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PRESERVICE ELEMENTARY TEACHERS LEARNING TO USE CURRICULUM MATERIALS TO PLAN AND TEACH SCIENCE

By

Kristin Lee Gunckel

A DISSERTATION

Submitted to
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ABSTRACT

PRESERVICE ELEMENTARY TEACHERS LEARNING TO USE CURRICULUM MATERIALS TO PLAN AND TEACH SCIENCE

By

Kristin Lee Gunckel

New elementary teachers rely heavily on curriculum materials, but available science curriculum materials do not often support teachers in meeting specified learning goals, engaging students in the inquiry and application practices of science, or leveraging students' intellectual and cultural resources for learning. One approach to supporting new elementary teachers in using available science curriculum materials is to provide frameworks to scaffold preservice teachers' developing lesson planning and teaching practices. The Inquiry-Application Instructional Model (I-AIM) and the Critical Analysis and Planning (CA&P) tool were designed to scaffold preservice teachers' developing practice to use curriculum materials effectively to plan and teach science. The I-AIM identifies functions for each activity in an instructional sequence. The CA&P provides guides preservice teachers in modifying curriculum materials to better fit I-AIM and leverage students' resources for learning.

This study followed three elementary preservice teachers in an intern-level science method course as they learned to use the I-AIM and CA&P to plan and teach a science unit in their field placement classrooms. Using a sociocultural perspective, this study focused on the ways that the interns used the tools and the mediators that influenced how they used the tools. A color-coding analysis procedure was developed to identify the teaching patterns in the interns' planned instructional approaches and enacted activity sequences and compare those to the patterns implied by the I-AIM and CA&P tools. Interviews with the interns were also conducted and analyzed, along with the assignments they completed for their science methods course, to gain insight into

the meanings the interns made of the tools and their experiences planning and teaching science.

The results show that all three interns had some successes using the I-AIM and CA&P to analyze their curriculum materials and to plan and teach science lessons. However, all three interns used the tools in different ways, and some of their ways of using the tools were different from the intentions for the tools. These differences can be accounted for by the variety of mediators that influenced the interns' use of the I-AIM and CA&P tools. These mediators were rooted in the Discourses at play in the various communities in which the interns participated during their teacher preparation program. Some of the practices and resources of these various Discourses interfered with or supported the interns' use of the I-AIM and CA&P tools. Each intern took a different trajectory through these Discourses and encountered different practices that mediated how each used the I-AIM and CA&P tools.

The results of this study suggest that the goal of preparing preservice teachers to use the I-AIM and CA&P tools should be to provide preservice teachers with opportunities to use the tools and help them develop the metaknowledge about the tools necessary to critically analyze the affordances and weaknesses of different approaches to teaching science.

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I entered the doctoral program in the Department of Teacher Education surer of what I was moving away from than what I was moving toward. I found a community of wonderful, caring, and intelligent people who welcomed me, invited me to participate in their intellectual pursuits, and guided me as I found my new direction. I am most grateful to my advisor, Dr. Edward Smith, who opened his heart and shared his passions with me. I benefited greatly from his guidance and support and deeply respect his commitment to science education, social justice, and family. I thank Dr. Christina Schwarz for sharing her friendship and mentorship, and Dr. Charles "Andy" Anderson for sharing his vision and experience. I would like to recognize Dr. James Gallagher, who made many experiences possible for me as part of the Center for Curriculum Materials in Science. I am indebted to Dr. Lynn Paine and Dr. Glenda Lappan for serving on my committee and offering helpful advice and direction. In addition, I would like to acknowledge the friendship and support of my colleagues and friends Dave Grueber, Blakely Tsurusaki, Mark Enfield and Felicia Moore. You all are truly amazing people who make the world a better place.

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Most of all, I want to thank my partner, Marcy Wood, who got me here in the first place. I am looking forward to new adventures as we move ahead into the next phase of our lives together.

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CHAPTER 1

Introduction

Situating the Study

Preparing elementary teachers to plan and teach science is a large task. A look through several science methods textbooks suggests there is some agreement on what preservice teachers should learn about teaching science. Most textbooks have chapters on what science is and why students should learn science, how students learn science, how to engage students in science experiences, and how to assess what students learn. Yet, few approaches to preparing elementary teachers to teach science emphasize how to use curriculum materials to plan and teach science lessons and little research has focused on how new science teachers use curriculum materials (Davis *et al.*, 2006). This dissertation study is part of a larger project focused on helping preservice teachers learn to use curriculum materials effectively. In this chapter, I will provide an overview of the problem and explain how this dissertation study fits into the larger design-based project. I will then provide an overview of the rest of the chapters in this dissertation.

Identifying the Problem

New elementary teachers face a challenging situation when teaching science. Science is not a subject area that many elementary teachers feel knowledgeable about or comfortable teaching (Chochran & Jones, 1998; Davis *et al.*, 2006). To compensate, new teachers tend to rely heavily on available curriculum materials to guide their planning and teaching, often following materials verbatim (Grossman & Thompson, 2004; Kauffman et al., 2002). This situation leads to several pitfalls. While states specify the science standards to which teachers are held accountable (recommended curriculum), the available curriculum materials often do not support students in meeting these standards (Kesidou & Roseman, 2002; Stern & Roseman, 2004). Reform documents advocate that teachers take an inquiry-oriented approach to teaching science (National Research Council, 1996, 2000), yet many materials do not support teachers in engaging students in scientific practices. Furthermore, curriculum materials are usually written for a wide audience, and may not support teachers in taking advantage of the cultural resources their own students bring to learning science (Luykx & Lee, 2007; Rosebery, 2005). Teachers who rely heavily on these materials may not recognize their inherent weaknesses and, therefore, fail to make modifications accordingly. Alternatively, when teachers do encounter high quality curriculum materials, they may not recognize the strengths or the educative features of these materials (Davis & Krajcik, 2004b), and may make changes to the suggested lessons, for a variety of reasons, that counteract their potential effectiveness (Ball & Feiman-Nemser, 1988; Ben-Peretz, 1990; A. L. Brown & Campione, 1996; Collopy, 2003; Grossman & Thompson, 2004; Schneider *et al.*, 2005). As a result, new teachers' uncritical or misguided use of curriculum materials may lead to missed student and teacher learning opportunities (Ball & Cohen, 1996; Ball & Feiman-Nemser, 1988).

In the past, one mark of a good elementary science teacher may have been the ability to create original science lessons and not rely at all on inferior curriculum materials (Ball & Feiman-Nemser, 1988). However, as more school districts mandate use of specified curriculum materials, the mark of an effective science teacher is shifting to one who can use the provided curriculum materials effectively to help all students learn science. Shulman (1990) notes, "Teachers must be prepared to serve as acute critics, analysts and adaptors of curriculum" (p. vii). Ball & Feiman-Nemser (1988) argue that teachers should learn from curriculum materials, even from poor curriculum materials, if they know what to look for. Similarly, Grossman & Thompson (2004) claim that new teachers need to learn how to analyze and critique curriculum materials, so that they can use the materials they have well and take advantage of the learning opportunities curriculum materials present. However, Shulman (1990) also notes that the challenge to teacher educators to prepare teachers who can individually and collectively play the roles of critics, analysts and adaptors is profound.

Work by Davis (2006) and Schwarz et al. (2008) showed that preservice teachers usually do have some criteria that they use when deciding how to use curriculum materials to plan and teach science lessons. Schwarz et al. (2008) showed that preservice teachers often focus on practical aspects of the lessons, such as the time required or the availability of materials for an activity. Preservice teachers tend not to consider how science content is represented in curriculum materials, how the materials support students in learning science, or how well curriculum materials match their own students' resources for learning (Davis, 2006; Schwarz et al., 2008). Davis suggested that preservice teachers might need long-term scaffolds to support them in using curriculum materials long after they have become experienced teachers.

Design-Based Research Project

This dissertation grew out of a larger design-based research project to develop an approach to teaching elementary preservice teachers how to use curriculum materials effectively to plan and teach science lessons to all students. Design-based research is an approach for understanding learning and teaching through the design and study of learning environments (Barab & Squire, 2004; Cobb et al., 2003; Design-Based Research Collective, 2003). Design-based research includes the development of educational tools, including curriculum materials, instructional approaches, and scaffolds (Design-Based Research Collective, 2003). It involves iterative cycles of design, enactment, analysis, and redesign. Each cycle results in explanations of observed phenomena that inform the next cycle of inquiry (Barab & Squire, 2004; Cobb et al., 2003; Design-Based Research Collective, 2003). Through this process, our research group developed an instructional model that could potentially serve as a long-term scaffold to help preservice teachers use curriculum materials, even poor materials, to plan and teach science lessons that engage students in scientific practices, help students achieve specified learning goals, and are responsive to students' resources and needs.

This dissertation research serves as an iteration in this design project. It follows three preservice teachers as they use the instructional model and supporting frameworks to plan and teach a science unit in their field placement classrooms. These three preservice teachers were all members of a university science methods course in which the instructional model and associated planning and teaching practices were introduced. As part of this dissertation research, I developed a method for analyzing the preservice teachers' instructional sequences, identifying their teaching patterns, and comparing their patterns to patterns implied by the instructional model. I used this analysis to examine how the preservice teachers used the instructional model and the meanings that they made of the tools and associated practices. I then looked across all three cases using Gee's (1989, 1999) Discourse framework as a lens to explain the preservice teachers use of the tools when planning and teaching their science lessons.

Design-based research is rooted in the pragmatic philosophies of John Dewey, where the goal of inquiry is to produce useable knowledge rather than grand truths (Barab & Squire, 2004). As such, design-based research is not just about formative evaluation of tools, but is also about the generation of "humble theories" that inform emergent understanding of learning processes, contribute to the development of productive learning environments, and attend to the types of problems and real-world situations that practitioners address in their everyday work (Cobb et al., 2003; Sloane & Gorard, 2003). The findings, conclusions, and implications of this study inform the continued revision and improvement of the instructional model and other long-term scaffolds for preparing elementary teachers to use curriculum materials effectively to plan and teach science. Furthermore, this study contributes to a growing understanding of how elementary preservice teachers learn to teach science and how they learn to use curriculum materials to plan and teach science lessons. Overall, this study contributes to the efforts to better prepare elementary preservice teachers to address the challenges they face teaching science in the classroom.

Overview of the Dissertation

To orient readers to this dissertation, I provide an overview of the following chapters.

Chapter 2: Frameworks

In this chapter, I lay out the conceptual frameworks that guide the design and analysis of this study. I begin with a conceptualization of curriculum materials and a description of a teacher-curriculum materials framework developed by Remillard (2005). I then describe a vision for how teachers could use curriculum materials to plan and teach science. I continue by describing the results of earlier cycles of the design-based research project that has informed this study. Next, I present the instructional model and other tools for helping preservice teachers use curriculum materials to plan and teach science. I end with the research questions that frame this study.

Chapter 3: Methods

This chapter presents the research methods I used for this project. First I give an overview of the methodology of the teaching development experiment (Simon, 2000) that I followed. Then, I describe the setting for the research and data collection. I also describe my analyses, including the analysis of the preservice teachers' use of the instructional model and the analysis of the meanings they made of the frameworks and practices offered in the science methods course. As part of this chapter, I describe the color-coding analysis procedure that I developed to examine the teaching patterns present in preservice teachers' plans and enactments. I end with a brief discussion of some of the limitations of this study.

Chapters 4, 5, 6: Cases of Dana, Leslie, and Nicole

In these three chapters I examine the experiences of three interns, Dana, Leslie, and Nicole, as they learned to use the instructional model to plan and teach a three-to-four-week science unit in their field placement classrooms. In each chapter, I describe their teaching setting and the topics they were assigned to teach. I then use the color-coding analysis procedure to describe in detail each interns' plans and enactments, comparing the interns' teaching patterns to the patterns implied by the instructional model. Each intern used the instructional model differently, producing different results. In each chapter, I examine the factors that may have influenced how each intern used the instructional model in her planning and teaching.

