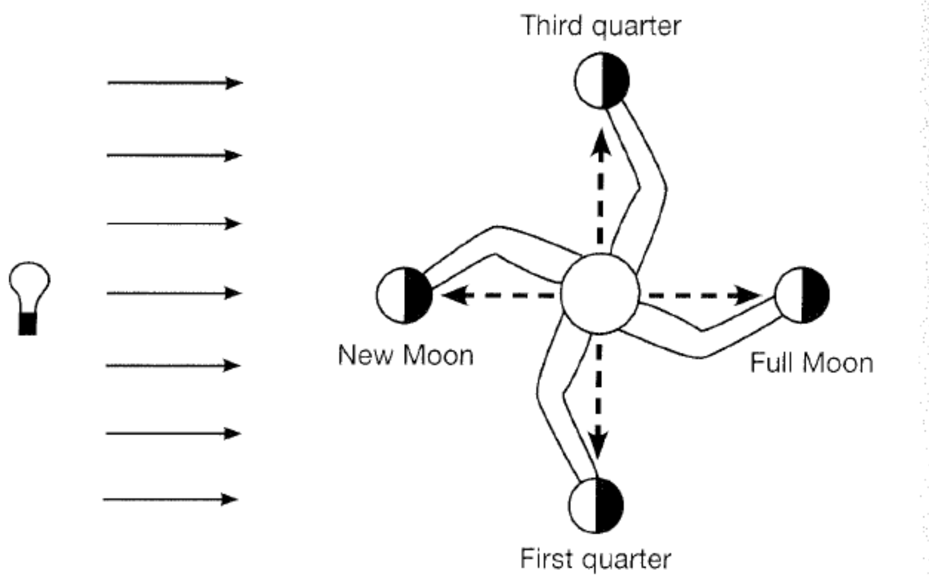

Figure 5.2. Illustration of moon phases model reproduced from FOSS curricular materials.

Meg held up the ball on a straw, representing the moon, and the light source (a bulb) as the intern read the curriculum materials. As Meg was holding the ball up towards the light, an intern mentioned that it was hard to see the light.

4 Meg: Well, these are little issues that are really important…

5 Intern B: Want the lights off? [to see the light bulb better]

6 Meg: Ya, we can try, I don't know if it will make a difference. This is why we are stepping through this. She asked about the light...this is a problem, at this moment, I see very little difference, Jill will attest to this, of this light coming from the bulb, now I could come closer, but now it's not a very good whole-class demonstration.

Meg helped interns see that curriculum materials might not present the activity in a way that is best for a discussion with many students. For the light to be bright enough to light up the Styrofoam ball moon, she would have to get very close to the light source, and that would restrict many students from seeing from their seats. She encouraged the interns to brainstorm their own concerns with the activity:

7 Meg: Alright. What other issues are we going to have with this model right now? One, it's not bright enough.

8 Intern C: The sun is not as big as...[inaudible]

9 Meg: Oh my gosh...[gives intern a high-five]...this is [pointing to the light], one-hundred thousand times bigger, it's not even, not only is this not big enough, it's not big enough in scale, right, if this is the earth [her face], this [the light bulb] should be that wall. The light would be coming from the wall, not from this bitty thing. K? This is a big problem, because of the lunar eclipse problem. So if you think that the scale is that, then you're going to see this lunar eclipse thing happen where the shadow of the earth goes over the moon, that's going to happen, it's a lot more easily understood that way if the scales aren't like this. Because I can easily make a shadow with my head over the model of the moon if this is the size of the sun. (Session 3, breakout moon phases)

An intern suggested that the sun is much larger compared to the other objects, and that their relative sizes in the model were misleading (Line 8). Meg expanded the intern's observation by explaining that this issue with the model could lead to confusion with science content, as the model would be showing a lunar eclipse more than phases of the moon. She went on to suggest a possible solution: using the whole wall as a light source.

10 Meg: But if we imagine that the sun is this wall, and all the light is coming from that, now we're a little closer to some sort of right scale. And then we might imagine that this is the moon, and there is a lot more light from the sun coming than my head could possible shadow. Also, for your content knowledge, the sun, moon, and earth are not in the same plane...the plane is not in the same plane with the other solar system body--so we don't get lunar eclipses as frequently as we would if they were all in the same. So these are things you might want to attend to when you're going to do this model.

By discussing the activity step-by-step as written in the FOSS unit, Meg helped the interns pinpoint potential logistical challenges of using a physical model to explain moon phases to a group of students. She helped them problem-solve about the best ways to hold the earth and moon so that the light would shine on the appropriate parts of the moon. After this discussion, many interns tried using the whole wall of windows in their classrooms as the light source, and considered using a ball that was colored in yellow on one half to better show the lighted side of the moon in the model.

Through structured debriefing of science discussions

Debriefing activities prompted interns to attend to parts of their own or others' teaching experiences so they could learn to identify evidence of what was successful or unsuccessful.

Example 28: Debriefing discussions modeled by Meg. While modeling discussions in the launch activities of the PBIS unit (see Examples 1 and 16), the interns acted as elementary students. In the second half of class, Meg asked the interns to switch gears and interpret her actions through the eyes of a teacher. After having interns share the general teaching moves for inquiry-based science that they noticed, she asked interns to identify specific actions of a launch discussion and to consider the rationale behind those actions. The following excerpts illustrate how structured debriefing helped interns identify components of launch discussions that they could use as a guide to plan their own launch discussions later:

1 Meg: Okay, let's start. So this is our class list of the kinds of things we want to make sure when we are developing the launch for the unit that you are going to teach with the third or fourth grade in Garden City, with your team, these are the things we want to be remembering to keep in mind in that planning stage. Okay, Anne?

2 Intern A: Okay, activate prior knowledge.

3 Meg: Okay. Can you help me just in parentheses [she is writing the list on the board] to define what you mean by prior knowledge? In a science classroom, what does it mean to have prior knowledge?

4 Intern A: What they come in thinking they know....

Meg continued by asking the interns to suggest other components of a launch discussion. As the interns listed ideas, she created a list on the board:

5 Intern B: Provide an engaging-open ended activity.

6 Intern C: An activity that is real-world or relevant to the students

7 Meg: So would it be provide an engaging, open-ended activity that is

8 Intern C: Relevant...

9 Meg: relevant to the students....(Class 1, part 5, 4:41)

One intern brought up the idea of all students having the opportunity to express their initial ideas, whether it was publically to the whole class or to a smaller group of peers:

10 Meg: Okay, Bob?

11 Intern A: Provides an opportunity at least once in the launch for every student to contribute...

12 Meg: Does that mean that everybody has to talk out to the group?

13 Intern A: No, I would picture that as talking in small groups, or maybe in pairs, but I think it's important for each student to get a chance to feel like they had something to say about this…

14 Meg: Okay, so we can do a different kinds of activity, small group, or…

15 Intern A: Lots of different ways...(Class 1, part 5, 8:08)

Another intern noticed that the launch discussion acknowledged students' responses so that they could be used to move the discussion further later:

16 Meg: Okay, what else? What don't we have on our list yet?

17 Intern B: We spoke to acknowledgement, and that acknowledgement and an expansion of the students' ideas, so whatever feedback they're giving you, recognize that you are using it to then catapult to more later...

18 Meg: Gaby, I think that that is absolutely true, and we did that in the launch, in the activities that we did, but even on a bigger scale, as we work through this unit and we talk about how that applies to the rocks and minerals and the sun, moon,

> and stars; those initial ideas then are how you move the entire unit along (Class 1, part 5, 21:30)

By the end of the discussion, the interns and Meg had identified a set of criteria for what to do during a launch discussion. Meg encouraged the interns to use the list to plan their first teaching experiences in the elementary schools:

- Activate prior knowledge (what students think they know)
- Provide an engaging, open-ended activity that is relevant to students (physical or interactive)
- Provide for each student to contribute in some way (at least once)
- Capture student interest (the Hook)
- Students should have opportunities to gain ownership and make real-world connections
- Students should ask questions, create curiosity
- Unpredictability through preparedness
- The essential question is stated-the students should know what it is
- Students' initial ideas are used to catapult to more
- Rule: do not introduce or define vocabulary in the launch (Field-notes, Session 1)

These ideas were a part of the content themes introduced in Chapter 4, and several of these aspects of a launch discussion applied to other types of discussions interns led as well (e.g., discussions to plan investigation, discussions of data, discussions to create explanations, etc.).

Example 29: Considering rationale behind not giving the answers in a launch discussion. While debriefing Meg's modeling of how to guide a discussion in the morning, several interns brought up their hesitation to collect students' prior knowledge without correcting inaccurate ideas. Because many interns were used to more traditional approaches, where the teacher provided accurate information to students, the idea of going through the entire opening launch discussion and allowing students' misconceptions to be collected on the board and not addressed as right or wrong made some interns uncomfortable. The following exchange illustrates how Meg helped the interns debrief the idea of putting both accurate and inaccurate ideas on the board, and seeing it in the context of teaching over an entire unit:

1 Meg: Patience is what you need in the beginning of the unit. Patience. Because what you want to do is tell everything. And it's not time for telling. It's time for listening. Intern A, you had your hand up?

2 Intern A: You learn something incorrectly, you have to unlearn it to re-learn it correctly [inaudible]...Problematic that you let all the bad information out in the classroom.

3 Meg: But it was already there, all we did was bring it up and make it public. If I [don't] let you make it public, then Katie is sitting there the whole unit thinking that the mechanism by which I get sick is when I don't wear a hat or two hats. Right? She could think that and I would never know it [if I didn't ask], but it's still there, I need to know in order to help her "unlearn." I can't un-teach her, she has to un-learn. (Class 1, part 5, 32:18)

Meg used the distinction between "unteach" and "unlearn" (Line 3) to help the interns see that students should be active participants in their own learning and that the teacher is the facilitator of that learning. She continued by reminding interns that simply eliciting the misconceptions on the first day was not enough; teachers must follow-up and return to those initial ideas as the unit unfolds and as students work towards answering the big unit question:

4 Meg: ....I'm there to give you experiences with stuff, we call it phenomena, to give you experiences with phenomena from which you can learn. But *you* [italics added] have to do the learning. So if I don't put it up, and make it public, it's still

there…but hopefully if we have made it public, then we can go back and use our investigations, use the evidence from our investigations, remind students, remember when you thought this, how is what we just did different from what you thought before? [….] Does that make sense Chris (Intern A)? Ya, no, he's still [doesn't believe it]...

5 Shelly: The key is to go back [inaudible]...can't just have the prior knowledge, have to go back to it.

6 Intern A: Well what if half the kids think going outside will make you catch a cold, and the other half didn't. Now we have to unlearn them and they were already in the right place...

7 Meg: So, I don't think, I've never had that experience in the classroom. One of the reasons we picked this question exactly worded this way, is "what do we THINK we know?" Because in science class, everything we think we know is tentative and is based on what our evidence is…we're not just throwing them out there. We are using those "what do we think we knows" to develop the questions in the next question which was "what do we want to investigate?" and then we are going to use those investigation questions to actually do investigations that help us have learning, supported by evidence...and then all of that is about well how does that connect back to answering the big question about good friends, preventing our good friends from getting sick. (Class 1, part 5, 36:06)

In Line 4, Meg reminded the interns that the teacher had the responsibility to provide students with many opportunities to investigate their ideas so they would have more information to make sense of both their accurate and inaccurate initial ideas. When Intern A brought up the idea of confusing students that already had accurate ideas in Line 6, Meg reminded him that all ideas are collected as what student *think* they know (Line 7). Therefore, it was then the goal of the students and teacher to help collect the appropriate evidence to back-up what they think they know, regardless of if their idea is accurate or not. Intern B tried to support the idea of eliciting student ideas, whether accurate or inaccurate, by directly addressing her peers concerns about enforcing or bringing up new misconceptions:

8 Intern B: One thing that Meg did [when she was modeling the role of teacher], she never said that it is true what your grandma said...I think she [Meg] is trying to

say it is important for students to question and wonder about what they know...they know what their parents told them or their friends told them, so she wasn't saying this is all true, I think she is saying these questions are out there, we are going to answer them.

9 Meg: In the launch [the introductory discussion and activity], that's the goal. These are the questions, this is what we think we know, these are the questions we might want to investigate, that's pretty much covers it. It's not about teaching or un-teaching, it's about, everyone in the room, knowing where the understanding currently is. And until you know what kids' understanding is, you can't help them learn something different. Unless you know how their heads are working, how they are processing information, you can't help them process it differently, it's not possible.

The preceding discussion illustrates the importance of debriefing in the methods course. Without an opportunity to express his beliefs about the image he saw of Meg making both accurate and inaccurate ideas public during the launch discussion, Intern A might have dismissed the action as inappropriate and in some ways, doing a disservice to his students (i.e., exposing those with accurate ideas with inaccurate ones). However, by discussing his concerns and hearing Meg’s rationale for her actions and a different way of thinking about how students draw on their prior knowledge, Intern A was in a better position to buy into the idea and try it in some of the teaching opportunities in ED 528.

Example 30. Structured debriefing prompts to connect methods course to teaching experiences. After each methods course meeting, interns had opportunities to reflect on the opportunities they had to learn the practice of guiding science discussions by responding to take-home message prompts. Instead of concluding, “it went well,” or “the students seemed confused,” the take-home message prompts helped interns use specific evidence from their enactments to discuss what they were struggling with or what they hoped to improve in their next teaching experience.

One prompt asked: “Please identify and describe the aspects of leading a science class discussion with elementary students that you worked on today (during rehearsals and teaching).” Interns shared the following examples from their experiences:

> During rehearsal, our group practiced some responses to student comments, such as: "What do others think about what Suzie said?" or "What other ideas do you have?" I had to be careful about my tendency to ask: "Does that make sense?" or to respond with "Great!" During the actual teaching, I was able to link students' ideas by prompting them to respond to one another (Who can build on what Gaby said? What else do you notice?) I slipped, however, and asked "Does that make sense?" before students performed the activity. Everyone just nodded. It was a reminder to watch my line of questioning and make sure that I continued to ask open-ended, thinking questions. (Vanessa, THM3)

Another take-home message prompt asked interns to reflect on their teaching experience and to “share an example of what you did while teaching in classrooms today (or what your partner teacher did) that would fall under the list of language to use or language not to use?” Again, interns had to provide specific examples of the way they were using language during discussions:

> …a perfect example was when Lisa asked something along the lines of "Can anyone tell me why you put the mock rock material into the water" which received no response, she immediately realized her mistake and rephrased the question as "who can explain why we put the mock rock material into the water" and suddenly three hands shot up (I43, THM6)

Take-home prompts also asked interns to generally comment on what about guiding science classroom discussions they were learning about or working on; these responses helped interns debrief their strengths and weaknesses while developing this practice:

> …I also dealt with a problem of practice which from my experience has been especially difficult during science lessons: listening to a student and understanding what they are saying, then trying to make sense of it in a way that can contribute to my educational goals when the student isn't really making much sense. I find myself wondering if it is better to cut a student off who could potentially confuse other students (because even I am confused) or by trying to pick something out of their rant that could maybe lead us in the right direction by saying something like, "Timmy mentioned that the salt came from the sand...where did the sand come from?" (I41, THM6)

Joint planning led by Meg and Shelly, guided interns to prepare for potential issues during the discussions that the interns might not anticipate as being problematic, as they were just beginning to learn how to guide science classroom discussions. Structured debriefing also prompted interns to reflect on particular aspects of their teaching so they could begin to analyze and learn from their teaching experiences.

Creating coherent experiences across pedagogical approach themes

A strength of the three pedagogical approach themes used across ED 528 was that they all worked together to provide interns with coherent experiences with the practice of guiding science discussions. To look more closely at how Meg used pedagogical approaches in both planned ways and in responsive ways to the developing needs of the interns, I will present a visual map[21] of the pedagogical approaches used in each course session and will discuss how experiencing one approach connected with experiences in another.

In Session 1, Meg modeled several science classroom discussions that accompanied the opening launch activities of the PBIS unit for the first three hours (see Figure 5.3). In the second half of class, she guided the interns to think carefully about what she modeled as the teacher and what the interns experienced while acting as elementary students. As mentioned earlier, simply providing the images was not enough, interns needed to make sense of what they saw and the structured debriefing was one attempt to provide opportunities for them to discuss Meg's rationale for each teaching action and the overall purpose of launch discussions. Also, Meg modeled the type of discussion (i.e., launch) that the interns were going to be responsible for enacting in the Garden City classrooms; thereby providing a direct connection between the types of questions and language she used and the planning they would have to do for their teaching enactment.

In the second course session, interns experienced several pedagogical approaches that prepared them for their upcoming teaching experience. When the line (see Figure 5.4) touches the bottom line that is not labeled, it illustrates that a pedagogical approach was being used that was not one of those identified in this dissertation as focusing on practice. For example, Session 2 began with Meg going over the logistics of working in the Garden City schools, so it began at the unlabeled bottom line. Next, Meg led a

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[21] The visual map will represent the pedagogical approaches used from the beginning of the course session to the end. The x-axis does not accurately represent duration of each pedagogical approach, instead it accurately illustrates the range of pedagogical approaches that were used and in what order throughout the particular course session. The line is continuous to represent how experiences during one pedagogical approach were connected to those in the next.

short, targeted rehearsal of how and when to introduce vocabulary in a science discussion. In Figure 5.4, the line hits the bottom again to represent Meg lecturing about the parts of the PBIS curriculum and how the unit was designed to encourage cycles of investigation to answer the big question for the unit.