Chapter 7: Discussion and Conclusions

Chapter 7 is the discussion chapter. I use Gee's Discourse framework to look at the results across all three cases. I discuss how the interns were drawing from many different Discourses in learning to use the instructional model to plan and teach science. Four Discourses emerge as most important. I discuss how each intern drew on these Discourses in different ways to produce the results she received. I end with a summary of the conclusions of this research.

Chapter 8: Implications

In this final chapter, I discuss the implications of this research for preparing preservice teachers to use tools such as the I-AIM and CA&P to plan and teach science. I also discuss implications for revising the tools and for future research.

CHAPTER 2

Frameworks

Chapter Overview

This research is part of a larger design-based research project focused on helping preservice teachers learn to use curriculum materials effectively to plan and teach science lessons that support students in learning specified learning goals, engage students in scientific practices, and leverage students' intellectual and cultural resources for learning science. This chapter provides the theoretical framework for this larger research project as well as this dissertation research. I begin with the theoretical framework for understanding teachers' use of curriculum materials. I then describe a vision for how teachers should use curriculum materials in their planning and teaching. Next, I explain how this dissertation research fits into the larger design-based project and how earlier design and enactment cycles of this project informed this dissertation. In addition, I describe the Experiences Patterns Explanations (EPE) framework, and the Inquiry-Application Instructional Model (I-AIM) and Critical Analysis and Planning (CA&P) tools designed in earlier cycles of this project to scaffold preservice teachers' science planning and teaching practices. I end by establishing the research questions that this dissertation explores.

Teachers and Curriculum Materials

Curriculum materials are all of the resources that guide teacher planning and enactment of lessons including textbooks, teacher guides, kits, student activity guides, Internet resources, trade books, and videos. This work is guided by the sociocultural perspective that teachers participate with curriculum materials in the design of the planned curriculum and co-construction, with their students, of the enacted curriculum (Remillard, 2005). Figure 2.1 shows Remillard's framework for the participatory teacher-curriculum materials framework. In this framework, both the teacher and the curriculum materials are viewed as active participants. The curriculum materials are considered tools that mediate teacher action through their affordances and constraints (M. W. Brown & Edelson, 2003; Grossman & Thompson, 2004; Remillard, 2005). The nature of the interaction between the teacher and curriculum materials and the resulting planned (and enacted) curriculum depends on what both the curriculum materials and the teacher bring to the relationship (Remillard, 2005).

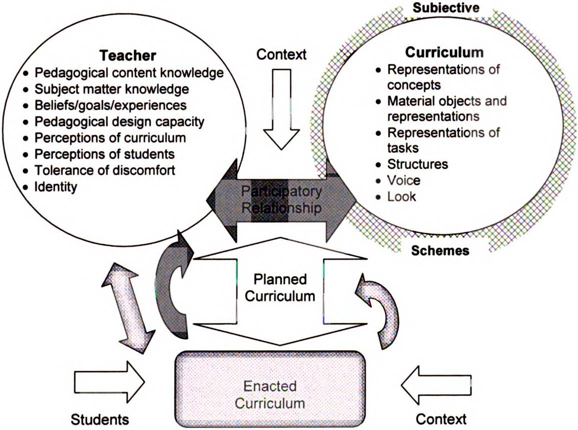

Figure 2.1. Remillard's teacher-curriculum materials framework (Remillard, 2005)

Curriculum materials are the products of social activity within cultural, historical, and institutional settings (Wertsch, 1991). As cultural tools, they represent and enable/ constrain human actions (M. W. Brown & Edelson, 2003; Grossman & Thompson, 2004;

Remillard, 2005; Wertsch, 1991). In one sense, curriculum materials are physical objects that include representations of concepts, task procedures (M. W. Brown & Edelson, 2003) and instructional approaches. The physical nature of these materials and their representations provide resources that teachers use in planning and teaching. The representations, activity procedures, and instructional approaches contained within the materials are also products of social activity in terms of both the disciplinary knowledge and pedagogy that they portray. As a result, curriculum materials are tied to and conveyors of multiple cultural, historical, and institutional ideas, values, and meaning. These ideas, values, and meanings mediate how teachers read, interpret, and use curriculum materials. Curriculum materials both provide affordances and place constraints on teacher actions and the planned and enacted curricula (M. W. Brown & Edelson, 2003; Grossman & Thompson, 2004; Remillard, 2005).

Teachers bring a range of "knowledges, capacities, beliefs, perceptions, and experiences" to teacher-curriculum materials relationship (Remillard, 2005, p. 237). Teachers must be able to use their subject matter knowledge, pedagogical content knowledge, knowledge of the curriculum, and understanding of who their students are to develop lessons that fulfill the curriculum intended by the school, district, and state benchmarks; use effective and appropriate pedagogy; and attend to student learning needs (Ben-Peretz, 1990; Carlsen, 1991; Shulman, 1986). Furthermore, teachers' beliefs about the subject area, teaching, their students, and curriculum materials influence how teachers interact with curriculum materials. For example, Remillard (1999) found that teachers who believed that mathematics is a collection of topics read and interpreted curriculum materials differently from teachers who believed that mathematics is a body of related ideas and relationships. The number of factors that influence the teacher-curriculum materials relationship makes the construction of the planned and enacted curricula complex and multifaceted (Remillard, 2005).

Teachers may participate with curriculum materials in many ways. For example, new teachers may rely heavily on curriculum materials as a way to negotiate the many demands of teaching that they are still learning to manage (Barab & Luehmann, 2003; M. W. Brown & Edelson, 2003; Grossman & Thompson, 2004). Also, both new and experienced teachers may view the curriculum materials as a source of authority (Ben-Peretz, 1990). Administrators and curriculum materials may suggest to teachers that they are primarily implementers rather than critical users of curriculum materials. In these situations, teachers may follow curriculum materials rigidly with little modification.

On the other hand, some teachers may view themselves as the primary creators of the planned and enacted curriculum. They draw on many resources and rely on their own principles and criteria to decide what and how to teach (Ben-Peretz, 1990; Remillard, 2005). Experienced teachers may participate with materials in multiple and complex ways by sometimes adapting materials to meet their teaching needs, sometimes following the materials closely ("off-loading", in Brown & Edelson's terms), and sometimes improvising new activities, often using the curriculum materials as the seed for innovations (M. W. Brown & Edelson, 2003).

Not all ways of participating with curriculum materials are necessarily productive. The teacher's perception of the authority of the curriculum materials may constrain their use of the materials (Ben-Peretz, 1990). Teachers who rigidly follow curriculum materials may miss opportunities to improve the match among the materials, the intended curriculum, and their own students' needs and resources (Ben-Peretz, 1990). Teachers who draw on multiple materials without robust criteria and reasoning guiding their curricular choices may develop approaches that undermine student learning, rather than supporting it (A. L. Brown & Campione, 1996). Teachers may unintentionally alter critical features of strong curriculum materials, thus altering the potential effectiveness of the materials to help students learn science (A. L. Brown & Campione, 1996; Schneider et al., 2005). In any of these situations, teachers may also miss opportunities to learn from educative features of curriculum materials (Davis & Krajcik, 2004a).

One goal of elementary science teacher preparation should be helping preservice elementary teachers participate with curriculum materials in a way that is productive for both student and teacher learning. Teachers should develop an analytical relationship with curriculum materials. They should be able to analyze curriculum materials for their strengths and weaknesses and make appropriate modifications to the instructional approach presented in the curriculum materials in order to guide students in developing understanding of the learning goals, engage students in the practices of science, and take advantage of the resources that students bring to learning science. In the next section I will describe a vision for what teachers should look for in their analysis of materials and the frameworks that underlie this vision.

A Vision for Analysis & Modification of Curriculum Materials

In order to identify strengths and weaknesses of curriculum materials, teachers must have a basis on which to analyze the materials they have available. They need to determine how well the materials align with the intended curriculum, analyze the instructional approach of the materials, and consider how well the materials match students' resources for learning science.

Aligning with the Intended Curriculum

The curriculum framework, usually established by district and school policy, defines the intended curriculum - the learning goals for what students should know and be able to do as a result of participation in school (Remillard, 2005). The first step teachers must take in analyzing curriculum materials is to decide if the activities offered in the curriculum materials address the learning goals for which they are responsible for teaching (Kesidou & Roseman, 2002). Often, the suggested activities and text do not address the learning goals or big ideas that they claim to address (Kesidou & Roseman, 2002) or the curriculum materials do not align well with the learning goals set forth in the intended curriculum. Analyzing the alignment of the curriculum materials with the intended curriculum requires that teachers have adequate subject matter knowledge to unpack the learning goals and understand what students need to know and be able to do in order to achieve the learning goals. Then, teachers must be able to decide if the activities offered in the curriculum materials build towards helping students reach these goals. If activities do not address the learning goals, teachers must either decide not to use the activities or make modifications to the activities to better meet the learning goal.

Analyzing the Instructional Approach

The instructional approach is the sequence of activities for instruction. Some curriculum materials are collections of activities, with no intended sequencing. Other materials include a recommended order for the activities. Within an instructional approach, each activity should serve a function that supports students in learning the specified learning goal (E. L. Smith, 2001). Instructional approaches should also engage students in the practices of science (Anderson, 2003). I will describe these functions and purposes in more detail.

Teachers should first recognize whether the materials have an instructional approach. If the curriculum materials do offer an instructional approach, teachers need to determine whether or not it represents an effective approach to learning science (Ball & Feiman-Nemser, 1988; Ben-Peretz, 1990; Collopy, 2003; Grossman & Thompson, 2004; Schneider et al., 2005; E. L. Smith, 2001). Teachers should be able to determine the purpose of each activity in the sequence, and recognize which activities are pivotal in the instructional approach so that when they make subsequent modifications, they avoid undermining the intent and directions of the activity sequence (Anderson, 2003; A. L. Brown & Campione, 1996; National Research Council, 2000).

For each learning goal identified, the instructional approach should engage students in a problem, take into account and build on student ideas, and provide a variety of experiences with phenomena. In addition, the sequence should provide scientifically accurate representations, promote student thinking about their ideas, and provide adequate practice for students to use their new understandings in familiar and unfamiliar contexts (Kesidou & Roseman, 2002; E. L. Smith, 2001; Stern & Roseman, 2004). The materials should also guide teachers in anticipating student responses and assessing student understanding throughout the sequence of activities. Teachers should be able to recognize when an instructional approach does or does not serve each of these functions.

Included in analyzing the instructional approach should be an analysis of the practices of science in which the activities engage students. What students learn about science is greatly influenced by the practices in which they engage. In order to understand what science is and how it works, students must engage in such practices as asking questions, looking for patterns in experiences, using evidence to make scientific explanations, and applying explanations to new situations (i.e., Anderson, 2003; Driver *et al.*, 1994; National Research Council, 1996, 2000, 2007; Rivet & Krajcik, 2004; Rosebery *et al.*, 1992; Sharma & Anderson, 2003). Teachers must analyze the instructional approach to determine whether and how the materials engage and support students in learning these practices.

Taking Students into Consideration

As Remillard's framework shows, while teachers participate with curriculum materials to produce the planned curriculum, what happens in the classroom (the enacted curriculum) is negotiated between the teacher and students (Calabrese Barton *et al.*, 2003; Gilbert & Yerrick, 2001; Page, 1999). Therefore, when analyzing curriculum materials, teachers need to consider the sociocultural backgrounds of their students, and recognize whether or not the instructional approach in the curriculum materials takes advantage of the resources their students bring to learning science, matches their students' interests and experiences, and supports their students' learning needs. Teachers should take a critical stance at this point, and examine how the curriculum materials position the students as knowers and doers of science. Teachers must know who their students are, including their funds of knowledge about the world and their ways of making sense of the world (Calabrese Barton *et al.*, 2008; Gonzalez *et al.*, 2005; Moje *et al.*, 2004; Moll *et al.*, 1992; Varelas *et al.*, 2002). For example, elementary students living in poor urban areas have a different set of experiences and a different perspective on the world than students living in more wealthy suburbs, rural farms, or Indian pueblos in New Mexico. Teachers should be able to decide if the instructional approach offered by the curriculum materials leverage the funds of knowledge that their students access and connects to their students' cultural knowledge about the world (Aikenhead, 1996; Jegede & Aikenhead, 1999; Lee, 1997, 2003; Lee & Fradd, 1998; Moje *et al.*, 2001).

How curriculum materials help students move from their ideas to more scientific ideas has important cultural implications that teachers should take into consideration (Calabrese Barton et al., 2003; Jegede & Aikenhead, 1999; Lee, 1997, 2003; Lee & Fradd, 1998). Sometimes, it might be important to recognize how scientific practices differ from students' own sense-making practices and help students transition from their own practices to scientific practices and back by recognizing when it is appropriate to use scientific practices and when it is not. In this manner, teachers make instruction congruent with students' sociocultural backgrounds as much as possible (Aikenhead, 1996; Jegede & Aikenhead, 1999; Lee, 1997, 2003; Lee & Fradd, 1998). For example, students who come from backgrounds where the elders are keepers of cultural knowledge may be uncomfortable and unfamiliar in the scientific practices of questioning and building explanations from evidence. Engaging these students in inquiry without recognizing and accommodating for this difference may make it difficult for these students to learn these practices. At other times, even with these same students, it may be important to highlight the similarities between students' ways of thinking and scientific practices (Calabrese Barton et al., 2003; Rosebery et al., 1992; Warren *et al.*, 2001; Warren *et al.*, 2005). For example, children's ways of connecting prior experiences to understand current problems may help them engage in science practices more authentically and learn the associated content more easily (Calabrese Barton et al., 2003). Finally, teachers should be able to determine if and how curriculum materials allow students to have voice and agency in the learning process. Teachers should be able to recognize if curriculum materials offer multiple points of entry for students to access science for purposes that are relevant to their lives and provide them with the power to use science to transform their own lives (Calabrese Barton et al., 2003; Calabrese Barton & Yang, 2000; Moje et al., 2004).

Modifying Curriculum Materials

Prepared with these analyses, teachers should modify the instructional approach offered in curriculum materials to align with the intended curriculum, engage students in scientific practices, and take advantage of the diverse resources students bring to learning science. Ideally, the teacher should be able to use ideas and activities offered in the curriculum materials to build what some refer to as a third space (Moje et al., 2004), composite culture (Hogan & Corey, 2001), or hybrid space (Calabrese Barton et al., 2008), that is neither solely a scientific space nor solely a student space. The goal would be to use and modify curriculum materials in a way that contributes to the development of a culturally responsive (Banks *et al.*, 2005; Gay, 2001) science learning community where the practices of the classroom support diverse students in learning the content and practices of science.

Part of the analysis of curriculum materials also involves recognizing which weaknesses or deficiencies in curriculum materials one can reasonably modify. Given the demands of teaching and the resources available, teachers may need to be selective in their modifications. Analyzing how well curriculum materials align with the intended curriculum, analyzing the instructional approach for supporting student learning and engaging students in scientific practices, and analyzing the match between curriculum materials and the resources students bring to learning science, represent idealized teacher practices. As Davis (2006) points out, preservice teachers need to develop beginning levels of proficiency with these practices so that they can grow into them as they gain experiences teaching. The goal of preservice teacher education, then, should be to support preservice teachers in building a foundation for developing a productive relationship with curriculum materials that enables them to analyze curriculum materials thoroughly, learn how to take advantage of the strengths that curriculum materials offer, and determine which deficiencies to modify. The next section explains an initial approach to teaching preservice teachers how to analyze curriculum materials and the results of research on that approach.

Previous Design Cycles

As part of a design-based research project, this dissertation builds off previous cycles of design and research. In this section I will describe the earlier cycles of research and the lessons learned that informed this dissertation.

The initial approach to preparing preservice teachers to analyze curriculum materials utilized the Project 2061 Instructional Criteria (DeBoer *et al.*, 2004; Kesidou & Roseman, 2002; Stern & Roseman, 2004) as a framework for analyzing the instructional approaches offered by curriculum materials. Preservice teachers in a senior-level science methods course (fourth year of a five-year teacher preparation program) were introduced to 10 of the 23 Project 2061 Instructional Criteria. They practiced using each criterion in class to analyze the strengths and weaknesses of example curriculum materials. Preservice teachers then analyzed the curriculum materials that they were using to develop the lesson plans that they eventually taught in their field placement classrooms. In addition, preservice teachers were introduced to several additional frameworks to use for planning inquiry-application oriented lessons, including the Experiences Patterns Explanations (EPE) framework (Anderson, 2003; Sharma & Anderson, 2003), conceptual change frameworks (E. L. Smith, 1991), and the BSCS 5E instructional model (Bybee, 1997).

Research conducted on this first approach showed that the Project 2061 Instructional Criteria, by themselves, did not provide a productive framework to help the preservice teachers learn to analyze and modify curriculum materials (Gunckel & Smith, 2007; Schwarz et al., 2008). Several issues were present. First, the preservice teachers tended to use their own criteria for analyzing curriculum materials. They often focused on issues of practicality rather than focusing on how well the materials might help students learn. When asked specifically to use the Project 2061 Instructional Criteria, the preservice teachers often did not use the criteria as intended. When planning their lessons, the preservice teachers struggled to modify materials that did not engage students in scientific practices. Finally, the preservice teachers expressed that they did not find the Project 2061 Instructional Criteria helpful in thinking about planning and teaching science.

These findings suggest that there were several deeper issues that needed consideration. First, analyzing curriculum materials may be a destabilizing experience for preservice teachers (Gunckel & Smith, 2007; Schwarz et al., 2008). Many preservice elementary teachers come to teaching science with a limited background in science, and thus may feel under-confident about teaching science (Chochran & Jones, 1998). To discover that the curriculum materials on which they were relying may not help them teach science well was not a comforting realization and may have left them feeling unsupported in teaching science. Many expressed frustration with the analysis process because they were unsure what to do once they determined that the curriculum materials had significant weaknesses. Furthermore, analyzing curriculum materials requires that preservice teachers question those whom they may perceive to be more knowledgeable and of higher authority than themselves (Bullough, 1992), including the curriculum materials designers who wrote and published the materials (Ball & Feiman-Nemser, 1988; Ben-Peretz, 1990; Davis, 2006), their cooperating teachers, and the school districts administrators who may have mandated the use of specific curriculum materials in the first place.

Second, preservice teachers may not recognize analysis and modification of curriculum materials as an authentic and central practice of teaching (Davis, 2006; Schwarz et al., 2008). Preservice teachers in methods courses with field placements are negotiating multiple learning communities, including the learning communities of their university courses and the learning communities in the field placement classrooms. Their cooperating teachers may talk about and engage with curriculum materials in ways that are different from the ways that their university course instructor talks about and engages with curriculum materials (Feiman-Nemser & Buchmann, 1985). Furthermore, they may not see their cooperating teachers explicitly engaging in curriculum materials analysis and modification. Cognition and learning are situated in communities of practice

(J. S. Brown *et al.*, 1989; Lave & Wenger, 1991; Putnam & Borko, 2000). Therefore, not seeing their cooperating teachers explicitly engage in curriculum materials analysis and modification may make it difficult for preservice teachers to recognize curriculum materials analysis and modification as authentic and central practices of teaching.

Another issue was the difficulty preservice teachers had in considering their own students when analyzing and modifying curriculum materials (Gunckel & Smith, 2007; Putnam & Borko, 2000; Schwarz et al., 2008). The analysis criteria included criteria targeted to helping preservice teachers decide if the curriculum materials matched their students' experiences and cultural ways of interacting with the world. These criteria were not part of the original Project 2061 Instructional Criteria. The preservice teachers often only considered students who were similar to themselves, or generalized from their perceived notions of what all students are like. The analysis process did not support them in getting to know their students, so they had difficulty assessing how well the materials matched their students' resources and needs. Other researchers have found similar patterns in working to help experienced teachers match their teaching to students' sociocultural backgrounds and experiences (Lee *et al.*, 2005; Luykx *et al.*, 2005).

Finally, preservice teachers come to elementary science methods courses with specific concerns that are relative to their position as preservice teachers just beginning to negotiate the complexities of teaching (Feiman-Nemser, 2001; Grossman & Thompson, 2004). Their concerns about planning and teaching science may not match the concerns about teaching science that underpin an analytical relationship with curriculum materials. That is not to say, however, that their concerns are not legitimate. Therefore, preparing elementary preservice teachers to analyze and modify curriculum materials needs to involve finding ways to incorporate preservice teachers' concerns into the analysis and modification of curriculum materials so that they can then learn about and focus on additional aspects of the analysis.

The Inquiry-Application Instructional Model and Critical Analysis & Planning Tool

The early cycles of design and research showed that simply providing preservice teachers with criteria with which to analyze curriculum materials was not productive. A new approach was needed to embed analysis of curriculum materials into practices that preservice teachers might recognize as important practices of teaching science, to reduce the number of discrete criteria that the preservice teachers needed to use, and to provide preservice teachers with a vision for what to do when they found curriculum materials lacking. In the next cycle of design and research, I was part of the team of researchers who designed the Inquiry-Application Instructional Model (I-AIM) and the accompanying Critical Analysis and Planning Tool (CA&P) to synthesize many of the criteria and frameworks introduced to preservice teachers in the early cycles of research. The I-AIM and CA&P were intended to scaffold preservice teachers into the analysis and planning practices described above. In the next section I will describe the I-AIM and CA&P tools and their underlying frameworks.

Experiences, Patterns, Explanations (EPE)

In the early cycles of the design work, criteria for analysis of curriculum materials included several criteria for engaging students in scientific practices. In addition, the preservice teachers were introduced to the Experiences Patterns Explanations (EPE) framework for describing scientific practices (Anderson, 2003; Sharma & Anderson, 2003). While the preservice teachers did not find the scientific practices criteria accessible or useful, they did find the EPE framework helpful in forming a vision for science teaching (Schwarz et al., 2008).

The EPE framework represents science as related practices of inquiry and application. Inquiry is defined as learning from experience. Scientists engage in inquiry by looking for patterns in many experiences and developing a small number of explanations for those patterns. These explanations are the models and theories that explain the big ideas of science, such as plate tectonics or evolution. Scientists then apply these explanations to understand other patterns and experiences. This practice is application, defined as using knowledge. This view of science contrasts with traditional school science where students learn a large number of explanations and may have little opportunity to see the patterns in experiences that support those explanations. Figure 2.2 shows the EPE framework.