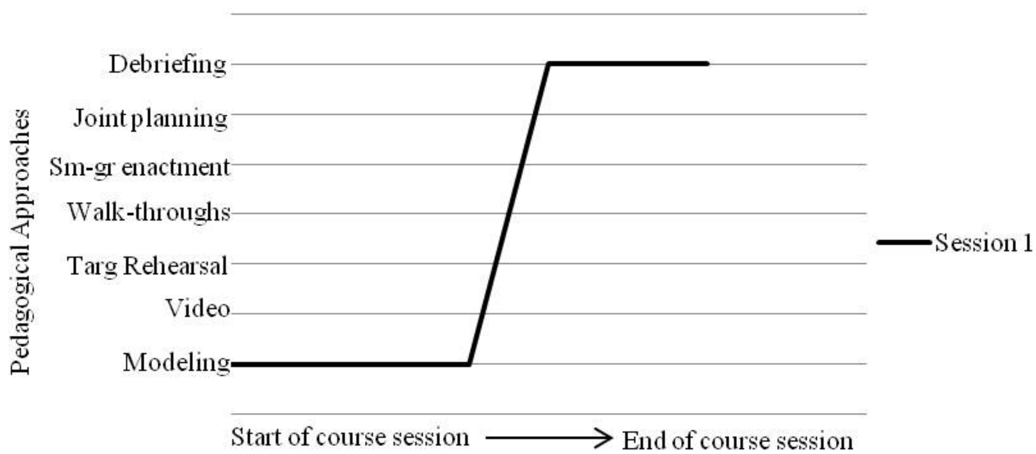

Figure 5.3. Pedagogical approaches in ED 528 Session 1

Next, Meg engaged interns in problem-solving during joint planning about how they would modify the FOSS curricular materials to incorporate the types of classroom discussions that they experienced and read about in the PBIS unit.

Together, they considered the strengths and weaknesses of different learning goals and big questions the interns proposed for their classroom discussions. Meg pointed out aspects of the FOSS units that might be confusing for students: for example, she warned interns about introducing the idea of shadows before teaching about moon phases. In this way, she directed the interns to possible areas to improve when developing their lesson plans for the launch discussion. Interns then engaged in walk-throughs, where they wrote and rehearsed the questions they would ask during their launch discussions. They met again as a full class to discuss their developing plans in a joint-planning discussion where they gave each other feedback on their ideas for a big question and learning goals. Finally, the interns returned to engaging in walk-throughs, where they could incorporate the feedback they had received in the larger joint-planning discussion. Moving between joint planning, walk-throughs, joint planning, and walk-throughs helped interns use Meg's expertise about important aspects of the launch discussion to better focus the issues they worked on during their peer walk-throughs.

In Session 3, the interns first enacted launches with small-groups of elementary students in Garden City based on the preparations they did during joint planning and peer walk-throughs in Session 2. When they returned from their teaching experiences, Meg provided them with prompts to help them debrief their initial experiences guiding a science classroom discussion using the FOSS unit. For example, she asked interns 1) what ideas of a good launch were they focusing on in their enactment; 2) what questions did they use that really "got to" what they wanted to know about student understandings; and 3) what did they learn about students' understanding about the science content (e.g., rocks and minerals or moon phases) that they will address in the next discussion? After debriefing individually, the interns were divided into two groups based on which unit they were teaching.

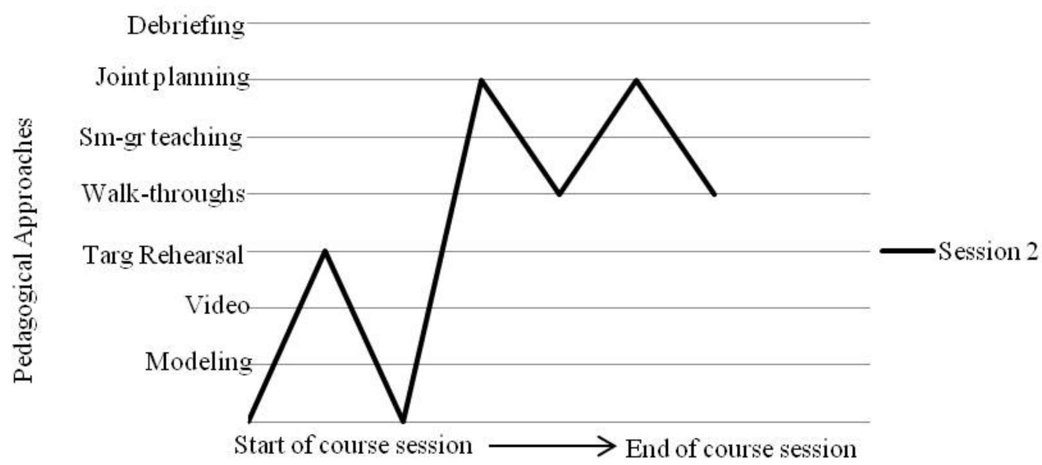

Figure 5.4. Pedagogical approaches in ED 528 Session 2

Meg then led a group debriefing with the interns teaching moon phases and Shelly debriefed the experiences of those teaching the rocks and minerals curriculum. Each group then engaged in joint planning, where they discussed ways to take students' initial ideas and questions from the launch discussion to move into the next discussion about the mock rock investigation or moon phases modeling. The interns then had time to plan and rehearse in their teaching groups during peer walk-throughs.

While circulating during the interns' walk-throughs, Meg and Shelly noticed stumbling points that the interns were experiencing. For example, interns were using terms like "the moon changes shape" and "seeing shadows" in the moon phases group and the other group of interns were struggling to help interns connect the mock rock investigation to their big question. Meg and Shelly addressed these issues by engaging the interns in more joint-planning, and then the interns worked again with their teaching groups to walk-through their lesson plans. Meg and Shelly used joint-planning to address the interns' struggles during their walk-throughs; in this way, the pedagogical approaches they employed were responsive to the interns' needs (see Figure 5.5).

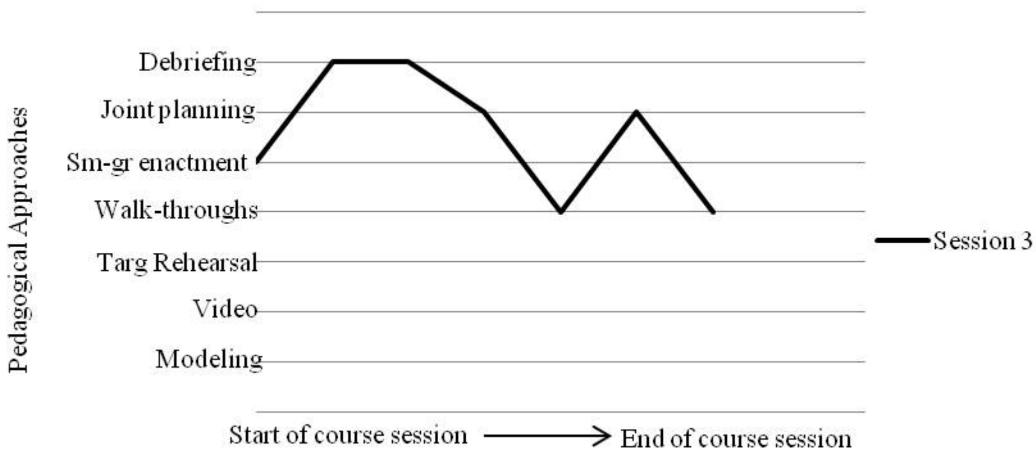

Figure 5.5. Pedagogical approaches in ED 528 Session 3.

In Session 4, interns engaged in walk-throughs of their lesson plans, enacted their lessons with small-groups of students in the elementary schools, and then engaged in structured debriefing back in the methods classroom. During the debriefing, Meg and Shelly shared questions that they observed interns using in their teaching enactments (e.g., does everybody understand?), and asked the interns to brainstorm ways to improve those questions. Then, the interns engaged in targeted rehearsal of ways to phrase questions in their upcoming discussion where students would be making sense of the mock rock investigation or their moon phase modeling. Specifically, Meg guided interns to rehearse questions and responses that would encourage students do more of the cognitive work and would include more students in the discussion. The interns then used the ideas from the targeted rehearsal to engage in another cycle of walk-throughs to prepare for their teaching. The enacted another round of discussions, and then debriefed their experiences by responding to prompts after teaching. In this way, interns had opportunities to plan and rehearse with the whole group of interns, with the teacher educators, and in their small teaching groups. They drew on those experiences to enact their discussions, and then had opportunities to make sense of what happened during structured debriefing with their peers and the teacher educators. The complete cycle of engaging in peer walk-throughs, teaching enactments, and debriefing can be seen twice in Figure 5.6.

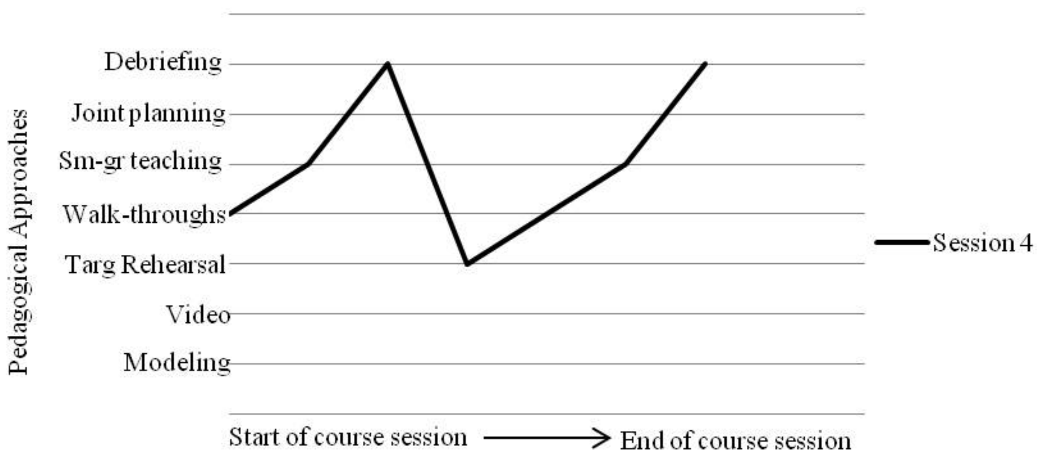

Figure 5.6. Pedagogical approaches in ED 528 Session 4.

In Session 5, Meg had interns engage in some logistical paperwork and then had them share videos of their teaching with peers in their teaching group and peers in other teaching groups. Meg then led a long discussion of assessment design that was not related directly to the practice of guiding science discussions (Figure 5.7).

Next, they engaged in joint planning of how interns could uncover student thinking about rocks and minerals or moon phases in their upcoming teaching experiences. Finally, interns had opportunities to try to practice the ways they would ask questions to find out if students had more than a superficial understanding of the content by engaging in peer walk-throughs.

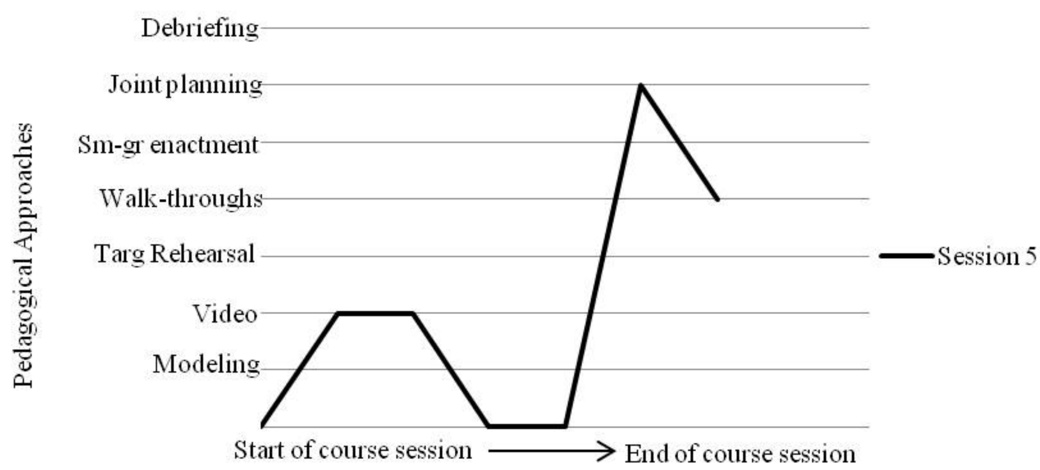

Figure 5.7. Pedagogical approaches in ED 528 Session 5.

In Session 6, interns engaged in an extended rehearsal targeted at how to respond to students' misconceptions using the moon phases model to represent "full moon" versus "new moon." Next, they engaged in joint planning, where they shared language in their lesson plans that they felt they should avoid or keep based on the earlier rehearsal of teacher talk. For example, one intern shared that they had planned on saying, "I'd like you to draw a picture of the phases of the moon on your worksheet." They discussed how this phrasing made it seem like they were only completing this task for the teacher, and it was also unclear what type of drawing they expected students to make. They also discussed using the phrase, "Please finish this worksheet before we get started." This implied that the worksheet was "busy work" used to just use up time instead of used to help students and the teacher understand students' ideas. Meg pointed out that if the worksheet was contributing to the students making sense of the science content, then completing it would mean they had already "started."

The line in Figure 5.8 then drops to the bottom to indicate Meg's lecture about the use of the outdated scientific method and helping students understand what scientists actually do. The interns then enacted their discussions, having discussed any revisions in the language they would use during joint-planning. They then returned to the methods classroom and engaged in structured debriefing by responding to a prompt individually. The class ended with the interns running a simulation of blood flow through the body, and Meg explaining the limitations of models and simulations and the instructional decisions to make when using them in a unit.

In Session 7, Meg and the interns watched and then debriefed the video of the third grade classroom discussion of magnets. Meg then gave a lecture on the *National Science Education Standards* and writing scientific explanations. Towards the end of the session, Meg helped interns plan how they would prompt students to explain moon phases or the differences between rocks and minerals in their last teaching experience.

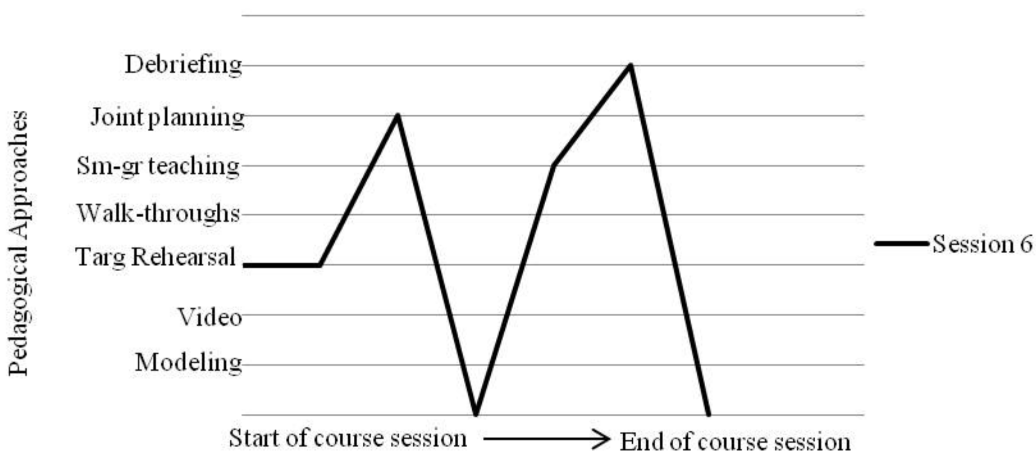

Figure 5.8. Pedagogical approaches in ED 528 Session 6.

They brainstormed what type of explanation was appropriate to expect from the students at this point in the units. The interns then spent time rehearsing the questions they would ask to help students provide evidence for their explanations during the last classroom discussion (see Figure 5.9).

In Session 8, interns engaged in their last small-group teaching enactment and then returned to the methods classroom. For the remaining activities, none of the seven identified pedagogical approaches were used, therefore it is not illustrated here. Meg provided logistical information about the interns final exams and final presentations, read a children's book that connected to ideas about students coming in with ideas about the world and what that means for teachers starting with those ideas. The last hour of class, interns shared information about the scientist they were assigned to study throughout the course.

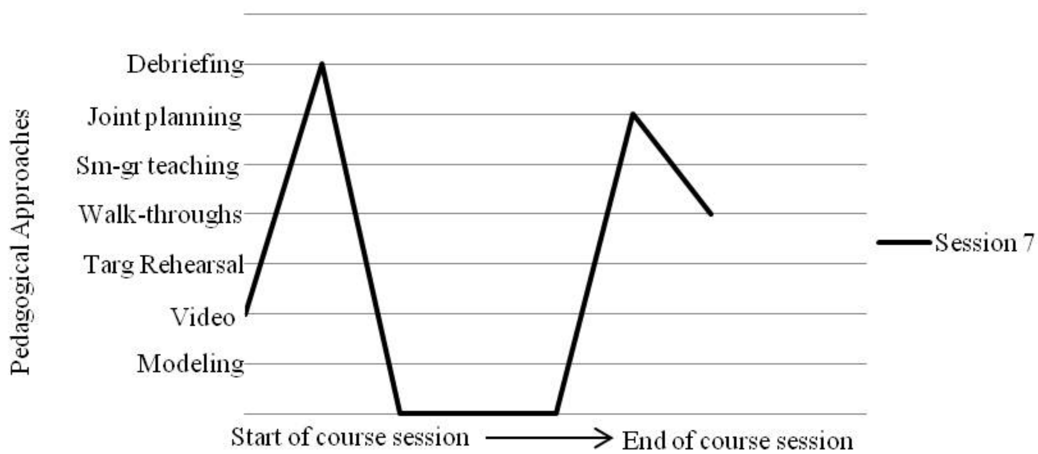

Figure 5.9. Pedagogical approaches in ED 528 Session 7.