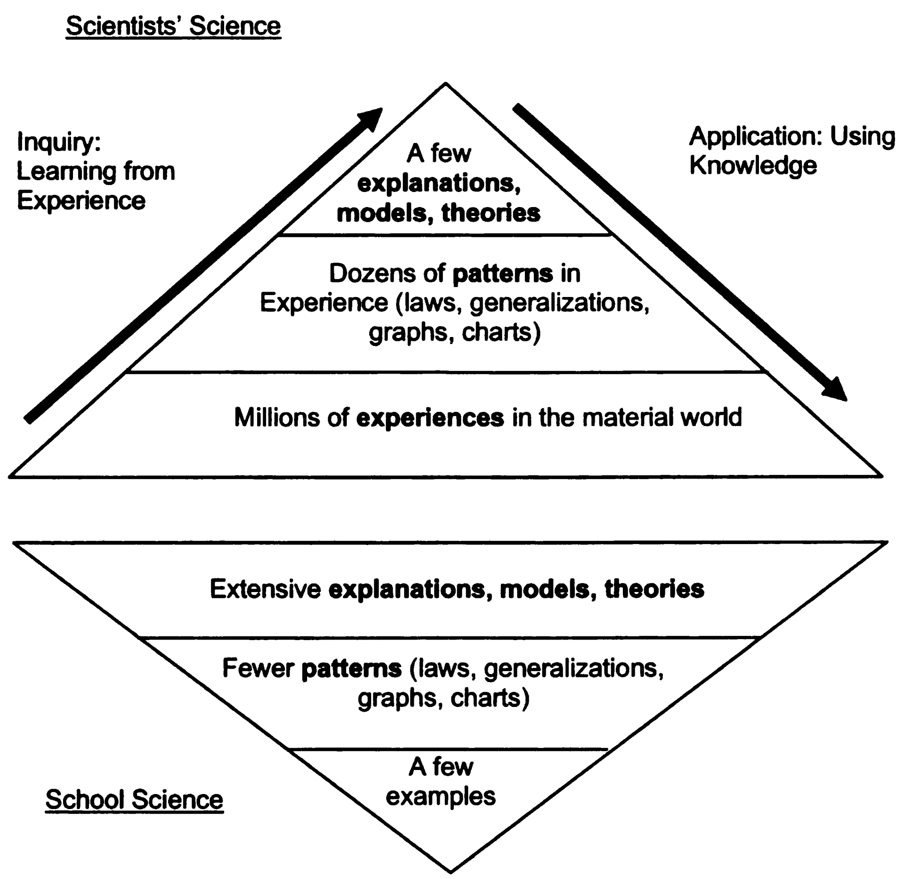

Figure 2.2. Experiences-Patterns-Explanations framework (Anderson, 2003)

Preservice teachers introduced to the EPE framework recognize that one goal of science teaching should be to make school science look more like scientists' science (Gunckel *et al.*, 2007). However, the EPE framework does not provide the scaffolding necessary to support preservice teachers in sequencing activities in a way that engages students in inquiry and application practices. The Inquiry-Application Instructional Model was designed to provide this scaffolding.

Inquiry-Application Instructional Model (I-AIM)

An instructional model is a framework designed to scaffold preservice teachers' planning and teaching by guiding their efforts to sequence activities into coherent learning experiences (Abraham, 1998; Schwarz & Gwekwere, 2007). The Inquiry-Application Instructional Model (I-AIM) was specifically designed to help preservice teachers use curriculum materials to plan and teach instructional sequences that support students in learning science and engage students in the scientific practices of inquiry and application (Gunckel et al., 2007). The model is founded on the premise that every activity in a lesson sequence should function in a specified manner in order to help move students towards achieving a specified learning goal (E. L. Smith, 2001). The model includes four stages that correspond to the inquiry and application aspects of the EPE framework. The inquiry phase of the I-AIM includes the Engage (also called the Question stage in more recent versions), Explore & Investigate, and Explain stages. The application phase overlaps with the Explain stage and continues with the Application stage. Each stage in the model serves two to three functions: Engage (establish a question; elicit student ideas), Explore & Investigate (explore phenomena to look for patterns; explore student ideas about patterns), Explain (students explain patterns, introduce scientific ideas; compare scientific ideas to student ideas/ revise student ideas), and Apply (practice with support in near and far contexts). Table 2.1 shows the main stages and functions of the I-AIM. The complete Inquiry-Application Instructional Model is found Appendix A.

The I-AIM includes several important features. First, the Engage stage involves establishing a problem that gives purpose to students' study and frames subsequent exploration and investigation (Reiser *et al.*, 2003; Rivet & Krajcik, 2004; E. L. Smith, 2001). The Explore & Investigate stage provides students with experiences with phenomena. This stage emphasizes investigation rather than open discovery (Schwarz & Gwekwere, 2007). Similarly, to distinguish from discovery models, the I-AIM includes the introduction of scientific ideas in the Explain step. Perhaps most important in terms of fitting the EPE framework, students are engaged in experiences with phenomena before explanations are introduced, and patterns in experiences are made explicit. In this way, students develop an understanding for the patterns in experience that scientific theories and models explain.

Table 2.1

Inquiry-Application Instructional Model (I-AIM)

EPE		Model Stage	Activity Strategic Function
Inquiry		Engage	Establish a question
Inquiry		Engage	Elicit student ideas about the question
Inquiry		Explore & Investigate	Explore phenomena & look for patterns
Inquiry		Explore & Investigate	Explore student ideas about patterns
Inquiry	Application	Explain	Students explain patterns
Inquiry	Application	Explain	Introduce scientific ideas
Inquiry	Application	Explain	Compare to & revise student ideas
	Application	Apply	Practice with support (model & coach)
	Application	Apply	Practice with fading support

Student ideas are elicited at every stage of the I-AIM. Instruction that follows the model provides students with opportunities to share their ideas, then revise their ideas as they engage in new experiences. Students compare their explanations for observed patterns with the scientific explanations introduced, thus supporting students in recognizing how scientific explanations are plausible and fruitful (Posner *et al.*, 1982; E. L. Smith, 2001).

The Application stage involves using newly-developed ideas to explain similar phenomena in new contexts. It fits the application cycle of the EPE framework, where new explanations are used to explain experiences. Students need practice in order to become proficient at applying new explanations. The I-AIM relies on the cognitive apprenticeship I (J. S. Brown et al., 1989; Collins *et al.*, 1989; E. L. Smith, 1991) to provide students with practice applying new explanations in both familiar and less familiar contexts.

Critical Analysis & Planning Tool (CA&P)

Using the I-AIM to create a culturally responsive science learning community requires that the teacher consider not just how well the curriculum materials fit the I-AIM, but also how well the materials match the cultural and intellectual resources that the students bring to learning science. The initial design cycle of this project revealed the difficulties that preservice teachers face in considering the cultural and intellectual resources of their students (Gunckel & Smith, 2007; Schwarz et al., 2008).

Often, preservice teachers have few tools and lenses to use to consider their own students strengths. The Critical Analysis & Planning Tool (CA&P) functions to scaffold preservice teachers in considering students in their analysis of the curriculum materials and the planning of the instructional approach. The CA&P provides a series of three questions for each stage and function of the I-AIM. The first questions focus on how well the materials fit I-AIM. The curriculum materials questions draw on Project 2061 Instructional Criteria and embed them into the I-AIM framework. The second question asks preservice teachers to consider what resources their own students bring to each stage of the I-AIM and asks how the curriculum materials fit or leverage these resources. The third question scaffolds planning decisions in light of the answers to the first two questions. Table 2.2 shows several example CA&P questions. The complete CA&P tool is provided in Appendix B. By using the CA&P questions as a guide, preservice teachers use the curriculum materials as a lens for thinking about their students, and their students as a lens for analyzing the curriculum materials.

Table 2.2

Critical Analysis & Planning Tool (CA&P)

Model Stage	Activity Function	Curriculum Materials Analysis Questions	Knowing My Students Questions	Planning Questions
Engage	Establish a Question	Is there a relevant, interesting, understandable problem that is set in a real world context that addresses the learning goal?	What problems are relevant and interesting to my students? How can I connect to my students' lived experiences?	What relevant, interesting, motivating, understandable problem will I use? How is this problem related to my students' lived experiences?
	Elicit Students' Initial Ideas	Does the material elicit student ideas and help the teacher understand student ideas about the learning goal?	What ideas do my students have related to this learning goal? How do my students make sense of their world?	How will I elicit student ideas? How will I have students share their ideas with other students?
Continues for all stages… For complete CA&P, see Appendix B				

Initial Results using the I-AIM and CA&P

In the design and enactment cycle immediately preceding this dissertation research, the I-AIM and CA&P tools were piloted in one senior-level science methods course and one intern-level science methods course. Overall, the preservice teachers in the courses reported that they found the model helpful in guiding them in the evaluation and modification of curriculum materials in their science lesson planning (Bae, 2007; Gunckel et al., 2007). Preservice teachers who had had previous exposure to the Project 2061 Instructional Criteria found the I-AIM facilitated curriculum materials evaluation in a more coherent, relevant, and useful manner. Preservice teachers' resulting lesson plans included more inquiry and application practices and met more of the Project 2061 Instructional Criteria than they had in previous semesters. The course instructors found that the I-AIM provided a more coherent basis for weaving together concepts, curriculum material examples, and unit planning opportunities. The I-AIM and CA&P seemed to make curriculum materials evaluation and modification more central, authentic practices of teaching.

Research Questions

The pilot test of the I-AIM and CA&P tools suggested that the tools could serve as scaffolds for preservice teachers learning to use curriculum materials to plan and teach science. However, more research was necessary to understand how the preservice teachers used the tools and the sense they made of the tools and the underlying EPE framework. This dissertation research served as the next iteration of research on these tools.

Remillard's framework describes how teachers participate with curriculum materials in the design of the planned and enacted curricula. The curriculum materials serve as tools that mediate teachers' actions. In this research, the I-AIM and CA&P tools scaffold preservice teachers' relationship with the curriculum materials. What becomes highlighted is the teachers' use of the I-AIM and CA&P tools, which themselves function to mediate the teacher-curriculum materials participatory relationship. As with curriculum materials, the I-AIM and CA&P also carry cultural, historical, and institutional meanings that influence how preservice teachers interact with them. Furthermore, preservice teachers bring a variety of perspectives, beliefs, knowledges, and practices that mediate how they interact with the I-AIM and CA&P tools and affect the resulting planned and enacted curricula. Figure 2.2 shows how the I-AIM and CA&P tools fit into Remillard's framework.

The ways that preservice teachers use the I-AIM and CA&P tools reflects the meanings that preservice teachers make of the tools and the underlying EPE framework (Erickson, 1986). This research focuses on how preservice teachers made sense of and used the I-AIM and CA&P frameworks to plan and teach a science unit in their field placement classrooms. It looks closely at the meanings that the preservice teachers made of the EPE framework, the stages and functions of the I-AIM, and their own students resources for learning science. Furthermore, it examines how the preservice teachers' use of the I-AIM and CA&P tools influenced the preservice teachers' resulting planned instructional approaches and enacted activity sequences. Finally, this research looks at the broader sphere of influences that may account for how the interns made sense of and used the tools. This research is set in the context of a science methods course that takes place during the 5th-year internship of a five-year elementary teacher education program. Specifically, the research questions for this project are:

How do the interns use the I-AIM and CA&P tools to plan and teach their science lessons?

What are the mediators that influence how the interns use the I-AIM and CA&P tools?