Across the Figures 5.2-5.9, the ways pedagogical approaches were used to create coherent experiences in course sessions were illustrated. For example, interns could use the issues brought up during joint planning with Meg and Shelly to help them plan and rehearse in their teaching groups during peer walk-throughs. While observing interns' walk-throughs, Meg and Shelly could notice common stumbling points to bring up during joint planning to help interns problem-solve about their lesson plans together. Finally, the range of content that made up the practice of guiding science discussions (Chapter 4) could be unpacked during structured debriefing of Meg's modeling, video-clips, and interns' teaching experiences.

In summary, the interns had opportunities to practice the practice of guiding science discussions with peers and real students, and then were guided to make sense of those experiences in ways that helped them prepare better for future teaching and also taught them to continue to learn from their teaching experiences. Additionally, in the way that Vanessa's walk-through experience about using the term "mock" directly connected to her small-group teaching enactment (Example 15), interns made their own individual connections among course experiences and their teaching. The individual patterns of connections among experiences for each intern are not reported in this chapter[22], however, the ways experiences in one pedagogical approach were connected to others are depicted in Figure 5.10.

The numbers at the arrowheads indicate in which course sessions there were connections among particular pedagogical approaches. The arrows represent how experiences in one activity were connected to experiences in another activity. For example, in Session 3, interns used ideas Meg brought up during their joint planning to guide their interactions during walk-throughs, and then they discussed issues that came up in their walk-through during joint-planning again. Therefore, there is a double-headed arrow between peer walk-throughs and joint-planning pedagogical approaches.

[22] Figure 5.10 does have an arrow between peer walk-throughs and small-group teaching enactment to illustrate Vanessa's experience in Example 15 of connecting something directly from her walk-through to her small-group teaching enactment. These types of connections are likely to have occurred often, but a detailed analysis of each intern's experiences during walk-throughs and then teaching enactments was beyond the scope of this dissertation.

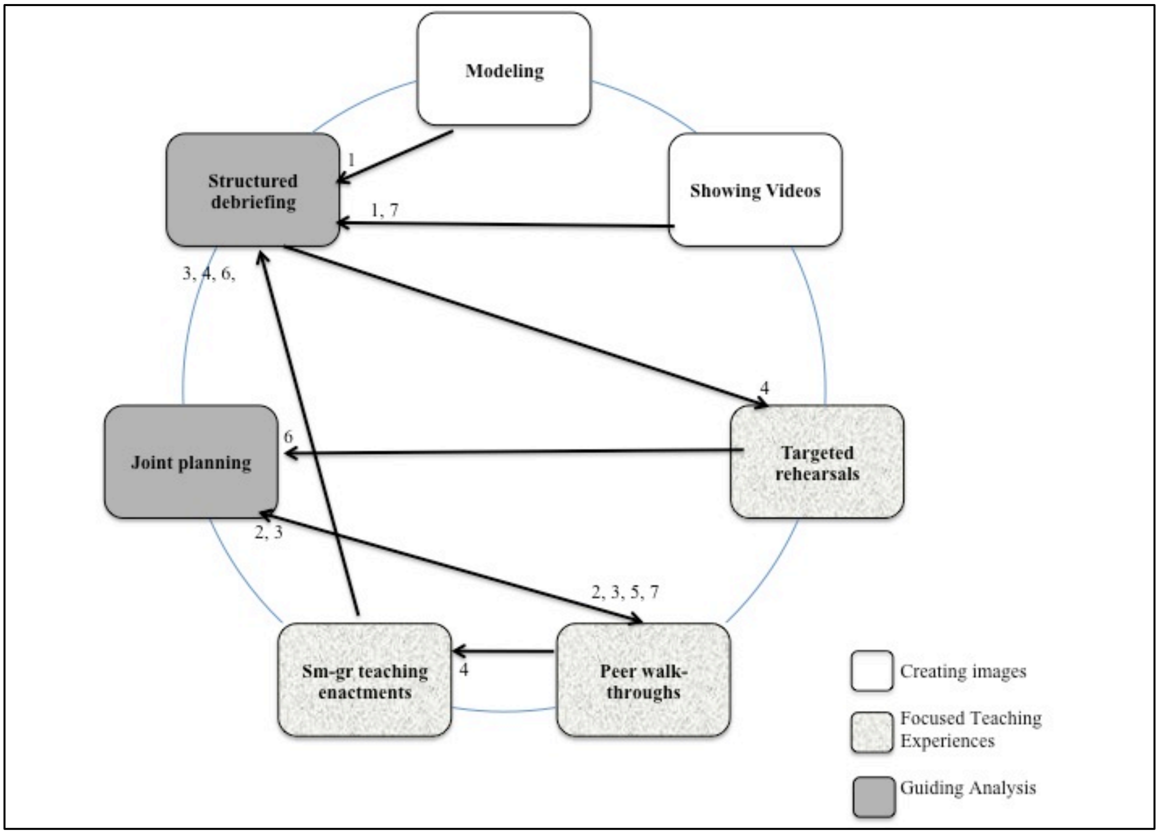

Figure 5.10. The pedagogical approaches that were connected across all eight course sessions.

Summary of Pedagogical Approaches

In this chapter, I introduced three main pedagogical approach themes that included seven total pedagogical approaches used across course activities in ED 528. These approaches supported interns to engage in the pre-active and post-active phases of teaching, such as joint planning and structured debriefing. They also engaged interns in the interactive phase of teaching through targeted rehearsals, peer walk-throughs, and small-group teaching enactments. Images of inquiry-based teaching provided a vision of reform-based teaching to strive towards or to learn from. Just like the content identified in Chapter 4 was connected and could not always be taught in isolation, similarly, these pedagogical approaches were used in concert throughout the course to help interns engage in the practice of guiding science discussions.

CHAPTER 6
DISCUSSION OF CONTENT AND PEDAGOGICAL APPROACHES

Discussion of the content in ED 528

Because the field of teacher education currently lacks a common language for talking about high-leverage teaching practices such as guiding classroom discussions, there is a need to analyze and name the content of these practices (Ball et al., 2009; Grossman & McDonald, 2008). While there is much literature about what classroom discussions are, their purpose in teaching, and the types of questioning and responding strategies that teachers can use, the field lacks a way of talking about teaching practice in ways that reflect practice, or what teachers actually do.

Surfacing content that prepares interns to engage in practice

In ED 528, the practice of guiding science discussions was the content focus for the course. Instead of following a fixed syllabus that set out to give the interns a set of rationales to guide their teaching in the future, the content of guiding science discussions was constantly responding and aligning with the interns' experiences in ED 528. The five content themes that surfaced in Chapter 4 came from the interns' and teacher educators' discussion of the practice before, during, and after enacting it. What the interns learned about guiding science discussions helped them know what to work on during their teaching experiences. Then, the successes and stumbling points from their teaching experiences were the impetus for content worked on in class. Thus, the content of guiding science discussions was necessitated by the interns' experiences practicing it.

When suggesting a particular set of teaching actions, Meg would help interns practice how to enact them *and* help them understand the reasons why they would do them. As Grossman, Hammerness and McDonald summarized: "…teacher educators must attend to both the conceptual and practical aspects associated with any given practice (2009, p. 278). The reasons for making particular teaching moves and how to make them were integrated across discussions (see examples in Chapter 4). That is, Meg's comments explaining why a teacher would elicit students' prior knowledge, or invite all students to contribute, or why students should do the cognitive work often came with discussions of the concrete actions the interns could enact.

Additionally, the way Meg talked about the content of guiding science discussions often moved away from more theoretical content of methods courses (e.g., "constructivism" and "scaffolding") and instead, revealed a more practical language to describe the work of teaching. For example, phrases like "2+2 is not equal to 5!" captured the idea that teachers did start with student ideas, regardless of their accuracy, but had the responsibility to guide students towards more accurate understandings over time. Other analogies like, "you're the driver of the car, you need to steer it to the right place," also captured the idea of guiding interactions towards learning goals.

In previous iterations of the course, Meg might have had to discuss lesson-planning or particular teaching approaches generally or theoretically because she was advising interns as a whole for their individual lesson plans that used a variety of curricular materials, focused on various content topics, and were going to be enacted in different teaching contexts. By preparing the interns for particular types of classroom discussions, in consistent settings (Garden City), using common curricular materials

(FOSS units), Meg was able to provide more specific guidance about "how" to enact the moves that make up science classroom discussions. She was not preparing them for lessons that they would teach long after the methods course was over; instead, she was preparing them for enactments that were often one or two days away. The content of the course was therefore, situated in practice, or in the work of teaching that the interns were beginning to enact on their own. The immediacy of having to "enact" what they were learning in the methods course made it necessary for Meg to use straightforward language that would help interns feel equipped to enact their plans.

The relationship between content and pedagogical approaches

Identifying the content and how to teach it in a science methods course was a "complementary and mutually reinforcing" process, as what content could be taught was dependent on how it was taught (Ball et al., 2009, p. 467). The content of guiding science discussions emerged because of the pedagogical approaches used in the practice-oriented course to focus on practice: reciprocally, the pedagogical approaches were adjusted to respond to the support interns needed in learning the content of guiding science discussions. For example, after experiencing Meg's modeling of a launch discussion (pedagogical approach), where student ideas and questions were collected publicly and projected in the classroom, Intern A (see Example 29) still had concerns about displaying both accurate and inaccurate ideas while teaching. Because Meg set aside time to engage interns in a structured debriefing of why she made particular teaching moves (pedagogical approach), the idea of eliciting students ideas at first and then returning to them over several discussions to help students actively build new understandings was discussed (content). Thus, the pedagogical approach of having a structured debriefing made it possible to discuss the content of why foregrounding student ideas (both accurate and inaccurate) was important. Reciprocally, after talking about the importance of having students do the cognitive work (content), an intern brought up her concerns about what interactions where students were being prompted to think would actually look like. This prompted Meg to lead a targeted rehearsal (pedagogical approach) to help the interns brainstorm how they would actually push hypothetical students, Sam and Bridgette, to do the cognitive work of improving their modeling of the full moon and new moon (Example 19). This type of back and forth between the content and pedagogical approaches further supported the practice-oriented nature of the course that led to more coherence in what was being taught and how it was being taught (Hammerness, 2006). This coherence is often missing in courses where teacher educators attempt to prepare interns for the interactive aspects of teaching by using pedagogical approaches that focus more on studying practice (e.g., pedagogies of investigation).

In sum, Meg matched the pedagogical approaches she used to the particular types of content the interns needed to learn. If they needed help unpacking the rationale behind using particular actions, she used structured debriefing to help interns make sense of practice by studying it. If the interns needed help knowing what to say and do during interactions with students, she used a targeted rehearsal to help them think about each question or response they might use in a particular scenario.

Discussion of the pedagogical-approaches in ED 528

New images to replace old images of what it means to teach science

Due to the lack of images of reform-based science teaching in their own experiences as students and even in their fieldwork experiences, prospective teachers can benefit from being provided with a range of new images that illustrate what reform-based science teaching looks like (Haefner & Zembal-Saul, 2004; Lortie, 1975). Several coherent images of reform-based practice can create a vision of how inquiry-based science teaching is possible, and can empower prospective teachers to begin to try teaching in this way (Darling-Hammond, Hammerness, Grossman, Rust, & Shulman, 2005; Feiman-Nemser, 2001; Wilson & Ball, 1996). Images can also provide prospective teachers with positive ideas about how teaching and learning through inquiry can support student learning when enacted successfully.

By experiencing Meg's modeling in the methods course, the interns had access to a new set of images that they could use to help filter their past experiences and better align their developing teaching skills with images of reform-based teaching. For example, by modeling how to enact a science discussion (Example 1, 16), Meg created images of the role of an elementary teacher as a "facilitator" versus a "teller."

As the interns pointed out in their take-home messages, the modeling provided an image of how the teacher was not the only person who asked questions in science discussions, but that it was important to encourage students to ask their own questions that could be addressed throughout the unit. Phrasing questions and using appropriate language so the responsibility for thinking was shared among students and teachers was also an important image to create, as it differed from the more traditional teacher and student roles many interns experienced as students.

Unlike modeling which happened in real-time, when showing videos, Meg could play the videos several times or pause the video to focus interns on particular actions that she wanted to focus on during the discussion (Grossman, 2005). Also, because interns were not busy interacting with Meg as science learners, they could notice more things about discussions by rewinding and viewing the video-clip. In this way, interns were able to see the interactive aspects of guiding a discussion in real-time. In the magnet video (Example 2), the interns were able to see images of a pre-service teacher and a more experienced teacher guiding different parts of the discussion; thus, they were able to relate to the student teacher and her efforts to guide the discussion, and to also see a vision of what this practice would look like after many years of experience.

The videos not only provided images of what the teacher did, but also the ways young elementary students interacted during discussions. The interns noticed that because of the culture the teacher had created, the very young students in the magnet discussion were comfortable responding to each other's ideas during a discussion. As the interns struggled to encourage their elementary students to talk to each other while teaching small groups, it was helpful for interns to have an image of what could happen if they had had enough time to set-up the classroom culture so the students would be more familiar with engaging in discussions in the classroom.

Viewing peer video clips provided a professional support base, where the interns experienced what it was like to share their practice with others and reflect on successes and stumbling points in a critical manner. Their peers' videos may not have always been an image of ideal practice, but they offered a common image of what the practice of guiding science discussions looks like as interns are beginning to learn how to enact it.

Because "visions of good practice may differ in different settings, and different settings may emphasize or demonstrate different tools, practices, and even dispositions," it was especially advantageous that the university, school district, and elementary school settings were all structured to support the views shared in ED 528 as much as possible (Hammerness et al., 2005, p. 388). Interns did not face as much resistance as they tried out reform-based teaching moves as they might have faced in their year-long internship classrooms with veteran cooperating teachers.

Even when presented with the learning theories and research studies supporting inquiry-based teaching methods, prospective teachers are likely to revert to images of teaching most familiar to them: these experiences often include teacher-led lectures, cookbook laboratory activities that provided questions and procedures without student input, and the memorization of vocabulary and facts (Haefner & Zembal-Saul, 2004; Newman et al., 2004; Windschitl, 2003). Therefore, images serve as important tools to start confronting interns' misconceptions about science teaching and to help provide examples of what to strive for when trying to enact more reform-based teaching. With these images to work towards, interns also require opportunities to begin enacting the moves that are enacted in the images. Focused teaching experiences in ED 528 provided those opportunities to practice guiding science classroom discussions with different types of supports.

Focused teaching experiences to "try-out" reform-based practices

Because learning to enact complex practices like guiding science discussions takes time to develop and refine, interns often fall back on less challenging traditional approaches when initial attempts fail in their student teaching or fieldwork experiences. Later, in their own classrooms as beginning teachers, interns may not have time to make mistakes, or to reflect and try different approaches, as they will face the pressures of assessments and documenting student progress. In this way, interns might continue to lose critical early opportunities to work on developing their reform-based teaching practices.

Therefore, having opportunities in the science methods course to "try out" challenging reform-based practices like guiding science discussions, with support planning before and debriefing afterwards, is critical. Targeted rehearsals and walk-throughs supported interns to practice their teaching moves without managing interactions with real elementary students.

Designed settings allow interns to work with real K-12 students, but control features in these settings so interns can learn teaching practices more efficiently (Lampert, 2006; Teacher Education Initiative). The elementary school settings in ED 528 offered a type of designed setting, in that interns could practice guiding science discussions with a small group of elementary students without pressures from the classroom teacher to meet other goals or to teach in other ways. The setting was designed to maximize interns' opportunities to experiment with the new ideas about teaching science that they were being exposed to in the methods course. In these settings, the interns were not responsible for teaching all subjects, all day, to their own class of students: they were only responsible for developing their ability to guide science discussions. In sum, the targeted rehearsals, walk-throughs, and small-group teaching enactments provided opportunities for interns to tackle the challenges of enacting science discussions, while expanding, refining and adapting their knowledge base for teaching.

Guiding interns to analyze salient features of teaching while planning and debriefing

With forty-three interns, eight class sessions, and two teacher educators, it was impossible for Meg to provide individualized advice for each teaching group as they planned for their teaching enactments in the elementary schools. However, it was also inappropriate to let interns plan on their own without being alerted of key aspects of the science content where their students might struggle. Joint planning offered a way for Meg to give interns direction in their lesson planning for discussions, and to ask interns questions about their plans that pushed them to anticipate possible issues they were still learning to recognize. For example, when planning to use the model of moon phases, Meg guided interns to consider the misconceptions that could arise from using the provided light source as a representation of the sun. Also, when planning to introduce the mock rock investigation, she pushed interns to think about the ways students might struggle with the idea of a real rock versus a model of a rock. With repeated opportunities to plan as a class, with peers, and individually, interns learned how to anticipate potential roadblocks and how to prepare to handle them-a skill they would continue to need in the future: “knowledgeable teachers may not know the particulars in advance, but they can anticipate many likely elements of students’ response to assignments and classroom situations (Ball & Cohen, 1999).

As prospective teachers, they were so many aspects of teaching that the interns could be distracted by while reflecting on their teaching: how they managed student behavior, how they used time, whether or not the students were engaged, if the students seemed interested, the ideas students had about the content, how difficult they thought the task was, etc. To help the interns move beyond surface-level reflection with remarks like, "it went really well," or "I had a lot of trouble with this discussion," Meg structured debriefing sessions to help focus interns attention on salient aspects of their practice (Sherin & van Es, 2005). For example, sometimes she asked interns to focus on the questions they used and to think about the ways their questions did or did not push student thinking. Other times, she asked students to reflect on their teaching by providing evidence for what their students were currently thinking about the content. In other words, just saying, "I think they got it," is different than providing evidence of what students said or wrote during a discussion that illustrates their understanding.

By providing this structured time to reflect and analyze their teaching in the methods course, interns could be prevented from "infer[ing] the wrong lessons from their early attempts at teaching" (Hammerness et al., 2005, p. 375). For example, if students were struggling to describe the difference between rocks and minerals, it might be easier for an intern to believe that the content was too hard for students to come up with the definitions on their own, and interns might feel it was better to directly tell students the definitions. With opportunities to debrief, interns might be asked to reflect on the questions they used or responses they made to student ideas, so they could consider the ways they did or did not make it possible for students to come up with the definitions on their own. Bryan and Abell summarized the importance of supporting interns to make sense of their teaching experiences:

> Experience as a professional provides perturbing encounters that highlight tensions in thinking about teaching and learning. Such encounters yield feedback; reflection stimulates reframing and revising practice. Therefore, teacher educators are challenged to coach prospective teachers to purposefully and systematically inquire into their own practice, encouraging them to make such inquiry a habit that will become increasingly valuable throughout their careers. (1999, p. 136)

Take-home message prompts offered another way to focus interns' analysis of their own and their peers' teaching since it was not possible for each intern to receive customized coaching or feedback on each teaching enactment during the course. The prompts were structured in ways that helped interns make sense of their own practice in meaningful ways. For example, some prompts asked interns how they oriented students to each other's ideas, how they focused the cognitive work on students, or how they used language to push student thinking. Without these prompts, the interns could just say "it went well," but by focusing on specific aspects of the practice of guiding science discussions in their reflections, they had to dig deeper into their developing practice and over time, learn how to monitor their own progress without the prompts.

Cycles of Pedagogies of Investigation and Pedagogies of Enactment

The pedagogical approaches identified in Chapter 5 engaged interns in cycles of preparing for practice in the formal methods classroom and then enacting practice with real students in the elementary settings. While the literature has not clearly defined the criteria for pedagogical approaches to be classified as pedagogies of enactment or pedagogies of investigation (Grossman & McDonald, 2008), I suggest the following classifications for the seven pedagogical approaches identified in Chapter 5.

Joint problem-solving while planning and structured debriefing of science discussions seem to act as pedagogies of investigation throughout the course. That is, they allowed interns to "study" the pre-active phase of teaching during planning and the post-active phase of teaching during debriefing. For example, by engaging interns in joint problem-solving while planning science discussions, Meg was able to introduce interns to possible misconceptions elementary students may have about specific science content. She could then support them in adapting curricular materials by identifying confusing terms that could promote additional misconceptions. During debriefing, the interns could study the language they used, the questions they asked, the student contributions they observed. They could use their investigations of those aspects of practice to better prepare for their next teaching experience. These pedagogical approaches did not require the teachers to engage in the interactive aspects of teaching. However, the work was still focused on practice; they were prompted to anticipate problems that could arise in practice and they have opportunities to analyze the strengths and weaknesses of their teaching practice.

The focused teaching experiences (targeted rehearsals, walk-throughs, and small-group teaching enactments) acted as pedagogies of enactment, in that they provided ways for interns to actually *do* the work of teaching. For example, targeted rehearsals prompted interns to practice asking questions or responding to student contributions when faced with particular scenarios that occur in teaching. In this highly supported format, with Meg helping them navigate the options and the opinions of their fellow interns, they were pushed to actually think, “What would I say? How would I respond? What would that student response tell me?” This was the type of thinking they would experience in real-time during their actual teaching enactments. Peer walk-throughs provided even more opportunities for interns to try responding to student contributions, even though their peers were providing the hypothetical student contributions. Finally, small-group enactments in real elementary classrooms helped interns work on the practice of guiding science discussions within the supportive setting of the methods coursework. In these ways, these pedagogical approaches focused more on enacting practice than talking about it.

Creating images did not fit as clearly into pedagogies of investigation or pedagogies of enactment. When the modeling and videos were debriefed and analyzed, the discussions about the images acted as pedagogies of investigation, teaching interns how to study the parts of the practice they observed. However, when the teacher educators was creating the images, she was providing opportunities for the interns to see the range of possibilities for what reform-based teaching looks like. They were not actively engaging in the work of teaching. Modeling and showing videos may be another type of pedagogy, like a pedagogy of vision-making, that helps interns see the role they must take as a science teacher during classroom discussions and to see illustrations of how students can respond to each other even at a young age. Providing those images and having interns want to work towards those images as they engage in pedagogies of investigation and pedagogies of enactment may be important for linking interns' intentions for teaching a particular way and their ability to actually carry it out (e.g., Crawford, 2007; Hammerness et al., 2005).

Applying Grossman's Framework as an Analytical Lens

Grossman and colleagues' framework for preparing novices for professional practice was introduced in Chapter 2. In the following discussion, I will use the framework as a lens for analyzing the ways the pedagogical approaches identified in Chapter 5 were practice-oriented.

Decomposition of practice involves identifying and naming smaller components of practice, or what teachers do, for the purposes of teaching and learning. Over time, the novice should be supported to start integrating these components into full practice. Representations of practice provide ways of seeing and understanding practice and they range in how comprehensive and authentic they are to full practice. They usually make some aspects of practice visible, while hiding others (Grossman, Compton et al., 2009, p. 2065). Approximations of practice are simulated teaching experiences that range in authenticity and complexity to real practice, the degree to which novices engage in the full practice, and the role of the instructor during these supported experiences. They provide novices with "…greater freedom to experiment, falter, regroup, and reflect" (Grossman, Compton et al., 2009, p. 2076) before having to enact the practice in real settings.

Images of Practice through the Lens of Grossman's Framework

Images of practice in ED 528 included Meg modeling science discussions and showing videos of experienced and prospective teachers guiding discussions.

Representation in Images of Practice

By creating images of the practice of guiding science discussions, Meg was providing interns with representations of practice that they could learn from and refer back to throughout course meetings. Meg's modeling of an elementary science teacher provided a live, real-time representation of what a teacher does while guiding science discussions. While the teaching moves Meg made were very similar to what she would use when teaching elementary students, it was not an entirely authentic representation, as the interns, despite their efforts, could not accurately portray the behavior and ideas of elementary science students.

Sharing videos of experienced and prospective teachers guiding discussions provided a recorded representation of practice, in that it was not happening live, but it still captured the interactions between teachers and students during a discussion in a classroom. Because it was a recording, it could be paused and played again several times, so interns could notice different aspects of teaching practice on multiple viewings, and could look for specific examples of what the teacher said or did in response to students.

The video of the magnet talk (see Example 2) was not comprehensive, in that it was only a short segment of a full lesson, and an even smaller slice of the teacher's full year of teaching. When an intern brought up how comfortable the young elementary students looked while sharing ideas during the discussion, Meg brought up the part of the practice hidden in the video: the development of a classroom culture that supports science discussions. She explained that the classroom culture had been established long before this video-clip took place, and this triggered Meg and the interns' brainstorming ways the teacher in the video could have set up that culture. Therefore, even though the video was not a comprehensive representation of all it takes to enact a science discussion, it offered a starting point for discussion and a good image of the type of thinking young students could engage in if supported appropriately.

Videos also allowed interns to analyze interactions that occur in real-time teaching: interns could listen to how the teacher was phrasing questions, notice where and how the teachers and students were sitting to encourage discussion, and focus on evidence of student learning in their responses. When observing discussions live in real classrooms or during modeling, interns might not be able to focus on all those aspects of practice at once. Video recordings allowed them to re-visit the discussion several times and consider each layer of what was happening.

Both images created by modeling and videos, provided representations that could be examined by the class as a whole. It would be impractical to take all 43 interns into a real classroom and observe teaching, therefore the representations helped bring the "practice" into the practice-oriented methods course so the interns could analyze and learn from these representations together. In this way, they could see and discuss coherent images of teaching that they would not have from the variety of experiences they had in their separate, yearlong internship classrooms.

Decomposition in Images of Practice

When interns observed Meg modeling discussions, they were watching her enact the practice of guiding science discussions in an integrated way versus breaking it down into its individual actions or teaching moves. Therefore, modeling did little to decompose practice. However, when showing videos and encouraging analysis of different aspects of the teaching represented, Meg was decomposing the practice into smaller, identifiable components. For example, Meg and the interns focused on the language the teacher used to invite students to share and feel ownership of their ideas. This was one component of the work teachers do while guiding science discussions. They also analyzed how to set up the classroom for discussion, by using evidence from the video of how students were seated and how the teacher chose to sit with them. These were smaller aspects of the practice that interns could learn and enact. Eventually, those concrete aspects would be integrated into more polished teaching practice.

Approximation in Images of Practice

Meg's modeling did not offer opportunities for interns to approximate practice, as interns were left in the role of "student." While watching the videos, the interns considered why a teacher made particular moves, so they approximated some of the reasoning that underlies teachers' actions. However, they were not engaged in enacting particular teacher actions themselves.

Focused Teaching Experiences through the Lens of Grossman's Framework

Focused teaching experiences included targeted rehearsals of teacher talk, peer walk-throughs of lesson plans for discussion, and small-group teaching enactments in real elementary schools.

Representation in focused teaching experiences

As Meg engaged the whole class of interns in targeted rehearsals of the ways they could phrase questions or respond to student ideas during a discussion, this created representations of practice for the interns. For example, when some interns were offering their ideas about how to phrase follow-up questions to push Sam and Bridgette's thinking about their modeling of the full moon, other interns were watching that interaction as a representation of the follow-up questions and comments teachers could use (Example

19). Similarly, during peer walk-throughs, the interns that were not taking the role of the teacher, acted as elementary students, and the ways their peer was phrasing questions and guiding the discussion acted as a representation of practice to discuss and analyze as a group. Finally, during the small-group teaching enactments in the elementary classrooms, the partner teachers that were helping with management issues and video recording the enactment, also had time to step back and observe what the intern was saying and how students were responding.

Decomposition in focused teaching experiences

During targeted rehearsals, Meg chose a particular component of practice to work on with interns. For example, she had them rehearse how to phrase questions or how to respond to student misconceptions. In this way, the targeted rehearsals broke down the larger practice of guiding science discussions so interns could work on rehearsing manageable parts. Peer walk-throughs provided opportunities to enact several components of discussions together in a continuous discussion; however, interns often stopped to work on a particular piece, such as deciding how to record student responses. Small-group enactments provided the supportive settings for interns to try to put a lot of the components of practice together in real-time; therefore, there was very little evidence of decomposition.

Approximation in focused teaching experiences

Just as "…approximations are designed to focus students' attention on key aspects of the practice that may be difficult for novices but almost second nature to more experienced practitioners (Grossman, Compton et al., 2009, p. 2078)," the targeted rehearsals provided opportunities for interns to practice aspects of discussions that were identified as challenging by their experienced teacher educators, Meg and Shelly. Targeted rehearsals focused on phrasing questions to help students do the cognitive work, since being purposeful with their language to support teaching was not something that was natural to interns. Interns often wanted to ask "yes/no" questions because they provided an instant result of whether or not the student had the right answer or not. Meg helped interns realize that responding "yes or no," even when choosing the correct answer, was not enough evidence to really grasp a student's understanding of a scientific concept. She guided interns to rehearse asking questions that went beyond yes or no and pushed students to revise and build their ideas over time. During targeted rehearsals, the interns practice several aspects of the content themes presented in Chapter 4: putting the cognitive work back on students, including all students in the discussion, and steering the discussion towards learning goals.

Targeted rehearsal of how to push Sam and Bridgette's thinking in Example 19, presented interns with authentic issues that Meg experienced in her own teaching: students often shared a misconception and struggled to pinpoint their error. What was less authentic and therefore made targeted rehearsals a powerful approximation of practice, was that the rehearsals did not take place in real-time or with real students. That is, the interns had more time to think of how to respond to the students, and had the added benefit of being able to brainstorm collaboratively with their peers. By focusing on a challenging aspect of discussions, how to guide students to revise their thinking, Meg provided opportunities for interns to discuss the pros and cons of using particular questions or making particular comments to guide a discussion.

In real teaching, they would not have so much time or the input of peers and Meg to make decisions in the moment. However, as interns just learning how to guide discussions in science for the first time, this approximation of practice was worthwhile for preparing them to translate the content of guiding discussions they were learning in the methods course into teaching actions.

Peer walk-throughs were authentic in that interns were practicing what they would say and what questions they would ask as they used the lesson plans for their next teaching enactment. However, they were approximating practice by taking turns playing the role of teacher with a group of their peers acting as elementary students. During walk-throughs, interns moved among the role of teacher, elementary student, and intern preparing to teach. For example, they would practice teaching and sometimes stop to problem-solve about anticipated or emerging issues in their plan. Thus, the walk-throughs engaged the intern who was rehearsing in enacting practice, but also provided interns the time to sort out their reasons for doing things and to try different variations of their plans before finalizing their lesson plans.

Preparing the detailed lesson plans for the walk-throughs was also a form of an approximation of practice. By preparing detailed lesson plans, interns generated a list of questions to ask students, anticipated a range of possible student responses, and listed follow-up questions they might use. Revising plans together in teaching groups allowed interns to slow down and collaboratively brainstorm with peers. They also had more time to prepare for the ways they would talk about and respond to the difficult science content that could come up. This additional time to consider alternatives was important when preparing for teaching, as the interns were still developing the skills needed to make those decisions in the midst of teaching.

Small-group teaching enactments took place in designed settings at elementary classrooms, where several aspects were authentic to real teaching practice: interns guided discussions with real students, in real classrooms, using real curricular materials that elementary teachers in the district were expected to teach. This designed setting, however, reduced the complexity and authenticity of real classroom teaching by having interns teach a small group of students. Thus, each intern had less student ideas to record, manage, and guide towards the learning goals. There was also a partner teacher and classroom teacher available to help with management issues that could be distracting or overwhelming while trying to keep track of student ideas and guide thinking. That is, management issues were made less of an obstacle so that interns could focus on complex aspects of guiding discussions like phrasing questions to steer thinking towards learning goals. Also, the interns were not responsible for teaching the entire unit. Instead, they could focus on preparing for particular types of discussion (e.g., the launch, discussions of data, etc.). It allowed them to work on a fairly constrained range of practices and have time in between enactments to debrief, reflect and make plans that built on what happened in the previous discussion.

In addition to reducing complexity, the designed setting in the elementary schools created low-risk conditions for interns to try enacting the challenging practice of guiding science discussions. These discussions were supplemental to what the elementary teacher was already teaching in the classroom; in other words, the additional opportunities for discussion with the interns provided the elementary students with extra support on a topic the students were exploring with their classroom teacher anyway. Also, there were no assessments that interns were responsible for preparing the students for since they did not teach the entire unit; thus, the interns did not have to worry about "teaching to a test" and could focus on developing their ability to guide science discussions instead.

The teaching enactments in real elementary classrooms engaged interns in supported versions of practice; they were supported with the preparation done in class, the suggestions from their teaching team, the logistical and management support while teaching, and the debriefing process afterwards. In sum, the focused teaching experiences offered a range of approximations of practice: Figure 6.1 illustrates how using approximations of practice as a lens mapped the practice-oriented approaches on a continuum of increasing authenticity and complexity[23].

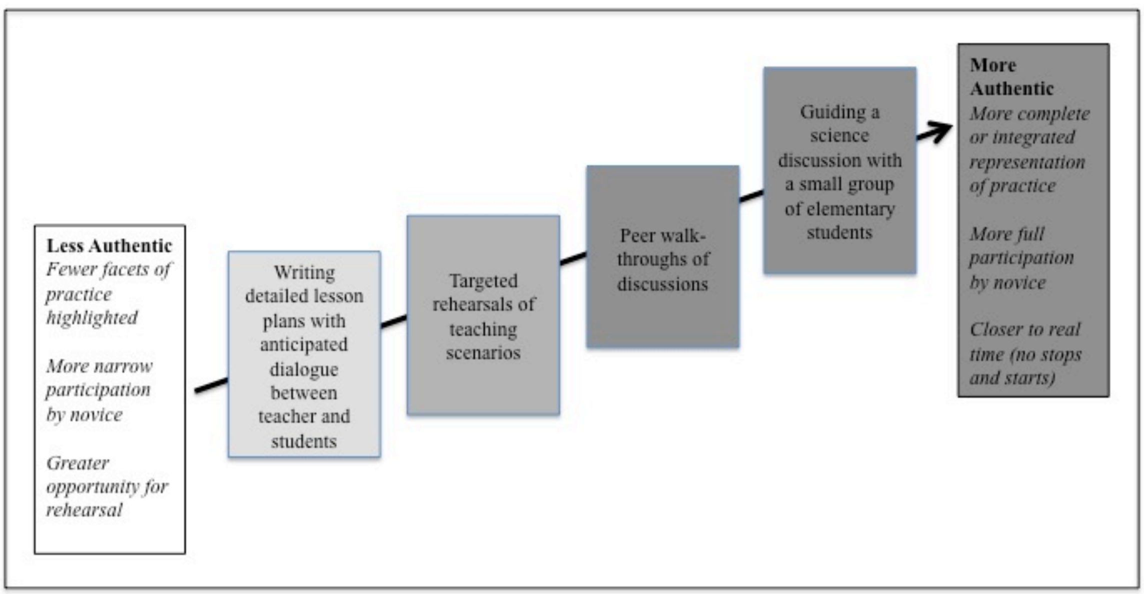

Figure 6.1. A continuum of practice-oriented pedagogical approaches that approximate practice (figure style adapted from (Grossman, Compton et al., 2009, p. 2079)).

[23] Grossman and colleagues presented a similar figure to represent the range of approximations they identified in their cross-professional study of preparation for professional practice. To create Figure 7.1, I replaced Grossman's examples with course activities from ED 528 in the middle four boxes. The rest of the figure was reproduced exactly.

Guiding analysis of discussions through the lens of Grossman's Framework

Guiding analysis of science discussions included joint problem-solving sessions while planning for discussions in course sessions, and structured debriefing of interns' teaching and observations of others' teaching.