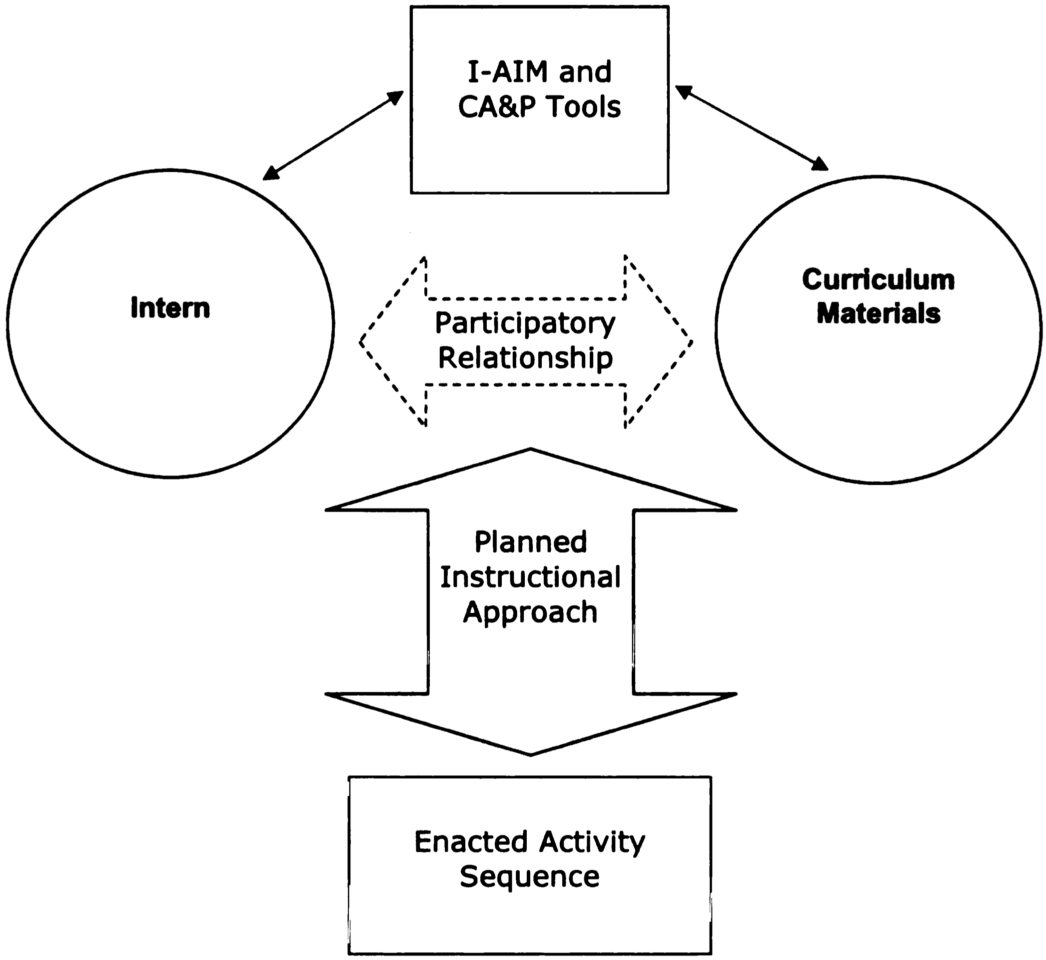

Figure 2.2. How I-AIM and CA&P Tools fit in Remillard's framework

As part of a design-based research project, this dissertation research is necessarily conjecture-driven (Cobb et al., 2003). The previous design and enactment cycles of this project pointed towards several important challenges that this cycle of design and enactment must address. As described in the previous section, the I-AIM and CA&P tools were designed to address some of these challenges. In this cycle of enactments, the conjectures were that these scaffolds would help preservice teachers grapple with and use the many frameworks introduced in the science methods course, recognize curriculum materials analysis as an authentic task of planning and teaching, connect curriculum materials analysis and lesson planning to their own students particular strengths and needs, and deal with some of the immediate concerns and uncertainties of teaching that preservice teachers are attendant to as beginning teachers.

However, design-based research is about more than testing whether or not interventions succeed. It is also about the generation of "humble theories" that contribute to the understanding of learning in real-world situations. (Cobb et al., 2003; Sloane & Gorard, 2003). Thus, this dissertation research looks beyond whether or not the I-AIM and CA&P tools functioned as conjectured. What is important is understanding how the interns think about and use the tools, think about their students, and plan and enact their lessons. This research informs not only the refinement of the I-AIM and CA&P tools and approaches to teaching preservice teachers to use curriculum materials, but also our understanding of how preservice teachers learn to plan and teach reform-based science lessons. In Chapter 3, I will describe the methods used to answer these research questions.

CHAPTER 3

Methods

Chapter Overview

In this chapter I provide an overview of the research methods and methodology used in this dissertation. I begin with a description of the teacher development experiment methodology and show how this research fits that approach. Next, I provide an overview of the context of the study, followed by a description of the sampling and data collection. I then describe my analysis framework and approach. Finally, I end with a short note about credibility in design-based research.

Study Design

This dissertation is a teacher development experiment (Simon, 2000; Simon & Tzur, 1999) that is part of a larger design-based project (Barab & Squire, 2004; Cobb et al., 2003; Design-Based Research Collective, 2003) focused on preparing elementary preservice teachers to use curriculum materials effectively to teach science. Teacher development experiments are design-based experiments that focus on creating teacher education learning environments with the goal of better understanding the development of preservice teachers' reform-based teaching practices. They deal with the messiness of complex teacher education learning environments where preservice teachers are both students in methods courses and teachers of students in K-12 settings by coordinating whole-class teaching experiments with individual case studies (Simon, 2000).

This study took place over the Spring, 2007 semester. Consistent with the whole-class teaching experiment aspect of the teaching development experiment, this study took place in an elementary science methods course that emphasized using the EPE framework and the I-AIM and CA&P tools to plan and teach science lessons. The course instructor, Dr. Adams, was a senior member of the science education faculty and a co-developer of the I-AIM and CA&P tools. As such, Dr. Adams served as a teacher-researcher in the overall design-based project. His job in this experiment was to promote the intern's developing science planning and teaching practices. He had the intimate understanding of the reform-based science teaching practices, the EPE framework, and the I-AIM and CA&P tools that were necessary to support the preservice teachers' pedagogical development (Simon, 2000). As a participant-observer, my role in the teaching development experiment was to observe the happenings in the course from a perspective outside the teacher-student relationship (Simon, 2000). While Dr. Adams had all instructional responsibility for the course, he and I met frequently between class sessions to conduct an on-going analysis of the interns' progress and plan or modify the instructional approach for the next class period. Data collected to document the whole class instruction in the science methods course included field notes of all class meetings; all class documents including the syllabus, hand-outs, and course readings; and an audio-recorded, semi-structured interview with Dr. Adams.

Teaching development experiments also include a case study approach to understand preservice teachers' experiences and developing practices. In this approach, the researcher uses reform conceptual frameworks as a lens to investigate preservice teachers' developing practice and to understand how the preservice teachers make sense of their experiences planning and teaching science. Simon & Tzur (1999) point out that this perspective is different from a deficit accounting of what developing preservice teacher's can and cannot do and at the same time, different from reporting what the preservice teachers might say about their own practice. Simon & Tzur call this approach "explaining the teachers' perspective from the researchers' perspective" (p. 254). This approach values the preservice teachers' perspective and experiences as true for that preservice teacher, but at the same time, explains the preservice teachers' experiences from within the researchers' frameworks. This approach informs the development of innovative teacher education approaches and theory.

This study followed three elementary preservice teachers, referred to in this work as interns, as they participated in the science methods course and used the frameworks and tools introduced in the course to plan and teach their science lessons in their field placement classrooms. The individual intern case studies involved developing accounts of the interns' use of the EPE frameworks and I-AIM/CA&P tools in their own planning and teaching. The accounts considered both how the interns used the frameworks and tools as compared to the intended uses, as well as their perspectives on and the meanings they made of their experiences planning and teaching science. In Simon's (2000) description of the teaching development experiment, the researcher takes on the role of a field supervisor, helping to develop the preservice teacher's practice in the field. As the researcher in this dissertation, I down-played the role of field supervisor because the interns already had a field instructor to whom they were accountable. However, consistent with the teaching development experiment methodology, I offered curriculum materials, activity suggestions, and management ideas when the interns asked for my advice.

Data on interns' use of the tools included copies of all course artifacts including unit and lesson plans, analysis and reflection reports on their teaching experiences, and science teaching philosophy statements; video-recordings of five to seven classroom observations of the interns teaching their plans in their field placement classrooms; audio-recorded, semi-structured interviews with each intern's mentor teacher; and three audio-recorded, semi-structured interviews with each intern. One interview with each intern occurred early in the semester before they began planning their science units and the other two interviews occurred after they had completed their science teaching in their field placement classrooms. All interviews and classroom observations were transcribed.

In order to understand how the interns used the tools, the meanings they made of the tools and frameworks, and their experiences planning and teaching science, analysis of the intern case studies took two forms. First, the analysis of the interns plans and enactments took an etic perspective (Watson-Gegeo, 1988) to compare the interns' use of the I-AIM and CA&P tools to the designers' intended use of the tools. This analysis provided a picture of what the interns did and framed their practice within the research framework. The second analysis took an emic perspective to gain insight into the interns' own goals, needs, concerns, beliefs, and understandings that were guiding their use of the tools (Watson-Gegeo, 1988). Through the process of analytic induction (Erickson, 1998), the emic data were coded and grouped to look for patterns and to test emerging hypotheses to explain the interns' experiences. Finally, an explanatory framework was developed that coordinated these analyses and explained the interns' experiences from the research perspective. The rest of this chapter provides the methodological details of this study

Context

The interns in this study were in their last semester of their fifth year of a five-year elementary teacher preparation program at a large, mid-western university. During the internship year, the interns' primary focus was learning to teach in their field placement classrooms. Interns were placed in a K-8 school classroom for four days a week for the entire school year. The assigned classroom teachers served as the interns' mentor teachers. The interns worked closely with their mentor teachers, with the interns gradually taking more responsibility for the planning and teaching of all subject areas as the year progressed. Interns also received support for their field experience from a university-based field instructor who made frequent classroom observations and held weekly field seminars with the interns.

In addition, the interns participated in two university graduate-level courses each semester. During the spring semester, one of these courses was a science methods course. This course was designed specifically to support interns as they planned and taught a three- to-four week science unit in their field placement classrooms. The course emphasized unpacking learning goals, identifying students' conceptions related to the learning goals, analyzing curriculum materials, developing an instructional approach, assessing student understanding, and building a classroom community that supported all students in learning science. The topic of the interns' science unit was assigned by the interns' mentor teachers and fit within the school science curriculum.

This graduate-level science methods course was the second science methods course that interns received during the teacher preparation program. During their fourth year, they had completed their first science methods course, which focused more broadly in the nature of science, science learners, and strategies for teaching science. In addition, all interns had taken at least eleven credit hours of science content courses during their undergraduate studies.

The science methods course was divided into three phases. During the first five weeks of the course, interns met weekly with a university science education professor for a three-hour seminar on science teaching. They read assigned course materials and completed assignments designed to scaffold their planning practices. In the second six weeks of the semester, called guided lead teaching, the course did not meet, and interns were responsible for teaching their planned science unit and all other subject areas to their students in their field placement classrooms. During at least three weeks of this guided lead teaching time, the interns' mentor teachers were not present in the field placement classrooms. For the last four weeks of the semester, the interns again met with the science education professor for weekly science seminar meetings.

The science methods course specifically emphasized the EPE framework and the use of the I-AIM and CA&P tools. Dr. Adams began the course with a demonstration unit about electricity that modeled a science unit that fit the I-AIM. He engaged the interns in the activities first, then provided the interns with the written activity sequence for the unit. He discussed the function of the activities in the sequence and provided a rationale for activities. He used the example electricity sequence to illustrate the difference between scientists' science and traditional school science as defined by the EPE framework. He also used the example electricity sequence to define the practices of inquiry and application. In addition, Dr. Adams held a special workshop at each of the interns' field placement schools for the interns and their mentor teachers. At the workshop, Dr. Adams introduced the EPE framework and the I-AIM and CA&P tools to the mentor teachers. He provided time for the interns and their mentor teachers to work together on the interns' science unit. He specifically asked the interns and mentor teachers to bring their available curriculum materials to the workshop so that they could begin analyzing the materials together and considering how to use and modify the materials to fit the I-AIM. Dr. Adams consulted with each intern/mentor teacher team to provide guidance and suggestions. Finally, he provided the interns with a detailed outline for their unit plans, including formats, details of required elements, and deadlines.

Sample Selection

Interns who volunteered to participate in the study were recruited during the first meeting of the science methods course. I gave the interns an overview of my project, explaining that I was interested in learning more about their experiences and perspectives on learning to teach science in the course and that I was specifically interested in their experiences with some of the tools for teaching to which they would be introduced in the course. I told the interns that I was asking for two types of participation in my study. First, I was seeking consent from each intern to observe them during their weekly science methods course meetings and have access to the assignments they all turned in to Dr. Adams. Second, I was seeking interns who would be willing to allow me to observe them teaching in their field placement classrooms and interview them about their planning and teaching experiences. Of the nineteen interns in the course, eighteen provided consent for me to observe them in class and examine their course work. Five interns agreed to the field placement observations and interviews.