Representation in guided analysis of discussions

During joint-planning, Meg led interns through PBIS and FOSS units, and helped them determine where to add discussions and what the purposes of the discussions should be to help guide student thinking in the unit. The curricular guides for these units included lists of questions to ask during discussions, or possible ways to encourage students to share ideas about a concept. These guides provided representations of what to consider when preparing for a science discussion: they made the planning phase of guiding discussions visible while keeping the interactive aspects hidden. Structured debriefing, in the form of a discussion led by Meg or by written take-home message prompts, provided images of the post-active reflecting phase teachers participate in after teaching to prepare better for their next teaching enactment.

Decomposition in guided analysis of discussions

Planning for discussions involved decomposing the larger practice into components that interns could focus on individually during their planning. For example, interns focused on how they would open the discussion by drawing on prior ideas from students, then how they would phrase questions and comments to guide student thinking, and how they would record student ideas. When debriefing what Meg modeled or their own practice, interns broke down practice so they could talk about components and how they all worked together. For example, on the first day of class, interns reflected on Meg's launch discussion and identified the components of what should be included in the launch discussion of a unit. They included components such as introducing the essential (or big) question, giving ownership of ideas to students, eliciting prior knowledge, and using student ideas to catapult the discussion further.

Approximation in guided analysis of discussions

Joint planning was authentic to the pre-active phase of teaching, in that planning is a task that real teachers do, and issues that real teachers must anticipate and prepare for surfaced. However, joint planning provided far more supports than what teachers would have when planning on their own. Interns were guided towards key aspects of a discussion that they should attend to, and had opportunities to share their thinking and revise their plans with input from their fellow interns.

Structured debriefing also included elements of the work teachers do after teaching (i.e., reflecting on what students learned, what misconceptions surfaced, where they need to go next). Debriefings of their own practice were authentic in that the interns used information from their debriefing to help plan their next teaching enactment. Again, the complexity of this task was reduced, however, as interns were only asked to analyze particular aspects of their teaching at a time. For example, sometimes interns focused on the use of language, other times they focused on their ability to orient student ideas to one another. Also, they only had to examine their interactions with a small number of students, instead of facing the complexity of unpacking what happened in the enactment of a discussion with a whole class of students. Joint planning and structured debriefing did not approximate the interactive aspects of teaching.

Utility of Grossman's Framework for Analyzing Pedagogical Approaches

By using Grossman's framework for analyzing each of the pedagogical approaches used in ED 528, I was able to unpack how pedagogical approaches were practice-oriented. For example, when rehearsing how they would respond to prompts that Meg was acting out during targeted rehearsals, interns were engaging in practice, but at a slower pace. Therefore, careful attention could be given to important aspects of guiding discussions that could be overlooked in the midst of real practice. By analyzing if the pedagogical approach decomposed the practice so it can be taught and learned, represented practice, or provided approximations of practice, I can argue for the utility of particular pedagogical approaches and how they can be revised to better prepare interns for practice.

Table 6.1 illustrates what aspects of Grossman's framework were most apparent in each of the pedagogical approaches identified. The images of science discussions, when debriefed and analyzed, aligned best as representations, as they offered representations of practice for interns and teacher educators to discuss and learn from together. The focused teaching experiences aligned strongly as approximations of practice. They provided opportunities for interns to practice enacting science discussions in structured situations that restricted the range of what interns were expected to do. Joint-planning offered opportunities to decompose the practice of guiding science discussions so interns could better plan for different aspects of it. Structured debriefing decomposed practice so it could be analyzed for evidence of what was working and what was not working in promoting student learning through discussion. Planning approximated the pre-active phase of teaching, and structured debriefing approximated the post-active phase of teaching.

Despite some pedagogical approaches making practice available in some ways more than other (see Table 6.1), they all focused on the practice of guiding discussions in ways that helped interns learn to engage in the pre-active, interactive, and post-active phases of this high-leverage practice. As course activities where these pedagogical approaches were used are refined to maximize intern learning, it could be useful to use the three parts of Grossman's framework as a way to analyze the degree to which course activities are being "practice-oriented."

Table 6.1
The degree to which seven pedagogical approaches in ED 528 decomposed, represented, and approximated practice.

	Decomposing practice	Representing practice	Approximating practice
Modeling discussions	-	x	
Watching videos of discussions	x	x	
Targeted rehearsals	x	-	x
Peer walk-throughs	x	-	x
Small group teaching enactments		-	x
Joint planning	x	-	x
Structured debriefing	x	-	x

Note:
An "x" denotes the primary way the pedagogical approach made the practice of guiding science discussions available to interns. A "-" denotes the indirect ways the pedagogical approach made the practice of guiding science discussions available to interns.

Possible Limitations of Grossman's Framework for Analyzing Pedagogical Approaches

While Grossman's framework was very useful in my analysis to uncover the ways the pedagogical approaches were practice-oriented, there were some aspects of what Meg and Shelly did in the practice-oriented course to prepare interns for reform-based teaching that were not captured well by looking for decomposition, representation, and approximation. For example, the framework did not help capture the role of "meta-talk," or the instances where Meg talked about what she was saying or doing. Meg often explained the rationale for why she was phrasing a question a certain way, or why she was making a particular decision about what teacher action to use. The role of hearing about an experienced teacher's decision-making about possible problems that arise during teaching did not necessarily decompose the parts of practice, but instead provided a commentary on practice for interns to relate to their developing ideas about teaching.

The role of real-world anecdotes to provide backing for the teacher actions and rationales Meg provided was also not captured by Grossman's framework. While the justifications for the content themes did come from current theories on teaching and learning, Meg often chose to share an example from her own teaching experiences instead of referring the interns to research they had little opportunity to study. In Example 29, when responding to an intern who was hesitating to bring potentially inaccurate student ideas to the forefront in a discussion, Meg assured him that she had never seen this teacher action lead to students being more confused: "…I've never had that experience in my classroom…" The ways personal anecdotes might help build rapport with interns and give “real-world” insights were not captured by my analysis with Grossman’s framework.

Finally, the role of images of reform-based science teaching was not captured fully by Grossman’s framework when analyzing the experiences of interns during modeling or while watching videos. Only when studying the videos and modeling during debriefing, did the images act as representations of practice. However, when interns were experiencing reform-based science teaching as students (during modeling) or watching a successful elementary science classroom discussion (in the video-clip), it was less the analysis and more the exposure to the images that was important. The images were being used as “visions of the possible,” and were used in some way, to get intern “buy-in” for the effectiveness of classroom discussions in elementary science teaching. Grossman’s framework did not allow me to analyze what was valued or highlighted by the interns by having access to those images.

CHAPTER 7
CONCLUSION

Re-Visiting the Research Questions

This dissertation study focused on describing the ways prospective teachers (interns) experienced opportunities-to-learn the practice of guiding science discussions in a practice-oriented science methods class. To unpack the opportunities-to-learn, I first reported *what* was being taught (the content) and *how* it was being taught (the set of pedagogical approaches) by addressing the following two research questions:

1. What was the content of guiding science classroom discussions that surfaced during practice-oriented course activities and
2. In what ways did the pedagogical approaches make this content of guiding science discussions available to interns to learn?

The Content of Guiding Science Discussions

The first research question, *what was the content of guiding science classroom discussion that surfaced during practice-oriented course activities,* led to the five content themes. The five content themes included: 1) creating a classroom culture to support discussions; 2) supporting students to do the cognitive work; 3) breaking down traditional teacher and student interactions; 4) foregrounding student ideas and questions; and 5) steering discussions towards the learning goals. Each theme had an associated set of teacher actions that were brought up throughout the course. Furthermore, some were actions teachers carry out before teaching (e.g., consulting the state standards and unit goals, anticipating student misconceptions), some were actions to enact during teaching (e.g., eliciting students' prior knowledge, asking open-ended questions) and others were actions teachers carry out after teaching (e.g., choosing student contributions to use in next discussion). The careful and purposeful use of language influenced teacher actions (e.g., phrasing questions to invite all students into discussion, phrasing responses to place cognitive work on students) across all five themes in the analysis of the course sessions.

Instead of learning the reasons why a teacher would enact particular actions while guiding a discussion first, and then practicing how to actually enact those actions while teaching later, the practice-oriented design of ED 528 surfaced both the rationale for doing something and how to do it in an integrated way across course activities. Consider the example I presented earlier, of interns rehearsing how to respond to Meg acting as students struggling to use a model to explain moon phases (see Example 19). While the interns practiced what they would actually say and do next based on student responses that Meg provided, Meg was also providing them with the rationale or reasons for making particular choices. For example, when the interns were thinking of how to respond to the students' confusion in using the model to illustrate full moon instead of new moon, Meg also highlighted the importance of steering the discussion towards the learning goals without directly telling the students that they were wrong and providing the right answer. She reminded interns to guide the students to figure it out on their own (i.e., to do the cognitive work) and if they continued to struggle, to find ways to invite other students into the conversation to help. Teaching practice (what teachers do) was always at the forefront of the course activities, and directly reduced the disconnect between theory and practice in teacher education programs, which is often blamed for prospective teachers' struggles in moving to enactment (Ball & Cohen, 1999; Brown et al., 1989; Putnam & Borko, 2000).

Pedagogical approaches to teach the practice of guiding science discussions

Three main pedagogical approach themes were identified in response to the second research question, *in what ways did the pedagogical approaches enacted in the course make this content of guiding science discussion available to interns?* These themes were creating images of practice, providing opportunities for focused teaching experiences, and guiding analysis of science discussions.

By modeling how to guide a discussion and showing videos of others guiding discussions, Meg was able to create images of what an inquiry-based science discussion looks like. It was important to provide these images since many interns had images of more traditional science teaching from their own experiences as students or from their observations in their yearlong classroom internships (Haefner & Zembal-Saul, 2004; Lortie, 1975).

Focused teaching experiences provided opportunities for interns to start to work on the different actions involved in guiding science discussions. Interns practiced enacting aspects of discussions in settings with reduced complexity and authenticity, so they were not faced with the overwhelming challenging of learning everything at once. Some focused teaching experiences were less authentic, such as interns brainstorming ways to respond to hypothetical students or to their peers acting as elementary students during targeted rehearsals and walk-throughs. Others were closer to authentic teaching, in that they took place in real elementary classrooms with real students, but were still designed to reduce the complexity of the practice so interns could learn.

Finally, by guiding analysis of science discussions, Meg guided interns to anticipate possible obstacles in their lesson plans and to learn to analyze the parts of a discussion so they could prepare better for them. Structured debriefing helped interns analyze their practice and others' practice for evidence of what was or was not supporting students' learning during discussions.

Limitations

There are a few important limitations to this study that are important to keep in mind when considering the implications of the findings. First, because there is no evidence of how the interns enacted science discussions in their fieldwork settings, student teaching, or early careers, this study cannot make any claims about the long-term effects of the practice-oriented science methods course on interns' future teaching and whether or not it supports elementary students' learning.

Also, it is possible that there were measurable differences in the successes of interns teaching the moon phases unit, which was more abstract and required modeling, versus the rocks and minerals unit, which involved more concrete investigations with actual model rocks and minerals. Because I studied the content of guiding science discussions and practice-based pedagogical approaches in the class as a whole, I cannot make claims about how interns teaching either unit may have had different needs, experiences, and outcomes on their learning how to guide science discussions. However, based on some take-home messages and observations in class, it seemed that content struggles appeared more often with interns teaching the moon phases unit.

Finally, in terms of sampling, due to my purposeful sampling strategies, the four interns in the focal group ended up being very reflective and dedicated to making the most of their experience in the course. While some groups became discouraged or had disagreements or difficulties getting along, the focal group worked well together. Studying more than one group may have helped see what variations arise in how interns learn while planning, practicing and enacting science discussions together.

Implications

This study can be viewed in two ways. First, it can be seen as an application of the current calls for reform in teacher education towards more practice-oriented approaches (Ball & Cohen, 1999). Specifically, it is the study of a course designed to be more practice-oriented, and to include more pedagogies of enactment to the more popular pedagogies of investigation. That is, it focused on preparing elementary science teachers to learn to *enac*t teaching, especially the practice of guiding science discussions, versus just talking about it. This work provided rich descriptions of what can be taught about practice and how it can be taught when there is a focus on practice in science teacher preparation. If viewed in this way, the results of this study have several implications for teacher educators who may be trying to make their science methods courses more practice-oriented as well.

The other way to view this study is as an effort to contribute to the development of a common language for studying the preparation of elementary science teachers and teachers across subject-areas and grade levels. These implications are directed towards researchers, who could benefit from having common ways of representing the content of practice-oriented courses and for comparing pedagogical approaches and their outcomes across methods courses in the United States.

Designing practice-oriented science methods courses

This study attempted to better define what practice-oriented preparation might look like in a science methods course context. The findings led to several implications for the design of practice-oriented science methods courses: where they take place, what content about the practice of teaching might be taught, and the need to prepare teacher educators to take the roles required in practice-oriented pedagogical approaches.

Settings. With a focus on preparing today's prospective teachers to enact reform-based practices, this study offers teacher educators with examples of how experiences across formal methods course settings (i.e., university classroom and community center classroom) and real school settings (i.e., Garden City elementary classrooms) tackled two common obstacles faced in science teacher education. First, the course engaged interns in experiences across both formal methods course classrooms and real elementary classrooms in an effort to reduce the disconnect between coursework and fieldwork. Coherence in messages across these settings resulted from a shared focus on guiding science discussions. Planning and debriefing experiences in the methods course aligned with the small-group teaching experiences so interns could connect their knowledge of "what to do" with opportunities to try practicing "how to do it." Furthermore, ED 528 designed the elementary school settings so interns could be supported to experiment with reform-based practices without push-back from veteran teachers to teach in more traditional ways.

Cochran-Smith and Zeichner asserted: "When the teaching practices that are allowed and encouraged by teachers in field experiences are congruent with the teaching practices advocated by teacher education program instructors, it is much easier to help prospective teachers move from simply wanting to implement a desired practice to actually being able to do so" (2005, p. 15). The alignment between what was being taught and practiced across the three course settings provided coherence, and a deliberate effort to remove influences that might discourage prospective teachers from trying reform-based approaches in real classroom settings was made. In sum, this study does not argue for holding the methods course in one setting over another; instead, it provides evidence for the affordances of created coherent experiences across multiple settings that allow interns to work on different aspects of practice (i.e., planning and debriefing versus enacting science teaching with students).

The content of science methods courses. The content themes that were identified in Chapter 4 could be used to create tools that could be used by teacher educators, interns, and cooperating teachers in fieldwork or student teaching classrooms. For example, Figure 7.1 provides an example of a practice profile that could be used to represent the content of guiding science discussions. The teacher actions and associated rationales listed in the practice profile were discussed during the practice-oriented course where interns were actually trying to enact the practice while learning different aspects of the practice: therefore, the profile is grounded in practice, or what teachers actually do. Larger content themes included underlying rationales (e.g., supporting students to do the cognitive work) and specific actions (e.g., record student contributions) are presented together in the course and in the practice profile, highlighting the importance of helping interns make connections between theory and practice in the methods course instead of asking them to do it on their own when faced with greater teacher responsibilities.

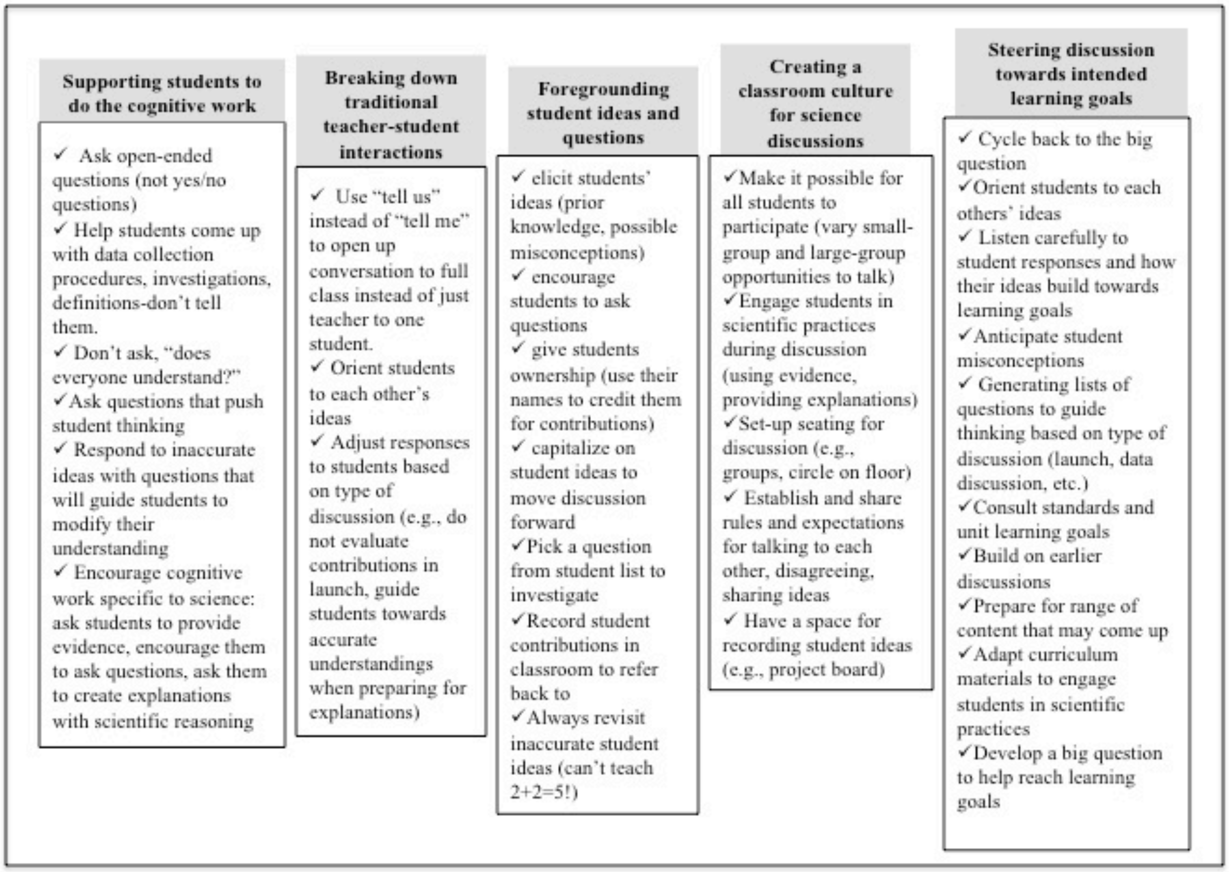

Figure 7.1 Sample practice profile for guiding science classroom discussions.