The study began with all five interns who had volunteered to participate in the case study aspect of the research. I had hoped to have interns who represented a wide range of interests in science and science teaching, grade level placements, diversity of field placement schools, and topics of instruction. One intern dropped out of the study in the fourth week of the semester, before interviews began, because she decided she did not have any extra time to participate in the project. The remaining four interns participated in all aspects of the study. However, because of scheduling conflicts during the guided lead teaching portion of the semester, I was able to observe one of the remaining four interns only one time and was able to conduct only one post-teaching interview with him. As a result, data were lacking and I decided not to include him in my analysis. A brief description of the remaining three focus interns follows (all names are pseudonyms).

Dana had a sixth-grade placement in a self-contained class in an elementary school. This school was in a formerly rural setting that was recently becoming more suburbanized. The school had thirty percent of the students on the free or reduced lunch program. Of the 21 students in this classroom, 70% were Caucasian, 20% were African American, five percent were Hispanic, and five percent were Asian. One student in the class had a visual disability that required accommodation. Dana desired to become a middle school science teacher and had been an integrative science major as an undergraduate. Her topic of instruction for her science unit was light and color.

Leslie had a fifth-grade placement in a fifth-sixth grade middle school. This school was also in a formerly rural setting that was becoming more suburbanized. In addition, school-of-choice students sometimes transferred from nearby urban districts. The school had thirty-five percent of the students in the free or reduced lunch program. Leslie's mentor teacher team-taught with another mentor teacher down the hall. As a result, Leslie taught her science lessons to two classrooms of students. Each class had approximately 21 students, with 75% Caucasian, 15% African American, seven percent Hispanic, and two percent Asian. There were no designated special education students in the class. Leslie had been a social studies major as an undergraduate. Her topic of instruction was broadly defined as the carbon cycle.

Nicole had a second-grade placement in an elementary school. Like the other schools, it was also in a district that had formerly been primarily rural and was rapidly becoming more suburbanized as the nearby urban areas expanded. 34% of the students in the school received free or reduced lunch. Nicole had 23 students in her classroom, of which about 85% were Caucasian, five percent were African American/Black, five percent were Hispanic, and five percent were Asian. This class had six students who were from families that had recently immigrated to the United State from Bosnia, Vietnam, Thailand, France, and China. Of those students all were bilingual and three were English Language Learners. Nicole was a language arts major as an undergraduate. Her topic of instruction was sound.

Data Collection

The data for this study were collected over the course of the semester. For each intern, a set of data included all course assignments turned in to the professor, five to seven video recordings of enactments of their science lessons in their field placement classrooms, three audio-recorded interviews with the intern, and one audio-recorded interview with the intern's mentor teacher. In addition, field notes from all university science methods course meetings and copies of all course documents were collected. These data sources are described in detail below.

Course Artifacts

As part of the university science methods course, interns completed and turned in to the professor the assignments listed below. I also had access to professor's feedback on the assignments each focus intern submitted for the class. These sources provided data on intern thinking and actions, as well as some of the context of both the science methods course and the field placement classrooms in which the interns were participating.

- Learning Goals and Experience-Patterns-Explanations (EPE) Chart that identified the appropriate Michigan Curriculum Framework benchmarks, the central question for the unit, the ideal student response, and a list of student experiences related to the learning goal, patterns that emerge from those experiences, and the related scientific explanation;
- Pre-Assessment Plan, Results, and Analysis that described at least two pre-assessment tasks that the intern administered to students in her field placement classroom, example results, and an analysis of student responses that included identification of goal and naïve student conceptions related to the learning goal;
- Student Status Chart that identified several focus students in the class and notes on their peer status and special needs;

- Analysis of Curriculum Materials that identified strengths and weaknesses of the curriculum resources the interns had available to plan the science unit;
- Planned Instructional Approach that outlined the sequence of activities for the entire unit and identified the strategic function of each activity;
- Daily Lesson Plan for two to four lessons that provided details for instruction and assessment;
- Post-Assessment Plan, Results, and Analysis that described at least two tasks that interns administered to assess student learning at the end of the unit. The plan identified features for analysis of student responses to the tasks. Analysis included interpretation of the results across the class and reflection on the results in light of the interns' planning and instruction experiences;
- Learning Community Plan and Report that outlined a characteristic of the classroom learning community that interns wanted to support during their teaching, their plan for building and supporting their learning community, and a report on the results of their plan after teaching their science unit;
- Science Philosophy Statement that interns wrote at the end of the semester to explain their personal science teaching philosophy.

Classroom Observations

During Lead Teaching, I made five to seven visits to each focus intern's field placement classroom. In the elementary schools, science is not usually taught every day. Therefore, I asked each intern to provide me with the dates on which they would be teaching their science units. I visited each classroom once before the interns started teaching to observe the context of each field placement classroom. For two of the three focus interns, I was able to observe the classroom mentor teacher teaching science during this initial visit. This observation provided me with a baseline understanding of the classroom learning community and characteristics of science instruction that were present in the classroom before the intern became responsible for planning and teaching science. In the third case, the mentor teacher did not want to be observed teaching, so I observed the intern teaching a math and a reading lesson. This observation still allowed me to become familiar with the overall classroom community and norms before the intern began teaching science.

On subsequent visits to each interns' classroom I observed the intern teaching science. These observations provided data on how the interns enacted their lessons and the context in which they were enacting the lessons. These observations also provided data on interns' instructional actions while teaching. Sometimes the interns were able to provide me with their lesson plans or outline before I observed the lesson. I set-up the video camera at the back of the classroom and focused the camera on the intern. The intern wore a wireless microphone. There were also microphones placed around the room to capture student responses during small group and whole class discussions. For one intern, Nicole, one observation involved a field trip and another observation involved an after-school parent event. Because of video-consent issues, I did not video record these lessons. I took field notes during all observations and supplemented the field notes with transcriptions from the available video recordings. As a result, there is a complete written and video record of each science lesson observed. For each intern, I was able to make between four and six observational visits total.

Interviews

Intern Interviews. I conducted three interviews with each focus intern. These interviews were audio recorded and lasted approximately one hour. All interviews were transcribed. Because the purpose of this research was to understand how the interns made sense of and engaged with the I-AIM and CA&P tools offered in the science methods course, the interview protocols borrowed from a phenomenological approach. Phenomenology is concerned with understanding how people experience certain events, how they construct meaning from those experiences, and what meanings they construct (Bogdan & Biklin, 2003; Pinar *et al.*, 2000). I used open-ended questions and probes as guidelines to invite the interns to share their experiences and tell their stories related to using curriculum materials to plan science lessons. These semi-structured conversations elicited interns' attitudes, beliefs, experiences, and understandings related to teaching science, lesson planning, curriculum materials, and who their students were.

The first interview took place early in the semester before the interns had delved deeply into their planning and teaching. The purpose of this interview was to get to know the intern and to explore ideas about planning and teaching science that the intern brought to the science methods course. The first few questions asked about interns' experiences in their field placement classroom and their relationship with their mentor teacher. Following were questions about interns' previous experiences planning and teaching science lessons. I then provided each intern with a planning scenario. I gave each intern a set of curriculum materials and a state science curriculum benchmark as a learning goal and asked the interns to describe how they would go about planning a science unit to address this learning goal and how they would use the curriculum materials to plan the unit. The curriculum materials and curriculum benchmark were selected to match the grade level of the classroom in which each intern was teaching. Probing questions asked the interns what they would look for in the curriculum materials, how they would decide what activities from the curriculum materials to include in their plans, how they would organize the activities, and how they would decide if the unit went well. These questions were designed to elicit intern visions, beliefs, and conceptions about how to plan and teach a science unit. The interview ended by asking the interns to describe their personal goals for the science methods course.

The second and third interviews took place after each intern completed teaching their science units in their field placement classrooms. The purpose of these interviews was to explore the planning and teaching decisions that each intern made. This sequence of interviews began with questions about the interns' perceptions of their students, including student resources for learning science and special needs. The next set of questions explored the interns' classroom learning community and how they managed the community to support their students in learning science. The interview protocol also included questions about the interns' perceptions of the strengths and weaknesses of their curriculum materials and how they used their materials when planning their lessons.

The majority of the questions in this interview sequence focused on the specific activities that the interns planned and taught. I asked each intern about each activity that they planned. During this phase of the interviews, I selected a video clip from the observation video recordings of each intern to go with each activity or set of related activities. I showed the clips to the interns during the interviews and asked them to comment on the video clip. I used the video clips to stimulate interns' recall about their thinking during both the planning and teaching of each activity (Borko & Shavelson, 1990; Simon, 2000). Specifically, I probed the rationale for including each activity and what the interns' hoped each activity would accomplish. I asked where they got the idea for the activity, what modifications they made to the activity from its original source, and why they made those modifications. I also asked interns what they were thinking about during the activity, how they thought the activity was working for the students, and their rationale for some of their specific actions and responses to students during their teaching.

Following the questions about the activity sequence, the interview protocol included questions to probe interns' ideas about their use of the I-AIM and CA&P tools, their experiences with the tools, and their thoughts about the usefulness of the tools. The interviews ended with another hypothetical scenario. I provided each intern with an activity sequence for a weather-related learning goal and asked the interns to analyze the strengths and weaknesses of the sequence. This scenario provided me with insight into the interns' ideas about the type and order of activities in a science unit and their use of those ideas to analyze activities in curriculum materials.

Mentor Teacher Interviews. In addition to the interns, I also interviewed each of the intern's mentor teachers. These interviews were also semi-structured in format, audio-recorded, and transcribed. The purpose of these interviews was to gather data that could be used to build a broader picture of the context in which each intern was teaching and to triangulate with interns' comments and actions. The protocol included questions about the school and district science curriculum and curriculum materials available, the mentor teachers' perceptions of science and approach to teaching science, and the mentor teachers' perceptions of the students in the classroom and the classroom learning community. The protocol also included questions about the mentor teachers' perceptions of the intern's experience during the year and the interns' science plans and teaching. These interviews usually lasted about one hour.

Course Professor Interview. Finally, I interviewed the science methods course professor. Like the other interviews, this interview was semi-structured, audio-recorded, and transcribed. The protocol included questions designed to elicit the professor's goals and intentions for interns' planning and teaching of their science units. It also included questions about the professors' perceptions of each focus interns' work and progress during the semester. This interview also lasted approximately one hour.

Science Methods Course

Data gathered on the science methods course provided information on the context of the science methods course. In addition, one feature of design-based research is that one of the phenomena of study is the design process itself and therefore, it is common for design-based research, including teaching development experiments, to include records to support a retrospective analysis of the design (Cobb et al., 2003; Simon, 2000). Data on the science methods course provide information that can help in future redesigns of the tools and instruction related to the tools. Data include field notes from all science methods courses. I also collected all documents made available to interns during the science methods course, including the syllabus, class notes, class readings, and in-class assignments.

In summary, data for each intern include all course assignments, five to seven classroom observations with associated field notes and transcribed video recordings, three transcribed audio recordings of pre- and post-teaching interviews, and one interview with the interns' mentor teacher. Data on the science methods course include field notes from all course meetings, all course documents, and transcribed audio recording of an interview with the course professor.

Data Analysis

I conducted two different analyses of the individual case studies. The first analysis involved comparing the interns' use of the EPE framework and I-AIM and CA&P tools in their plans and enactments to the intended use of the frameworks and tools. This analysis took an etic perspective because it used the researcher/designers framework as the point of reference for performance and meaning making (Watson-Gegeo, 1988). The second analysis took an emic perspective as it focused on uncovering the interns' beliefs, goals, visions, experiences, and perspectives that guided their use of the frameworks and tools. This second analysis was a more interpretative analysis and assumed that what people do is mediated by their interpretations of their experiences (Erickson, 1986). Like phenomenology, it is concerned with understanding the meaning that people make from their experiences. I will explain each analysis in detail.

Analysis of Interns' Planned Instructional Approach and Enacted Activity Sequence

Interns' plans included their planned instructional approach as well as their lesson plans. I focused primarily on the interns' planned instructional approach because it provided the overall sequence of activities for the entire science unit. Interns used a tabular format to outline the sequence of activities in their instructional approach. Table 3.1 shows an excerpt from an example instructional approach for an electricity unit that the interns were given as a model. This format delineates activities as small-scale events. A new activity is defined when the focus or purpose of the activity shifts (E. L. Smith, 2001). For example, a whole class discussion is a separate activity from a hands-on exploration, which is in turn a separate activity from a small group of students sharing ideas, which is different from individual students recording their ideas in science notebooks, even though all of these activities may belong to the same overall lesson. For each activity, interns assigned an activity label and provided a brief description of the activity. In addition, interns were instructed to assign an I-AIM activity function for each activity in the sequence.

For interns' enacted activity sequence, I developed a table using the same format as the planned instructional approach based on my observations of the interns' teaching enactments in their field placement classrooms. I dissected the interns' classroom enactments into activities, described each activity, and assigned an activity function based on how I observed the activity to function in the classroom.

Table 3.1

Portion of an example instructional approach from a model unit about electricity

No.	Activity Label	Activity Description	Activity Functions (Why this activity in this sequence?)
1	Exploring a flashlight	Students examine a flashlight, taking it apart and observing its parts. They construct a first draft explanation of how they think the flashlight works.	Establishes a problem for the sequence, "How do flashlights work?" and elicits student's initial ideas about it.
2	Sharing ideas	Student share their explanations. The class shares their ideas and teacher lists the different ideas.	Share ideas and show that people have different ideas about flashlights and electricity.
3	Investigating a simpler system: Designing a hookup to light a bulb	The teacher introduces the strategy of investigating a similar but simpler system. The students will be given a flashlight battery, a bulb, and wire. They will work in pairs to connect the components to make the bulb light. They will first design a hookup and record it in their journals. They will then test their prediction and other hookups.	Explore ideas about electricity and electrical components.
4	Testing the designs	Students work in pairs to test their designs, recording their results in their journals. They then test other hookups, recording each and whether of not it lit the bulb.	Explore phenomena of various hookups lighting or not lighting, testing ideas
5	Forming a rule	The students report the hookups that worked and those that did not as the teacher records them on a chart or overhead transparency. They then construct a rule for how the battery and bulb must be connected to light the bulb. They check the rule to be sure it covers all of the hook ups that worked and did not work.	Look for patterns in what hookups light the bulb and which do not, recording observations.
Continues....			

I devised a color-coded analysis method to determine how the interns' planned instructional approaches and enacted activity sequences fit the I-AIM and CA&P. First, I assigned each stage and function of the I-AIM a unique color (Table 3.2). I then color-coded the interns' planned instructional approach using these colors. Unless otherwise noted in the results chapters, I assigned the colors based on the activity functions described by the interns in their planned instructional approach. I could then examine the color-coded planned instructional approach and enacted activity sequence to identify patterns in the activity functions that would characterize the interns' use of the I-AIM and CA&P. Tables in this dissertation describing the interns' planned instructional approach and enacted activity sequences are presented in color.

Table 3.2

Color codes used in the I-AIM analysis

<table>
<tr><th colspan="2">EPE</th><th>Model Stage</th><th>Activity Strategic Function</th></tr>
<tr><td rowspan="7">Inquiry</td><td rowspan="4"></td><td rowspan="2">Engage (yellow)</td><td>Establish a question (light yellow)</td></tr>
<tr><td>Elicit student ideas about the question (dark yellow)</td></tr>
<tr><td rowspan="2">Explore & Investigate (green)</td><td>Explore phenomena & look for patterns (sea green)</td></tr>
<tr><td>Explore student ideas about patterns (light green)</td></tr>
<tr><td rowspan="5">Application</td><td rowspan="3">Explain (blue)</td><td>Develop student explanations (about patterns) (dark blue)</td></tr>
<tr><td>Introduce scientific ideas (light blue)</td></tr>
<tr><td>Compare to & revise student ideas (sky blue)</td></tr>
<tr><td rowspan="2"></td><td rowspan="2">Apply (purple)</td><td>Practice with support (model & coach) (violet)</td></tr>
<tr><td>Practice with fading support (lavender)</td></tr>
</table>

The I-AIM is not intended to be a linear model, and there are many pathways or cycles that a sequence of instructional activities can move through, resulting in many possible color patterns. However, there are a few features of these color patterns that indicate whether or not the instructional sequence meets the intentions of the I-AIM and EPE frameworks described in Chapter 2. First, the instructional approach and enacted activity sequence should include an Engage stage activity that establishes a central question for the unit (light yellow) (Reiser et al., 2003; Rivet & Krajcik, 2004; E. L. Smith, 2001). This activity should come near the beginning of the unit and near the beginning of any major shift in learning goals in the unit. Second, the position of the Explore & Investigate stage and functions (greens) relative to the Explain stage and functions (blues) is important. Inquiry learning as defined by the EPE framework requires that experiences come before explanations. As described in Chapter 2, providing experiences with phenomena before offering explanations and making the patterns in the experiences explicit distinguishes scientists' science from traditional school science (Anderson, 2003; Sharma & Anderson, 2003). Therefore, the Explore & Investigate stage and functions must come before the Explain stage and functions. That is, greens should come before blues. Previous rounds of research in this design project show that preservice teachers often do not place experiences before explanations (Bae, 2007; Gunckel *et al.*, 2007); therefore, looking for this feature is especially important for determining if the interns used the I-AIM as intended. A more detailed analysis of this pattern should show that the Explore & Investigate stage activities are related to the learning goals, include experiences with phenomena and make patterns visible (dark green), and elicit student ideas about the patterns (light green). In places where interns' planned or enactment sequences suggested that they were making patterns explicit, I examined the transcript of the classroom observation carefully to determine to what extent the interns were able to make the intended patterns in experiences explicit in their teaching.

Next, when looking at Explain stage activities, the planned instructional approach and enacted activity sequence should provide students with opportunities to develop their own ideas about the patterns (dark blue), provide scientific information (light blue), and compare student ideas to the scientific ideas introduced (sky blue). Finally, the planned instructional approach and enacted activity sequence should engage students in the practices of application (Anderson, 2003) by providing students with opportunities to use their new understanding in new contexts (purples) (J. S. Brown et al., 1989; Collins et al., 1989).

Analysis of the extent to which the interns accounted for student intellectual and cultural resources for learning science in the planned activity sequence involved examination of the planned instructional approach for references to student naïve conceptions, previous learning experiences, prior knowledge, funds of knowledge, or ways of being in the world. I also analyzed the transcripts and field notes of the enactments for examples of interns explicitly acknowledging or acting on student intellectual or cultural resources. In addition, I analyzed the transcripts of the second and third interviews, when interns were talking about their planning and teaching decisions for each activity, for instances when interns explicitly or implicitly referred to student resources for learning.

Table 3.3 summarizes the EPE, I-AIM, and CA&P features that I was looking for in the color-coded planned instructional approach and enacted activity sequence, and the interviews and transcribed classroom observations.

Table 3.3

Instructional approach and enacted activity sequence analysis framework

Tool	Analysis Foci
I-AIM: EPE	• Establish a Central Question • Experiences before Explanations • Patterns made explicit • Opportunities for Application
CA&P: Taking Account of Students	• Consider student conceptions • Consider student cultural resources

Analysis of Beliefs, Goals, Perceptions, and Experiences that Guided Intern Use of Tools

In addition to understanding how the interns' use of the I-AIM and CA&P tools compared to the intended use of the tools, I also wanted to understand the interns' perspective on the tools, their experiences planning and teaching science in their field placement classrooms, their ideas about the university science methods course, and their visions for teaching. This analysis took the emic perspective in order to understand the interns' experiences from their point of view (Watson-Gegeo, 1988). I analyzed all course assignments, interviews, and classroom observations. I coded each of these data sources using two types of codes. One type of code highlighted what the intern was paying attention to in her planning and teaching decision-making, such as student conceptions, types of experiences, scientific explanations, etc. The second type of code characterized interns' comments about planning and teaching. These codes noted, for example, clues to their perceptions of the students or their understanding of the assigned task. Using the process of analytic induction (Erickson, 1986, 1998), I looked across the two sets of codes for key linkages that would connect as much of the data as possible together to support the emerging explanations for how each intern used the tools. Finally, I looked across the data for all three interns to find similarities in the influences on how they used the tools. In Chapter 7 I will present the explanatory framework that coordinates the analysis of the ways interns used the tools and the analysis of the influences that guided their use.

Limitations

There are several limitations of this study. To begin, these cases are complex and necessarily incomplete. That is, there are probably data that I did not collect that might have provided a different picture of the situation. Given the interpretive nature of this work, there could be many other stories that could be told about these interns and their experiences planning and teaching science (Bogdan & Biklin, 2003). In these chapters I present one particular story that focuses on how these interns used the tools introduced in the science methods course. I try to provide enough data for the reader to consider several perspectives, and draw attention to alternative interpretations when possible (Erickson, 1986, 1998).

As a teaching development experiment, this research took place in naturalistic settings. Research in naturalistic settings is subject to the criticism that such research is not generalizable because there are too many uncontrolled variables. Furthermore, the teacher (course professor) and researcher are not independent of the context (Barab & Squire, 2004; Simon, 2000). Design experiments, including teaching development experiments, are necessarily messy. However, the goal is not to uncover universal truths or tools that can work in all situations. Rather, research in naturalistic contexts provides important information on how designs and tools work in real settings. Furthermore, it leads to flexibly adaptable theory – that is theory that can explain many diverse teaching situations (Barab & Squire, 2004).

Another common critique of teaching development experiments is that the results are dependent on the expertise of the teacher-researcher, in this case, the course professor Dr. Adams (Simon, 2000). Teaching development experiments rely on teacher-researchers who have a deep understanding of the teaching practices that the experiments are designed to develop. Experienced teacher-researchers serve to insure the validity of the research. That is, it insures that the course instructor is developing in preservice teachers the practices that the research is investigating. Previous experiences in other cycles of this research suggest that instructors who are not familiar with the frameworks they are asked to use often do not have the resources to flexibly respond to preservice teachers' struggles in learning to use the frameworks (Schwarz, 2007, Personal Communication). In this dissertation research, Dr. Adams was a co-developer of the I-AIM and CA&P tools and had a long history of teaching elementary science methods courses and supporting elementary preservice teachers in learning to plan and teach science. He knew intimately the practices he wanted his preservice teachers to learn. While the results of this research did depend heavily on his expertise, without such expertise, the validity of these results would have been much more questionable.

Another important limitation of this research is the selection bias of the focus interns. These interns volunteered to participate in this project. They were motivated, high-achieving individuals who chose to participate in this study during the hectic, high-pressure second semester of a demanding teacher preparation internship. Furthermore, all three interns were of the same age, gender, and ethnicity. They all worked in schools with similar student populations in terms of socio-economic status and ethnic diversity. As such, these focus interns do not represent the range of preservice teachers and their uses of the I-AIM and CA&P tools do not represent all possible uses. Future research would be helpful to examine how different preservice teachers use the I-AIM and CA&P tools in other teaching contexts. However, the point of this research was not to examine all possible outcomes. Nor is it to suggest that the results are generalizable to all cases (Bogdan & Biklin, 2003). Rather, as qualitative research, and specifically as design-based research, the purpose was to understand a particular situation and use that to develop "humble theories" that remain useful when applied to new contexts (Barab & Squire, 2004; Cobb *et al.*, 2003; Design-Based Research Collective, 2003).