The practice profile could act as a tool for designing course activities around the high-leverage practice of guiding science discussions. For example, to help interns address Science Teaching Standard B, "orchestrating discourse among students about scientific ideas" (National Research Council, 1996, p. 32), teacher educators could organize their syllabi using the practice profile. For example, course activities would be organized around teacher actions and rationales that make up practice (e.g., phrasing questions to push thinking, recording student contributions) instead of a set of topics to discuss (e.g., what is inquiry, how do students learn science, what is the role of discourse in science). Teacher educators could use agreed upon practice profiles across different courses so several aspects of learning to guide classroom discussions could be talked about with similar terms for actions and rationales in math, science, reading, social studies and other subjects. This would be helpful for prospective teachers who are often faced with different terms and ideas about teaching in each subject-area methods course.

In addition to being used as a design tool by teacher educators, the practice profile could be used as a tool by interns to track their developing practice during their first years of teaching. For example, they could use the practice profile to debrief their teaching experiences and pinpoint possible areas of weaknesses or teacher actions that they use more or less than others. It is important to note that using the practice profile as a simple checklist of things to do is not the intention. Pedagogies of enactment such as targeted rehearsals, peer-walk throughs, and small-group enactments should be used to help interns use teacher actions deliberately by considering what their intention is by asking a particular question or responding to a student in a particular way. That is, simply completing "actions" without considering the underlying rationales and purposes for using particular actions, in particular interactions with students loses the interactive nature of teaching practice. The practice profile, however, can help remind interns of key aspects of discussions to consider and provide them with a tool for knowing where to start when faced with the complexity of teaching. Atul Gawande has reported the importance of checklists in the work of surgeons, pilots, and military professionals (2010). He reported that many surgeons were skeptical and even resistant to the idea of using checklists to remind them of basic steps to remember during surgery. However, his work reports that checklists helped surgeons catch several issues (e.g., performing surgery on the wrong side or not checking for patients' allergies to medicine) that could have led to potential complications during surgery. In this way, checklists do not take away the “thinking” and “decision-making” that professionals must do; instead, they act as a guide for helping professionals avoid overlooking important aspects in the midst of real-time work. Similarly, the practice profile does not outline what a teacher should say and do each minute of a science discussions, but instead, it provides a guide for the five big themes they should keep in mind and offers possible starting points (e.g., actions based on associated rationales) to help them enact those themes as they make decisions about what to say and do during a discussion.

Finally, the practice profile could also be used to communicate the practices taught in the university setting to interns’ cooperating teachers in their yearlong internship classrooms. Instead of expecting the cooperating teachers to read all the literature about reform-based teaching, they could be provided with a practice profile as a map of what the interns should be working on in their classrooms. This might help cooperating teachers have a better sense of what to look for while observing the interns and might help them provide more focused feedback that better aligns with the messages from the methods course.

It is important to note that this practice profile is the product of the analysis of one science methods course with an experienced teacher educator, during its pilot implementation of a design that more explicitly focused on the practice of guiding science discussions. Therefore, the practice profile is not exhaustive, and will require several rounds of refinement as more data from practice-oriented science methods courses are collected. Specifically, studies of other science methods courses that focus on related practices with different emphases may be able to add to the content of guiding science discussions. For example, in a course that focused more specifically on guiding interns to teach "science as argument," more specific actions for using evidence and creating explanations may be added to the profile (see Zembal-Saul, 2009 for a detailed framework for teaching science as argument). Instead of having several representations that only hold meaning in a particular science methods context, it would be best to have a standard practice profile for a set of high-leverage practices that could be adopted across teacher preparation programs. Based on the goals of a particular course (e.g., science as argument or teaching with PBIS), teacher educators and interns could then add the ways their particular approach impacts the agreed upon aspects of the practice profile.

Pedagogical approaches and the role of teacher educator. This study also provided detailed examples of what it means to use practice-oriented pedagogical approaches in a science methods course. The way images, focused teaching experiences, and guided analysis of science discussions were designed to bring practice to the forefront was shared in a set of extended examples in Chapter 5. These examples uncovered several demands on the teacher educator that should be considered when designing the teams of instructors for practice-oriented methods courses. For example, while leading the targeted rehearsal in Example 19, the teacher educator had to move among the role of teacher educator, elementary science teacher, and elementary student to help guide interns to consider how they would respond to student misconceptions in the midst of a classroom discussion. As the teacher educator, Meg had to know what aspects of the discussion to highlight and what particular problems and challenges to bring up for the interns to tackle so they could learn about carefully selecting questions and responses during discussions. In order to model ways of phrasing questions and responses, she took on the role of elementary science teacher, and acted out what a teacher would say or do based on the interns' suggestions. Finally, she took the role of an elementary student, based on her experiences working with students, to act-out possible comments students would say so interns could brainstorm possible responses as teachers. As she moved back and forth through these roles, the teacher educator also had to be comfortable translating more theoretical ideas about teaching into practical language that could help interns grasp the rationale for using particular teacher actions. Additionally, the use of pedagogies of investigation and pedagogies of enactment to respond to the needs of the interns (see Figure 5.10) required the teacher educator to flexibly help interns "study" particular aspects of teaching and then also learn to "enact" those practices in more or less authentic settings. Thus, the examples of the range of pedagogical approaches used in the course have implications for the way science methods course designers put together teams of teacher educators for practice-oriented courses.

Laying the Groundwork for a Common Language

Common language for talking about "practice." In Chapter 1, I introduced the many meanings of the term "practice" in the current teacher education literature (Lampert, 2010). After attempting to use the many uses of the term "practice" throughout this study, I will now revisit the meanings and add clarifications to ways the field may choose to talk about practice based on the findings from this study. Table 7.1 revisits the terms from Table 1.1 by providing an additional column to possibly help clarify ways of talking about practice for the field. First, instead of referring to the theory versus practice divide (meaning 1, Table 1.1), it could be more useful to discuss the theories behind teaching and learning versus the clinical work of teaching. That is, there are many theories about how people teach and learn (Bransford et al., 2000); however, there are also clinical, interactive aspects of teaching (Grossman and McDonald, 2008) that refer to the relationships between teachers and students and concepts in a particular subject-area. In the methods course, interns worked on those interactive aspects of teaching by experiencing pedagogies of enactment in the methods course and in elementary classroom settings. They later worked on those clinical aspects of teaching in their yearlong internship classrooms.

Table 7.1
Revisiting the use of the term "practice."

Use	Meaning	Clarifying meaning based on working with these terms in this study
1. *Practice* v. Theory	The dichotomy of practice (what teachers do while teaching) versus theory (what teachers know about teaching).	The dichotomy of studying the theories behind teaching and learning (in methods courses) versus engaging in the clinical work of teaching (through pedagogies of enactment and fieldwork)
2. Teaching as a collection of *practices*	Practices (plural noun), referring to the things teachers do. In this study, the science methods course will focus on the development of the practice of guiding science classroom discussions.	Teaching is made up of a collection of practices, and those practices (at different grain sizes yet to be agreed upon in the field), are made up of several teacher actions with associated rationales.
3. To *practice* doing something	This is the most common everyday use as a verb: to practice means to do something repeatedly to get better at doing it.	Pedagogies of enactment were introduced as ways for interns to "practice" the work of teaching
4. The *practice* of teaching	Practice here refers to the shared set of work that people in a profession do—just like the "practice of law" or 'practice of medicine." This meaning captures what I mean by "practice-oriented" course.	The practice of teaching or the work of teaching can be divided into practices, and then further into actions with associated rationales.

In Figure 2.3, I illustrated how the practice of teaching (meaning 4, Table 1.1) represents the work of teaching that represents the collective work teachers do as professionals (Ball & Forzani, 2009; Lampert, 2001) and this overall work of teaching can be broken down into practices at different grain sizes (meaning 2, Table 1.1). In this study, I chose to focus on the practice of guiding science discussions. It is a "practice," because it is something that teachers do as a part of their clinical work as professionals. The things teachers do and say while enacting a practice like the practice of guiding science discussions have been broken down and labeled differently in the literature: for example, some have identified parts of practices as teacher moves (Moore, 1979), discourse moves (Krussel, Springer, & Edwards, 2004) or techniques (Boerst, Sleep, Ball, & Bass, under review).

In this work, I have called what teachers do and say while enacting a particular practice, teacher actions. Those teacher actions were all associated with rationales that supported the five content themes that were identified. If teacher educators can choose which high-leverage practices are the best to focus on during teacher education programs, they can begin to identify and study the teacher actions and associated rationales that make up those practices. Teacher educators can then provide prospective teachers with opportunities to engage in pedagogies of enactment to practice (meaning 3, Table 1.1) how to draw on the associated rationales to know when and how to use a particular action in the midst of teaching. In other words, simply learning a set of actions is not the work of teaching; instead, teachers must learn to make sound judgments using the associated rationales for why particular actions will best guide student learning in particular interactions during teaching.

Finally, it might be useful for the field to draw on the Ball and colleagues' focus on specifying the content and pedagogical approaches in a practice-oriented course as well as the content themes from this study to shift how they try to define and label "practices" (meaning 2, Table 1.1). They could think of what makes up the work of teaching as the "content" of a course instead of using particular terms (discourse moves, strategies, etc.). In this way, teacher educators and researchers can focus more on, "what does it mean to teach interns *how to* guide science discussions," versus worrying about what to call the different parts at different grain sizes.

Common language for the content of high-leverage practices. A weakness often identified in the teacher education literature is that a universally accepted way of talking about teaching within and across subject areas and grade levels does not exist (Feiman-Nemser, 2001; Grossman & McDonald, 2008; Lortie, 1975). Teacher educators may differ in the way they label and name, describe, and breakdown practices, such as guiding science discussions, even when they are teaching courses in the same subject-area or the same university teacher preparation program. As practice-oriented approaches are being studied in different teacher education contexts, products of this work should be used to communicate across these contexts in an effort to build a common language. For example, in this study, the "practice profile," offers a set of terms or labels for the things teachers do while guiding a science discussion. Future research in other methods courses may attempt to add to, modify and refine this profile. In other words, this profile can be considered a "working draft" of the practice of guiding science discussions which would be open to critique and evidence-based changes from future studies of prospective teachers learning this practice.

Grossman and McDonald call for a common language and common set of instruments to unite the research community so, "…researchers can build on prior work and communicate their findings more powerfully both to each other and to practitioners" (2008, p. 198). Because guiding classroom discussions has been identified as a high-leverage practice that teachers must enact across all subject areas, efforts to study the ways this practice profile can apply across subjects and the ways it is subject-specific would further the ability of teacher educators to have a common language. For example, math educators and science educators may be able to agree on common moves that teachers can do to support students in doing the cognitive work, such as asking open-ended questions. However, science-specific moves may involve pressing students for scientific evidence from data or encouraging students to provide scientific reasoning.

Identifying commonalities and subject-specific differences across content areas would be especially beneficial for elementary teachers who must teach several subjects. Instead of learning a new set of terms and teacher moves in each subject-area methods course, they could use a common set of "practice profiles" for a core set of high-leverage practices, and then learn the subject-specific ways to enact them in each methods course. All teachers elicit prior knowledge and record student contributions (either publicly or to track student ideas themselves); however, discussing how eliciting prior knowledge and recording student contributions is similar and different when teaching about magnets versus teaching about fractions is what requires teacher educators and researchers across subjects to have a common way to talk about practice. If teacher educators continue to refine a starting profile and work on improving approaches for teaching them, it will be possible to move towards a common way of discussing the content of high-leverage practices and how to teach them to prospective teachers.

In addition to researchers being able to communicate across the field, the practical language that Meg used to talk about "how to do" the practice of guiding science discussions provides the beginnings for language teacher educators need to make the theoretical ideas about science teaching more practical for interns to enact. Meg translated a lot of abstract ideas about science teaching and learning into everyday terms that were accessible to interns and helped them "do" teaching instead of thinking about teaching. For example, she used phrases like, "you need to steer the car," "join the students on the rim of the tire," "don't stop at the crème brulee understanding," and "we're not teaching 2+2=5!" to help interns have the practical language that would guide them while teaching. Being able to capture the most effective analogies, examples, and descriptions that teacher educators use when supporting interns to enact practice would help to build a language for talking about and evaluating an interns' developing teaching.

Common language for comparing practice-oriented approaches and their effectiveness. Grossman and colleagues framework for teaching professional practice offers a subject-neutral way of analyzing practice-oriented approaches in teacher education. Whether examining the pedagogical approaches in a math, literacy, science, social studies, or other methods course, evidence for how practice is decomposed, represented, and approximated can be analyzed.

By using the framework as a lens for unpacking the pedagogical approaches in ED 528, I was able to communicate features of the pedagogical approaches that could be compared to other courses. If studies of methods courses reported their results using similar language (e.g., representation, decomposition, approximation), claims about what approaches are more or less effective could be made with evidence across several methods courses instead of the more common study design of teacher educators studying their own courses (Clift & Brady, 2005).

For example, at the University of Michigan, there are school-wide efforts at the School of Education to focus teacher preparation on practice. In order to compare what I referred to as "walk-throughs" and what Lampert and Graziani call "rehearsals" in their analysis of pedagogical approaches used in a foreign language teacher education program (see Lampert et al., 2010; 2009), we need a common way of making sense of practice-oriented pedagogical approaches used across teacher preparation courses:

> Currently there are too few studies investigating similar questions and starting from similar theoretical bases to enable us to learn by aggregating across studies. The ability to aggregate is critical if we hope to learn about more and less effective practices as advocated by teacher education programs." (Cochran-Smith & Zeichner, 2005, p. 16)

One solution is to use Grossman's framework as a lens for analyzing how practice is decomposed, represented, or approximated in these two pedagogical approaches so we can compare the similar and different ways they help interns develop their practice. Across science methods courses, rubrics based on Grossman's framework could be used to compare whether or not prospective teachers in courses with different scores on the rubric do or do not enact particular practices successfully in their early teaching.

Consider three hypothetical methods course that were analyzed using a rubric[24] that identified how many opportunities interns had to see representations of practice, be introduced to decomposed aspects of practice, and to participate teaching in approximations of practice (see Table 7.1). Particular dimensions of each of these components of the framework could be included in a more detailed table to provide more information than just frequency. For example, approximations could be identified by their level of complexity and authenticity to real practice and by the role of the teacher educator in guiding the experience. Studies could compare the teaching practices of interns from these three methods courses during their yearlong internship and first years of teaching.

The interns' practice could be measured using observation protocols and scoring rubrics that identified what aspects of the "content" of a particular high-leverage practice were being enacted and the degree to which their enactment was guiding student learning. Outcome measures could also include student performance measures, after controlling for differences in the settings where the interns might be working. Overall, "…rather than conducting small case studies of individual courses or individual programs, teacher educators could agree to develop the same well-specified approaches to preparing teachers across institutions and then use common metrics and instruments for assessing these interventions and their outcomes" (Grossman & McDonald, 2008, p. 199).

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[24] I acknowledge that simply counting the frequency of these opportunities in a course may not be as meaningful as also including a rating of the quality and features of the representations and approximations. Table 7.1 is meant to outline a general study design idea and not to be considered an established analysis protocol.

Table 7.2
Sample of how analysis of pedagogical approaches with Grossman's framework can allow researchers to compare the effectiveness of methods courses

	Decomposition	Representations	Approximations
Methods course 1	xxxxxxxxxxxxxx	xx	x
Methods course 2	x	xxxxxxxxxxxxxxx	xxxx
Methods course 3	xxx	xxxxx	xxxxxxx

In this case, Methods courses 1-3 would be analyzed with the same rubric and would measure the same outcomes of teacher enactment of practices and student learning. This approach could help researchers make claims with evidence across multiple teacher education settings about what types of pedagogical approaches are best suited to preparing interns for practice. In the context of this study, translating the affordances and limitations of pedagogical approaches in ED 528 with the language of Grossman's framework makes it possible to compare pedagogical approaches in different courses, even if they are "called" different things.

While courses may be analyzed through the lens of Grossman's framework, they can also be designed based on this framework (see Davis, under revision; Nelson, in progress). Based on the sample findings in Table 7.1, course designers might realize that they offer many representations of practice, but need to provide more opportunities for interns to engage in approximations of practice. Teacher educators may also choose to map approximations in their course on a continuum like Figure 6.1. They may notice that they have several approximations that offer low complexity and a lot of support and then one approximation that is highly authentic (e.g., providing many walk-throughs in class throughout the methods course, and then asking interns to teach a full unit on their own in field placement). Thus, course designers might add experiences along the continuum that gradually increase to more authentic experiences or cycle through the continuum several times with different science content foci throughout the methods course.

Directions for Future Research

This study examined what opportunities-to-learn were made available based on the researcher's analysis and prospective teachers' reflections. This work is important for unpacking what is really happening in a practice-based methods course that is different from other methods courses. The short-term and long-term impacts of these experiences must be studied carefully in order to build the case for practice-oriented teacher education courses. In other words, simply shifting to new settings and changing the content of courses to focus on practices in the effort to connect theory to practice, is not enough to invest the resources needed to prepare teacher educators to do this demanding work and to have the resources at their disposable to do so. We need empirical evidence that focusing on particular high-leverage practices and using particular practice-oriented pedagogical approaches better prepare prospective teachers to enact these practices successfully beyond the science methods course and teacher preparation program.

Future studies should use standard rubrics to track individual interns' progress in developing a particular practice over time, both in science, and in other subject-areas. This way, preparation for high-leverage practices in subject-specific ways and general ways could be tracked. For example, does Intern A guide discussions as successfully in science as he or she does in mathematics? What aspects of guiding discussions in science seem to be more difficult for Intern A and why?

Studies are also needed to compare practice-oriented methods courses so well-supported ideas about the combinations of content and pedagogical approaches that most successfully prepare interns for the work of teaching. For example, a study might compare several courses like Methods Course 1 and several courses like Methods course 3 (see Table 7.1) to consider (both quantitatively and qualitatively) whether more approximations really do lead to interns successfully enacting particular teaching practices in their fieldwork. Furthermore, long-term studies are needed to explore if interns who begin to enact practices successfully in methods courses continue to enact them in their own classrooms during the first years of teaching. Even more important is finding evidence that their teaching results in improved student learning. For example, could Haley, a focal group intern, continue to enact several actions she learned in ED 528 when teaching her own class of elementary students about rocks and minerals? What would her students be able to say about the difference between rocks and minerals at the end of a unit where she enacted several classroom discussions to guide their thinking (see Example 25)? While this study was a necessary first step to articulating what the practice of guiding science discussions entails and how it can be taught, a careful examination of how the opportunities-to-learn in future iterations of this course are taken up and enacted beyond the interns' training is necessary for arguing that changes towards more practice-oriented preparation for teachers is warranted.

Final Thoughts

In closing, I wish to emphasize the potential benefits of using a common framework to analyze the pedagogical approaches used in teacher preparation courses. As this dissertation was being drafted, another graduate student was studying an elementary science methods course in the same university setting. The course used different curricular resources, had a different schedule for course sessions, and was taught by different teacher educators. However, we were able to compare the ways interns were working on science teaching practices in both courses by using Grossman's framework to describe how practice was being represented, decomposed or approximated in the course activities. Without attending the other methods course or watching videos of the course activities, I was able to understand how practice was being addressed in each course activity. The dialogue between our work motivates me to consider the ways more researchers can collaborate and share findings to understand how we can better prepare prospective teachers for not only the knowledge and dispositions they need for teaching, but also the skills and moves they need while actually enacting teaching. This dissertation offers insights for tackling the questions of what the content and accompanying pedagogical approaches of practice-oriented science teacher preparation might look like. Building a language cannot occur in isolation, and I hope my findings can enter many conversations to come as the field works to build teacher preparation programs to meet the needs of tomorrow's teachers.

APPENDICES

Appendix A
Essential Features of Classroom Inquiry and Their Variations

From: http://www.sedl.org/afterschool/toolkits/science/pdf/ast_sci_inquiry_table.pdf

Essential Features	More ◄---------------- Amount of Learner Self-Direction ----------------► Less Less ◄-------- Amount of Direction from Teacher or Material ---------► More **Variations**			
1. Learner engages in scientifically oriented questions	Learner poses a question	Learner selects among questions, poses new questions	Learner sharpens or clarifies question provided by teacher, materials, or other source	Learner engages in question provided by teacher, materials, or other source
2. Learner gives priority to evidence in responding to questions	Learner determines what constitutes evidence and collects it	Learner directed to collect certain data	Learner given data and asked to analyze	Learner given data and told how to analyze
3. Learner formulates explanations from evidence	Learner formulates explanation after summarizing evidence	Learner guided in process of formulating explanations from evidence	Learner given possible ways to use evidence to formulate explanation	Learner provided with evidence
4. Learner connects explanations to scientific knowledge	Learner independently examines other resources and forms the links to explanations	Learner directed toward areas and sources of scientific knowledge	Learner given possible connections	Learner given all connections
5. Learner communicates and justifies explanations	Learner forms reasonable and logical argument to communicate explanations	Learner coached in development of communication	Learner provided with broad guidelines to use to sharpen communication	Learner given steps and procedures for communication

Appendix B
Syllabus for ED 528

Education 528 - ELMAC 12
Teaching Science in the
Elementary and Middle School
Winter 2010

INSTRUCTOR: **Mary L. Starr, PhD**, Science Education,
Program Manager, IDEA Institute, The University of Michigan, 3236 Undergraduate Science Building, 204 Washtenaw Avenue, Ann Arbor, MI 48109-2215
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Teaching Support: Shannon McGrath

Observer: Ashima Mathur

LEARNING OUTCOMES

My goal in developing and implementing Education 528 is to assist you in developing approaches to supporting children's meaningful science learning that are consistent with reform-oriented science teaching. The following learning outcomes have informed my selection of class activities and assignments.

- Promote classroom discourse for all science learners.
- Develop subject-specific pedagogy for teaching science in ways that enhance conceptual development and explanation-driven inquiry.
- Capitalize on children's natural curiosity to promote positive attitudes toward science.
- Integrate the nature of science and scientific inquiry, into the science learning experiences you prepare for children.
- Use principles of learning and assessment information about children's prior knowledge to design differentiated science learning experiences that are developmentally appropriate for all students.
- Create and/or adapt instructional resources, including applications of technology, for supporting meaningful science learning.
- Systematically collect assessment data about children's science learning and use it to analyze the effectiveness of your teaching and prepare for future instruction.
- Develop a stance toward teaching that involves continued professional development in science through inquiry into problems of practice, collaboration with colleagues, interactions with professional organizations and/or exploration of online resources for science teachers.
- Use appropriate resources and strategies to develop deep understanding of the science concepts you will teach.

COURSE OVERVIEW
This science methods course takes into consideration that the best science teaching requires classroom experiences. In the past it has been difficult to have common learning experiences upon which to develop course discussions. Therefore, this semester, we are going to have a field –based course. The access to 3rd and 4th grade classrooms in Garden City Public Schools will provide a common focus, opportunities to engage students in science talks around content, and experience with common elementary school curriculum materials. One important focus of the course will be on planning, implementing and assessing classroom discussions in elementary and middle school science classrooms. Science talks provide opportunities for teachers to elicit and guide student thinking and for students to engage in scientific discourse.

You will have opportunities to develop this practice by a variety of examples of science talks as well as engaging in your own planning and implementation of science talks. Additionally, you will have supported opportunities to rehearse and teach while using classroom discussions in real elementary school classrooms.

PARTICIPATION, PROFESSIONALISM & ATTENDANCE
This course operates on the premise that developing meaning requires active engagement in a community of learners focused on problems solving. Therefore, your presence and participation is essential to the development of the group's understanding of learning to teach science.

As it pertains to the course, professionalism refers to your overall attitude and approach to learning. Dimensions of professionalism include, but are not limited to, your preparation for class (including readings and homework assignments), the quality of contributions you make in class and online, the nature of your collaborative efforts with peers and other members of our developing learning community, and the enthusiasm you convey with regard to your personal professional development.

High quality participation is expected with consistency. I reserve the right to deduct points from the final grade if expectations for participation/professionalism, as described here, are not met. No absences are "allowed." Absences will result in your course grade being lowered.

ACADEMIC INTEGRITY:
All students are expected to act with civility, personal integrity; respect other students' dignity, rights and property; and help create and maintain an environment in which all can succeed through the fruits of their own efforts. An environment of academic integrity is requisite to respect for self and others and a civil community.

Academic integrity includes a commitment to not engage in or tolerate acts of falsification, misrepresentation or deception. Such acts of dishonesty include cheating or copying, plagiarizing, submitting another persons' work as one's own, using Internet or any other sources without citation, fabricating field data or citations, "ghosting" (taking or having another student take an exam), stealing examinations, tampering with the academic work of another student, facilitating other students' acts of academic dishonesty, etc.

Students charged with a breach of academic integrity will receive due process and, if the charge is found valid, academic sanctions may range, depending on the severity of the offense, from F for the assignment to F for the course.

LEARNING RESOURCES:
Required Texts:
Project-Based Inquiry Science *Good Friends and Germs* (teacher's planning guide and student text)

- Good Friends and Germs Teacher's Planning Guide 978-1-58591-631-3 $84.99
- Good Friends and Germs Student Edition 978-1-58591-620-7 $18.89

Optional Resources:

Teaching Science in Elementary and Middle School Classrooms: A Project-Based Approach (paperback) by Joseph S. Krajcik, and Charlene M. Czerniak (third edition).

Teaching Science as Investigations: Modeling Inquiry Through Learning Cycle Lessons (Paperback) by Richard H. Moyer, Jay K. Hackett, Susan A. Everett, ISBN: 0132186276

Understanding by Design (second edition). Grant Wiggins, Jay McTighe, ISBN: 013093058X, about $22.00 at Amazon, used

It would benefit you to get a student membership in the National Science Teachers Association (NSTA), with a subscription to Science & Children (elementary) or Science Scope (middle school). Visit the NSTA web site for more information http://www.nsta.org/memstudent. Membership applications will be distributed at the first class.

Other readings will be assigned throughout the semester. These will be free of charge (from online sources or from the UM library) and available via the web. A plethora of reading material is available from the library at the IDEA Institute, 3236 Undergraduate Science Building. Many titles are listed online at librarything.com: http://www.librarything.com/catalog/ideainstitute

CRITICAL USE OF TECHNOLOGY

Throughout the course, various technology applications will be implemented. You will be expected to learn and use efficiently, most of these tools. Applications such as ctools, podcasts, audio recording on the computer, instructional software such as Inspiration, Microsoft Word, and Timeliner, video recording and editing using Flip Cameras and Software will be used frequently and ubiquitously. It is critical to develop a working knowledge of these tools for both executive and instructional tasks. There are many sources for developing these skills on campus and elsewhere. It would be prudent to begin searching for these if you feel uncomfortable with your skills.

GRADING

Your grade for ED 528 will be based on your performance, which should reflect effort and quality of work. There will be no extra credit opportunities. The assignments that will be assessed are described below. Rubrics for assessment will be supplied as the semester unfolds. *Specific details associated with each assignment will be provided in class.*

SUMMARY OF COURSE ASSIGNMENTS

Task/Assignment	**Points**	**Due Date**
Background and Exit Survey	5	1/4/10 for background and 2/10 for Exit
Take-home messages	5	Completed at the end of each class meeting; additional comments can be added by midnight.
Lessons Plans/Reflections for enactments in Garden City (small group work with individual write-up)	30	48 hours prior to each Garden City enactment
Video Analysis of Garden City teaching experience, attendance at Presentation event	20	2/19
Final Exam	30	TBD
Miscellaneous course work, readings, reflections, assignments, class participation and attendance	10	Due dates will be provided, appropriate time will be given for assignment completion
	100 points total	

Course grades will be assigned using this scale.

A	95-100	B+	87-89	C	75-79
A-	90-94	B	84-86	D	71-74
		B-	80-83	F	< 70

AGENDA (FIRST 5 WEEKS OF CLASS)

Date	Time/Location	Course Activities	Assignments Due Today
1/6	**9am-4pm SOE (Rm. 2229)**	Thinking about Science Teaching; Exploring Project-based Science Teaching/Learning **Assignment for next class:** Readings on Argumentation: a separate page will be provided. Additional readings from Foss materials, pages to be assigned. Using instructional materials – What is in a student book? What is in a teacher guide?	Background surveys were submitted Jan. 4 by noon Complete class reflection (3:20) Syllabus discussion (3:45)
Note that there are 6 days between the first and second classes. Therefore, there will be reading assignments and written work that will take approximately 6 hours of your time. During this time, support for the readings and/or writing can be solicited from Mary or Shelly. Questions are always welcome – especially via email. Meetings in the Undergraduate Science Building can easily be arranged.			
1/12	**9am-4pm SOE (Rm. 2229)**	Discuss role of student ideas during discussions – use PBIS to rehearse importance of eliciting prior knowledge Work in groups of 4 to prepare for first discussion with students **Planning for Teaching Approximation #1:** Teaching a small group of students on your own; a discussion that elicits their prior knowledge and introduces the driving question for the unit	Readings from FOSS materials completed Readings about Argumentation completed. Turn in review. Complete take-home message reflection; Submit list of questions for first discussion Submit preliminary lesson plan at the end of class.
1/14	**1pm-2:30pm (Garden City Classrooms)** **2:30pm-4pm (Garden City Conference Room)**	**Please note that you are expected at Garden City classrooms at 1. The classroom teachers are aware that you are driving from Ann Arbor. While slight time delays are understandable, considerable tardiness is unprofessional. Please call Mary at 7346128780 if you will be more than 10 minutes past the 1 p.m. time commitment.** Observe assigned classroom for 30 minutes Introduce unit through **Teaching Approximation #1** Videotape your enactment of the discussion Group reflection of experience work with FOSS kits in groups of 4 to prepare discussions about data	Complete take-home message reflection Prepare Group reflection of experience. Specific instructions will be provided.

Appendix C
Summary of course meeting dates, times and activities

Session No.	Date	Time	Setting	Course Activities
1	1/6	9am-12pm; 1pm-4pm	UC	• Meg modeled a "launch" (PBIS unit, Learning Set 1) with interns acting as students • Group discussion about what she did and why • Discuss Garden City Logistics • Brainstorm parts of a launch and good science teaching
2	1/12	9am-12pm; 1pm-4pm	CC EC	• Discuss protocol for observing assigned classrooms today • Discuss role of vocabulary • Discuss design of units in PBIS: interns research standards for their unit and brainstorm learning goals and big questions • Break-out sessions talking about each unit (moon phases versus rocks and minerals) • Planning time in teaching groups for launch • Share their big question ideas/discuss
3	1/14	1pm-4pm	CC EC	• Interns guide launch discussion • Interns talk about what they learned about their students • Discuss content of units in break-out groups
4	1/19	9am-12pm; 1pm-4pm	CC EC	• Interns do walk-throughs of their mock rock lessons • Interns guide mock rock investigation discussion • Discuss how to phrase questions better • Interns do walk-throughs of their analysis of mock rock lessons • Interns guide analysis of investigation discussion • Interns share their experiences teaching today
5	1/21	1pm-4pm	UC	• Share videos of teaching with peers • Discuss possible assessments for last teaching experience; work in teaching groups to plan assessment sheets
6	1/26	9am-4pm	CC EC	• Discuss language use when teaching science • Walk-through how to respond to students' ideas

				• Discuss creating culture of classroom • Discuss structure of PBIS unit-idea of cycling back to big question • Interns guide crystals discussion • Interns do circulatory system model from PBIS and discuss use of models/simulations
7	1/28	1pm-4pm	UC	• Watch video of magnet science talk and discuss teachers' language use • Discuss NSES and GLCEs • Introduces parts of a scientific explanation • Interns write explanations, and brainstorm how their elementary students can start to do similar thinking in last discussion
8	2/2	1pm-4pm	CC EC	• Interns guide last discussion-making explanations for moon phases or what is a rock and mineral. • Mary shares details of March 2 presentation night and final assignments • Read book FISH is FISH and discuss role of prior knowledge • Interns share information about the scientists they have been researching

Key:
CC: Community Center at Garden City
UC: University Classroom
EC: Elementary Classrooms at Garden City

Appendix D
Project-Based Inquiry Science (PBIS) Unit: Good friends and Germs

Project-Based Inquiry Science Unit: Good Friends and Germs
Time: 47 class periods for entire unit (40-50 min. class periods)

Unit Content Overview:
"In this unit, the *Big Question* that students focus on is *How can you prevent your good friends from getting sick?* During *Learning Sets*, students investigate smaller questions and update the *Project Board*, create a summary of what they are learning about diseases, disease spread, and disease prevention. Students consider how what they are learning can help them answer the *Big Question*." (Teacher's Guide, p.2)
Meg modeled Learning Set 1 on the first day of class.

Learning Set 1

- Students are given the big question
- They set up a project board (*Meg used PowerPoint where they typed in intern ideas)*
- Students pass around a beanbag covered with an undetectable powder that is sensitive to UV light. PBIS teacher's guide suggests introducing the big question and then asking the students to share (when they have the beanbag) one thing they know about how you get sick. At the end of the activity, the students got to see the powder on their hands using UV light and discussed how disease is transferred.
- The teacher engages students in a discussion about their ideas about how people get sick, and encourages them to ask questions that they can put up in the class to explore throughout the unit.
- Students engage in a water-sharing activity that simulates how disease is spread. Students are given cups of water, one of which has been "infected" with a harmless chemical. Through a series of water-sharing interactions, the chemical spreads from one student to another. An indicator that changes color in the presence of the chemical is then added to each student's cup of water to reveal who has become "infected." Students are challenged to identify the initial carrier.
- Students learn about how diseases spread. Sometimes you cannot know who is sick. Often, sick people do not appear sick and yet they can spread their disease. The investigation also demonstrated that spreading disease can be very easy, however, it is not always easy to figure out who the initial carrier is.
- Students realize that no specific directions were given to record each interaction, so it is difficult to determine the carrier with the information they remember.

They develop a strategy to collect and analyze data to determine the initial carrier of the "disease"

- They analyze their data to identify the carrier
- Students complete "stop and think" questions to reflect on their learning

Appendix E

Full Option Science System (FOSS) Curricular Units used in ED 528

This appendix offers a summary of the learning goals and activities in the FOSS curricula that the interns were using in ED 528 (during formal class and to plan and enact teaching in elementary schools). Italicized sections point out changes made for the purposes of ED 528.

Sun, Moon and Stars Unit (4th graders)

Content Goals based on National Science Education Standards: Earth and Space Science

- Develop students' understanding of objects in the sky.
    - The sun, moon, stars, clouds, birds, and airplanes all have properties, locations, and movements that can be observed and described.
- Develop students' understanding of changes in the earth and sky.
    - Objects in the sky have patterns of movement. The sun, for example, appears to move across the sky in the same way every day, but its path changes slowly over season. The moon moves across the sky on a daily basis much like the sun. The observable shape of the moon changes from day to day in a cycle that lasts about a month.

Overview of unit:

Investigation 1: The Sun
Investigation 2: The Moon
Investigation 3: The Stars

In ED 528, the interns were only responsible for doing Investigation 2, the MOON, with the elementary students. The classroom teachers were going to do the other parts of the larger unit later.

Investigation 2: The Moon

Students observe the Moon in the sky during the day and night for a period of 4 weeks. *The classroom teachers started this activity with the students before the interns began ED 528.* They record the appearance of the Moon and analyze the data to discover a sequence of changes, the lunar cycle. Students learn the names of the Moon phases and how to predict the next step in the sequence. Concepts are reinforced though simulations, readings, a video, and writing. (p.4, overview, teacher's guide)

Activities:

- Ask students about their observations in their logs of the moon phases
- Modeling the Moon Phases using small Styrofoam ball on a thin straw or stick, light source (overhead projector or light bulb) and the student's head is the Earth (the student's eye is an observer on Earth).
- Ask questions to orient students to the model (FOSS Provided the following question prompts and answers):

- Where does the light on the Moon come from? [From the Sun (light source).]
    - How much of the ball is lighted by the light source [Half.]
    - Where is the part of the ball (Moon) that is in the dark? [The side facing away from the light source.]
- Demonstrate phase modeling
- Let students explore the phases by using the models
- Discuss the modeling activity
- Reinforce Vocabulary
- Reading Activities *(the interns did not guide reading activities about the Moon)*

Earth Materials Unit (3rd graders)

Content Goals based on National Science Education Standards: Earth Science
Develop students' understanding of properties of earth materials.

- Solid rocks are earth materials, and they have different physical and chemical properties that make them useful in different ways, for example, as building materials. Earth materials provide many of the resources that humans use.

Overview of unit:
Investigation 1: Mock Rocks
Investigation 2: Scratch Test
Investigation 3: Calcite Quest
Investigation 4: Take it for Granite

In ED 528, the interns were responsible for doing investigations 1 and 3, with the elementary students. The classroom teachers were going to do the other parts of the larger unit later.

Investigation 1: Mock Rocks
Students made observations of mock rocks to discover:

- an earth material has properties that can be observed and described--such as color, shape, and texture
- a rock is an earth material composed of different ingredients called minerals
- a mineral is a rock ingredient that cannot be physically reduced to more elementary minerals
- Some materials, such as salt and alum, dissolve when they are mixed with water, but re-form when the water evaporates

Activities in Investigation 1:
1: Investigating mock rocks: Students make and record observations of mock rocks. They compare the properties of mock rocks with those of real rocks. *Interns enacted a launch discussion to introduce students to earth materials and a discussion to set-up the mock rock investigation.*

2: Taking Rocks Apart: Students use a nail as a geologist's pick to take a mock rock apart. Not all ingredients can be separated in this way, so students use water to effect a further separation. Students shake vials containing water and earth material and observe them before and after settling. *Interns enacted a discussion to make sense of what they observed after taking the rocks apart, they also discussed what they could do to find out more about what was inside the rocks.*

3: Observing Crystals: After vial ingredients settle overnight, students observe the separation that has occurred. They set up evaporation dishes to determine any further ingredients. After the water evaporates, students find crystals in the dish. They determine these are salt crystals. *Interns have students discuss the results of their evaporating, and identify crystals in a discussion. In the final discussion, interns guide students to explain the differences between rocks and minerals.*

Appendix F

Letter to interns about participating in this dissertation study

UNIVERSITY OF MICHIGAN

SCHOOL OF EDUCATION

Ashima Mathur
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January 5, 2010

Good morning!

My name is Ashima Mathur, and I am a fourth year graduate student in the science education doctoral program here at SOE. I wanted to describe my role in your ED 528 experience coming up this winter. I will be attending all the class meetings. You will see me videotaping Mary while she teaches and taking notes as I walk around the room during small group work. I will also be collecting your post-class reflections to help me understand what you are taking away from each class.

I will be collecting these video, audio, and written data for my dissertation research work. My research interests include how elementary science teachers can be supported to use inquiry-based teaching practices, especially the practice of leading classroom discussions. Specifically, I am interested in the ways ELMAC courses have recently been redesigned to really focus on teaching practices by using video, rehearsals, modeling, etc.--that is, I'm interested in studying how methods courses prepare you to practice and think about HOW to teach instead of just telling you in lecture-format WHAT to teach.

Besides seeing me moving cameras around, the data I am collecting from you (e.g., written reflections after class, videos of you rehearsing) are already a part of the course requirements anyway, so I will not add any additional work or assignments to your already busy schedules. For example, I will be analyzing videos of your rehearsal sessions; you would be videotaping these sessions even if I was not collecting data--so it does not require any additional work from you. Four of you will be asked to participate in semi-structured interviews before and after your Garden City teaching experiences; these interviews will go beyond your normal classwork, but should not take more than 10-15 mins. Mary, Shelly, and I hope my study will help us better design supports that guide you in becoming confident, prepared, and successful in the classroom. Feel free to email me at amath@umich.edu if you have questions about my work. Also, please know that I do not mind sharing my data or my write-ups as I go along; so if you would like to meet with me to discuss my findings and what I am writing about my observations, I am happy to schedule time to have that conversation.

Thanks for being patient with my presence in the classroom. I look forward to discovering how this course best supports you to become a great elementary science teacher!

Sincerely,
Ashima Mathur

Appendix G
Start-List of Codes for Pedagogical Approaches used in ED 528

Code	Title and description of code	Example from observations of Meg teaching science methods in the past
PK	Elicits and addresses PSTs prior knowledge and beliefs about science teaching	Meg asks PSTs to compare the inquiry-based lesson they just experienced to an elementary science class experience they remember.
D	Defines and provides examples of general science teaching terms and concepts (e.g., modeling, inquiry, scientific literacy, standards)	Meg shows a PowerPoint presentation that defines scientific modeling and provides examples of student modeling
MC MCJ	Models the practice by breaking down each components Models the practice by breaking down each component and providing justification	"And here I was eliciting prior knowledge, and here I was making student thinking visible to other students and to myself with this chart." After teaching a full lesson, Meg goes back with video clips at the next class and defines each of her moves. For example, "I was *eliciting prior knowledge* here to know if I needed to show students examples of these animals before asking them to think about the ways they get energy."
ME	Models the practice by enacting all components	Meg enacts a classroom discussion or PSTs watch a video that models a full classroom discussion
AP	Analysis of practice	PSTs work individually or in groups to analyze practice in cases, video, or their own teaching practice.
F	Provides focused feedback to PSTs while they are planning, analyzing or enacting practice.	As PSTs are rehearsing their classroom discussions with peers, Meg stops them and points out ways to improve the practice. "Let's try that again, except this time don't use the phrase, "we are going to learn hard science vocabulary," because that will just turn students off to science. What's another way you could introduce these terms with some context so they make sense to students?"
NF	There is no feedback when PSTs are	PSTs enact their lessons with small

	planning, analyzing or enacting practice; PSTs are left to make sense of the activity themselves	groups of students and then are asked to reflect on their own.
I	Does it make the interactive aspects of teaching visible (e.g., student-teacher interactions, student-student interactions, replying to students, engaging all students.	Meg pauses a video of a classroom discussion and asks PSTs to focus on what they would do next and what they would say to the student who just shared a misconception. PSTs enact a discussion with a small group of students.
IH	Does it hide the interactive nature of teaching and focus on teacher moves?	PSTs engage in a planning activity where they consider what materials they will need to set-up a particular experiment. PSTs read background content texts to prepare for their lesson.
S	Offers opportunities for PSTs to make sense of terms, ideas, or components of practice by discussion, questions, reflection.	PSTs look over the National standards and brainstorm which standards they will be able to cover and how in their mini-lessons.
PA	Shares personal anecdotes of teaching (often loaded with opinion and personal attitudes towards science teaching)	Meg shares, "one time when I was teaching I asked students to make a prediction about what would happen if I added acid to the solution and I found out later that they were not doing the task because they didn't know what acid was. Never assume what students know—always ask, find out, so you know where to start."
ECP	Opportunities to practice the enactment of components of practice with peers	Students work on orienting student ideas to one another by practicing ways to display student ideas in the classroom during a lesson (with peers acting as students)

ECS	Opportunities to practice the enactment of components of practice with elementary students	In Garden City, PSTs work on eliciting student ideas in small groups of five elementary students. Or, if "planning for CDSCR" is a component—then using student worksheets to prepare next lesson is another form of enactment with real students' work.
OP	The activity offers opportunities for PSTs to learn from their own practice	PSTs engage in reflection right after enactment by watching videos of their teaching and pulling out examples of stronger and weaker attempts to support student learning during a classroom discussion. PSTs discuss what they struggled with in a reflection discussion at the beginning of class after interacting with students for the first time.
E	Enactment of classroom discussions in schools.	Teaching in their field placement.

Appendix H
Re-coded content codes

Name of Raw Code	Sources	References	Notes
R_Culture of Science Classroom	6	8	
R_Activate prior K	2	2	-discussing launch -fish is fish
R_adaptingcurricular materialsforbetter discussions	3	3	-connects to adapting them to let students do the cognitive work, and to foreground student ideas (don't show video of model first) -fixing launch
R_anticipatingwhatstudentswillsayinplanning	4	6	
R_becarefulandintentionalwithlanguageindiscussions	4	8	-careful with word shadows; careful with "apparent" change in shape of the moon -using pieces, materials, ingredients for minerals....(Class 4, afternoon debrief) -tell us, tell me
R_contentofmisconceptions	2	2	
R_discussiondoesntmeananythingoes	1	1	Same as know where you are going
R_elicitandmakemisconceptionspublic	3	3	
R_givingstudentsownership	2	3	Class 1, part 5: "Ownership really comes from many things: from activating prior k, from having a good question" --students asking questions gives them ownership
R_guideideastowardsgoal	10	15	Good questions take you towards the learning goals... -we do not wing it--teaching is intentional--always know where you are going; anticipate what u think students will say--circling back to the big question
R_identifyingthecontentterrain	2	2	
R_includingallstudentsindiscussion	2	2	
R_languagetoencouragediscussion	2	2	Language

R_leadingadiscussionwitha MODEL	4	4	
R_managementindiscussion	2	2	Creating culture
R_managementsostudentscantalktoeachother	3	4	Can someone build off of what pam said? what does a good listener look like? building classroom culture
R_movealongwithstudentideasquestions	8	13	
R_noevaluationinlaunch	2	2	Getting student ideas out on the board
R_noyesnoquestions	1	2	have them do the cognitive work
R_orienting students to each others' ideas	2	2	Breakdown traditional teacher-student interactions
R_parts of scientific explanation	2	2	Scientific discourse-an explanation--have some evidence.--science inquiry make observations, explain natural world based on evidence/explanations.
R_phrasingquestionstopushstudentthinking	5	10	Not yes/no, could u make full moon other way, they have to think for themselves--take cognitive work. lead them to think to use water--what in nature could break it apart? answer question, pull it together with their reasoning.
R_rationaleagainsttradapproaches	5	7	Not tell,memorize, test. Right answers do exist...but let them get there--don't give it to them right away. Can't be wrong. LISTEN, negotiate the convo towards learning goals--but you don' t have to be center of it.
R_respondingtoinaccurateideasindiscussion	1	2	
R_roleofGLCEstandards in planning	2	4	
R_sciencerequiresevidence	4	5	
R_sciencerequiresquestions	3	4	
R_studentsdoingworkofscientists	2	3	"thinking like scientists"
R_studentsguidedtoaskquestions	4	5	
R_studentshavetodocognitivework	6	11	
R_useinfofromonediscussiontofuelthenext	5	6	
R_Writedownstudentcontributions	3	4	Combine with use project board code
R_use project board	3	5	

Appendix I
Moving from raw codes to five content themes addressing research question 1

Theme Name: Foregrounding student ideas and questions
Categories (based on raw codes) included in this theme:
1. R_Activate prior K
2. R_elicitandmakemisconceptionspublic
3. R_givingstudentsownership
4. R_movealongwithstudentideasquestions
5. R_respondingtoinaccurateideasindiscussion
6. R_studentsguidedtoaskquestions
7. R_Writedownstudentcontributions

Re-named categories to better represent codes within each category:
1. Elicit students' ideas (prior knowledge/experiences/possible misconceptions)
2. Encourage students to ask questions (about phenomena, observations)
3. Give students ownership of the discussion (give them credit by name for contributions)
4. Capitalize on student ideas to move discussion further
5. Pick questions to investigate from a class list
6. Record student contributions in classroom to refer back to
7. Always revisit inaccurate student ideas (can't teach 2+2=5)

Connector: Foreground student ideas and question WHILE steering discussions towards learning goals

Theme Name: Steering the discussion towards learning goals
Categories (based on raw codes) included in this theme:
1. R_guideideastowardsgoal
2. R_orienting students to each others' ideas
3. R_discussiondoesntmeananythingoes

Re-named categories to better represent codes within each category:
1. Cycle back to the big question
2. Orient students to peer ideas that are on-topic
3. Always know where you are going; teaching is intentional
    a. Plan appropriate language for students (tool vs. instrument)
    b. Anticipate students misconceptions (moon phases/rocks and minerals)
    c. Select language for questions to guide thinking
    d. Prepare for range of content that may come up
    e. Consult science standards and unit learning goals
    f. Build on what happened in last discussion
    g. Adapt curriculum materials to engage students in scientific practices
        i. Students should provide have opportunities to provide evidence
        ii. Students should ask questions
        iii. ask students to create explanations with evidence
        iv. ask students to choose evidence from collected data
    h. Develop big question

Theme Name: Breaking down traditional teacher-student interactions
Categories (based on raw codes) included in this theme:

1. R_leadingadiscussionwitha MODEL
2. R_rationaleagainsttradapproaches
3. R_orienting students to each others' ideas
4. R_noevaluationinlaunch

Re-named categories to better represent codes within each category:
1. Use "tell us" instead of "tell me"
2. Orient students to each other's ideas
3. Teacher as facilitator, not teller

Connector: Breaking down the traditional teacher-student interactions makes it possible to let the students do more of the cognitive work.

Theme Name: Having students do the cognitive work

Categories (based on raw codes) included in this theme:
1. R_noyesnoquestions
2. R_studentshavetodocognitivework
3. R_sciencerequiersevidence
4. R_sciencerequiresquestions

Re-named categories to better represent codes within each category:
1. Ask open-ended questions (not yes/no)
2. Don't tell procedures, answers, defintions-guide students towards them
3. Don't ask, "does everyone understand"
4. Respond with questions to guides students to modify their own inaccurate ideas
5. Doing the work of science
    a. science requires evidence
    b. science requires questions
    c. ask students to create explanations with evidence
    d. ask students to choose evidence from collected data

Theme Name: Creating a classroom culture that supports science discussions

Categories (based on raw codes) included in this theme:
1. R_includingallstudentsindiscussion
2. R_languagetoencouragediscussion
3. R_managementindiscussion
4. R_managementsostudentscantalktoeachother
5. R_Writedownstudentcontributions
6. R_students as scientists

Re-named categories to better represent codes within each category:
1. Set-up room for discussion (i.e., seating in rows, groups, circle on floor)
2. Establish and make clear rules and expectations for talking to each other, disagreeing, sharing ideas.
3. Have a space for recording student ideas in the classroom (e.g., project board)
4. Use language to invite all students into discussions
5. Don't use discussion as management (e.g., “What did she just say?”)
6. Students do work of scientists (be careful with this analogy when teaching)

Connector: creating a classroom culture that supports discussions will allow you to foreground student ideas and questions, steer the discussion towards learning goals, breakdown traditional teacher-student interactions, and have students do the cognitive work.

Appendix J
Moving from raw codes to three pedagogical approach themes for research question 2

Raw Codes from initial rounds of coding	Pattern Codes	Themes
Modeling a hook in a launch Modeling eliciting prior K and beliefs Modeling making thinking public in classroom Modeling orienting students' to each other's responses Modeling picking a question to investigate Modeling pressing for evidence Modeling prompting for explanations Models asking students to propose questions to investigate	Modeling the role of the elementary teacher during science discussions	Creating images of inquiry-based science discussions
Discussing video of magnet lesson Sharing own video-clips with classmates	Analyzing videos of experienced and prospective teachers guiding science discussions	
phrasing questions to push student thinking practicing language or phrasing of responses to students in group need to prepare for discussions by anticipating student responses	Targeted rehearsals of responses to student contributions during discussions	Providing focused teaching experiences
psuedo-rehearsals acting out student difficulties	Peer walk-throughs of lesson plans	
Only teaching part of lesson to half a class Only teaching a launch to 4 students Able to learn in less complex scenarios	Small-group teaching enactments in real elementary classrooms	
phrasing questions to push student thinking practicing language or phrasing of responses to students in group need to prepare for discussions by anticipating student responses when to introduce vocabulary using PBIS as a resource adapting curriculum materials (FOSS)	Joint problem-solving during planning	Guided analysis of science discussions
Addressing PTs misconceptions about science teaching (giving answers) Defining parts of a launch	Structured debriefing activities	

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