Finally, the bias of the researcher is important here as well. As a participant in the research as well as the researcher in this project, my own perspectives and views carried bias into the results and interpretations of this work. Such bias cannot be eliminated (Bogdan & Biklin, 2003). I made a sincere attempt in this research to examine issues from multiple perspectives and to present the data in a way that would allow readers to examine the data from their own perspectives as well. The goal of this research was not to pass judgment on any of the participants, including the interns, course professor, or mentor teachers. Rather, the goal was to add to our understanding of how preservice teachers learn to use tools to plan and teach science. As such, I believe that my perspectives and frameworks have contributed to, rather than detracted from, this goal.

CHAPTER 4

Dana

Chapter Overview

Dana was an intern with a strong vision for how she wanted to teach science. She wanted to engage her sixth grade students in hands-on activities and conversations with each other to help them construct canonical explanations for science phenomena. Furthermore, she wanted to demonstrate to her mentor teacher that science teaching could involve more than reading science in the textbook. Dana was assigned to teach about light. She chose to write her unit for her science methods course on the topic of light and color. She used an example instructional sequence from her science methods course as a template for her unit, which allowed her to enact aspects of her vision for science teaching and meet the requirements of the science methods course in an efficient manner. In the process, Dana engaged in many of the reform-based practices that the example instructional sequence and the I-AIM and CA&P tools represented. However, Dana did not engage the I-AIM and CA&P tools in a substantive way in planning her instructional approach. As a result, even though the example instructional sequence provided her with access to the practices that I-AIM was intended to scaffold, Dana did not develop the generalized understandings for the frameworks that the I-AIM and CA&P were intended to represent.

In this chapter, I will describe Dana's teaching situation and the expectations that she had to negotiate in her planning and teaching of science. I will describe Dana's planned instructional approach, and it's similarities to the example instructional approach from the science methods course. I will also describe the enacted activity sequence and compare the practices she engage in during the enactment to the practices I-AIM and CA&P were intended to scaffold. Then I will explain Dana's vision for science teaching and how her use of the example instructional approach helped her realize her vision while meeting the expectations of the science methods course and her mentor teacher. I will end with a discussion of the implications of Dana's use of the example instructional approach for her practice and her understanding of the reform-based principles that the I-AIM and CA&P represent.

Planning a Light and Color Unit

One of Dana's challenges in her internship was negotiating the various expectations place on her science teaching. On the one hand, she was expected to cover all of the topics on light in the school district sixth-grade curriculum. On the other hand, she was expected to develop a three-week unit on one topic for her science methods course. Dana herself had certain expectations for what good science teaching entailed. She also had a personal goal to teach her science unit differently than how her mentor teacher taught science. All of these expectations influenced how Dana went about choosing and planning her unit on light and color. In this section I will describe Dana's teaching situation and how she identified the unit she planned to teach. I will then describe how she went about planning the unit, including her analysis of her curriculum materials and her development of her planned instructional approach. I will end with a comparison of the unit that Dana planned to teach with the example instructional approach that she used to guide her planning.

Dana's Teaching Situation

Dana interned at Libby Elementary School, a suburban school located on the outskirts of a small city of about 36,000 people. The school served approximately 375 K-6^{th} grade students. About 30% of the students in the school received free or reduced lunch. Dana's class was a self-contained 6^{th}-grade. She had 21 students in her class, of which approximately 70% were Caucasian, 20% were African American, five percent were Hispanic, and five percent were Asian. One student in the class had a visual disability that required accommodation.

Dana's class was the only 6th-grade classroom in the building. Dana would have preferred a middle school placement where students switch teachers for different subjects.

> I was a little disappointed. I am not going to lie. Because I had hoped for middle school. And, 6th grade was as close as they got me. So, I am happy, but I really wanted to have a sort of middle school experience because it is a lot different. Especially since mine is self-contained 6th grade. So we never have a different teacher except for specials. (Dana Interview, 1/18/2007)

Dana's mentor teacher, Melinda found the situation isolating. Melinda would have preferred to have had at least one more 6th grade class in the school so that she and the other 6th-grade teacher could share resources and team teach some subjects.

> Teaching a 6th grade has been a totally different experience from when I taught 4th grade...Unfortunately, it has been a lot more difficult teaching the 6th grade science because we don't have anything here in this building. Plus, teaching all subject areas, I don't have the time. The 6^{th}-grade teachers [at another district school], that is what they do all day because they team...They have a separate room that is full of everything... Everything you could possibly need for that lab. That was nice. I am finding that with 6th grade, it has been so much harder to fulfill any of the labs. I am a little disappointed. And I shared that with Dana. (Melinda Interview, 3/22/2007)

Both Dana and Melinda saw their teaching situation as one they just had to accept and work with the best that they could.

Identifying the Learning Goals

The school district 6th-grade science curriculum spiraled across grades 6-8, so that students had some life science, Earth science, and physical science in each of the three grades. The students used the same textbooks, from the *Holt Science and Technology* textbook series in all three grades, with certain topics assigned to each grade level. The school district had a scope and sequence document plus many supporting materials elaborating on the benchmarks that Melinda showed to me during an interview. However, Melinda only provided Dana with a note card with textbook page numbers listed on it and told Dana that she was responsible for teaching the content on the listed pages. The content covered topics in both light and sound. Dana was not excited about the topics listed.

> I mean, it's a little discouraging because this doesn't excite me, really. Like, I didn't like physics, at all. And, I think light is ok. Light is kind of cool. But the sound part of it really doesn't interest me at all. (Dana Interview, 1/18/2007)

The science methods course instructor, Dr. Adams, suggested to the interns that they should choose one set of related learning goals to focus on for their planning for the science methods course. Dana explained this suggestion to Melinda in an intern-mentor teacher co-planning workshop in an attempt to negotiate fewer topics to cover.

1 Dana: We're supposed to have one central question so that is why instead of being light and sound, I have to focus on one because there is no way I could do this for both.

2 Melinda: Right. But if we look at the division of the four chapters. Nature of waves, property of waves, what is sound, properties of sound, interaction, and then it basically does the same thing.

Interactions with light waves, light and color, sources. So this would probably be your dividing line between the two.

3 Dana: Right, but I am only doing all this for one.

4 Melinda: For one. Gotcha. All right. That would be impossible. Ok.

(Workshop Transcript, 1/19/2007).

Melinda agreed that Dana could be responsible for teaching the light topics only: waves, light sources, and light and color. Dana decided that for the science methods course, she would write her unit about seeing color.

> I just looked at what it was that they had wanted to cover and I thought that, "Why we see things the way we see them," is the best thing I could use for the model that he [Dr. Adams] had wanted us to. (Dana Interview, 4/9/2007)

Dana decided that her central question would be "Why do we see colored objects?" (Dana Learning Goals Assignment, 2/7/2007).

By providing Dana with a list of topics to teach and no other supporting materials besides the textbook, Melinda was sending the message to Dana that teaching science was about covering the required topics. Dana recognized that Dr. Adams was asking her to do considerably more than just cover the topics. Dana negotiated with Melinda for a reduced number of topics to cover, and then selected one topic that she would develop more fully for her science methods course. Thus, during her planning and teaching, Dana was negotiating between these two sets of expectations: Melinda's expectation that she would cover the content, and Dr. Adams' expectation that she would fully develop a unit of instruction using his frameworks. Dana also had her own expectations for her science teaching, which I will talk about later in this chapter.

Curriculum Materials Analysis

One of the assignments that each intern completed prior to developing an instructional approach was an analysis of the curriculum materials they had available to use to plan their units. Interns were asked to use the questions in the CA&P tool as a guide for analyzing the strengths and weaknesses of their materials.

Dana analyzed the *Holt Science and Technology: Physical Science* textbook. Overall, she thought that the textbook presented good framing questions to the students and did a good job explaining scientific terms with examples and pictures. However, she was critical of the materials. "I mean the content of the book is great, but it doesn't provide enough hands-on opportunities or opportunities for sharing of ideas" (Dana Interview, 4/9/2007). In her view, these weaknesses meant that the materials did not support students in changing their misconceptions.

> The activities that are included do not provide opportunities for the students to explore their own preconceived ideas about the topic. This type of learning helps to eliminate misconceptions and clarify the true relationships. (Dana Curriculum Materials Analysis Assignment, 2/27/2007)

In her planned curriculum materials modifications, Dana claimed that her unit would address these weaknesses, "Students will be forced to clear misconceptions. They will be expected to share prior thoughts and explain how their ideas of how things work have changed after given the experience of working with the phenomena first hand." (Dana Curriculum Materials Analysis Assignment, 2/27/2007).

The curriculum materials analysis assignment also asked interns to use the CA&P to consider how well the curriculum materials matched students' sociocultural resources for learning. Many of Dana's comments show that she thought that being able to explain why we see color was something that related to her students' lives and was something they would be interested in learning. For example, in response to the question that asked if students would find the experiences provided in the curriculum materials interesting and relevant, Dana said, "Light is something that my students deal with on a daily basis and they will be interested to understand how it interacts with various materials and how it allows us to see". Later, she said, "This concept is very relevant and interesting. Students should walk away from this unit thinking about light and color of objects frequently throughout their day" (Dana Curriculum Materials Analysis Assignment, 2/27/2007).

Dana's curriculum materials analysis shows that she thought that the topic of seeing color would be something her students should be interested in learning about, but that she was concerned with how well the materials supported students in changing their misconceptions. Dana planned to improve on the curriculum materials by providing students with hands-on explorations of phenomena and opportunities to talk about their ideas with one another. In this way, she hoped to help students change their ideas about why we see color.

Planned Instructional Approach

Table 4.1 shows Dana's planned Instructional approach. Dana used the I-AIM activity functions in the descriptions of her plans. In my analysis of her plans, I assigned my own activity function to each of her activities and then compared my assigned functions with the functions Dana assigned. The functions that Dana assigned to each activity matched the functions that I assigned.

Table 4.1

Dana's planned instructional approach

Activity number	Activity label	I-AIM stage (color code)	Activity function (color code)
1	Exploring a mirror	Engage (yellow)	Establish a question (light yellow)
2	Sharing ideas	Engage (yellow)	Elicit student ideas (dark yellow)
3	Investigating a system: Understanding how objects are seen	Explore & Investigate (green)	Explore phenomena (sea green)
4	Testing the designs	Explore & Investigate (green)	Explore phenomena (sea green)
5	Forming a rule	Explore & Investigate (green)	Explore phenomena (sea green)
6	Explaining the rule	Explain (blue)	Students explain patterns (dark blue)
7	Testing the illumination theory	Explore & Investigate (green)	Explore phenomena (sea green)
8	Testing the color of light mixing with the color of the object theory	Explore & Investigate (green)	Explore phenomena (sea green)
9	Testing the light is reflected theory	Explore & Investigate (green)	Explore phenomena (sea green)
10	Inventing the idea of light absorption and reflection	Explain (blue)	Introduce scientific ideas (light blue) Compare to & revise student ideas (sky blue)
11	Revising explanations of why we see colored objects	Apply (purple)	Practice with support (model & coach) (violet)

Dana planned to begin her unit with students using a flashlight and a mirror to examine the phenomenon of reflection (Activity 1 Exploring a Mirror) and then sharing their explanations for how light is reflected (Activity 2 Share Ideas). She then planned to have students investigate what they would see when they placed tissue paper of different colors over a flashlight and shined the light on objects of various colors (Activity 3 Investigating a System). Dana explained the pattern she wanted the students to see from this activity.

> I wanted them to be able to see that if they were given a light, the objects would appear the color that we see them everyday. If they were given a

color of light that wasn't the color of the object, that the object was supposed to be black, and that we weren't supposed to see it as the color that we see it. (Dana Interview 4/9/2007)

At this point, Dana planned to ask the students for their ideas to explain this pattern (Activity 6 Explaining the Rule). She anticipated two common naïve conceptions that the students might have and planned activities that would challenge these ideas. First, she planned to test the idea that an object is the color of the light that shines on it. She planned to have students shine blue light on red objects to find out if the objects looked blue under the blue light (Activity 7 Testing the Illumination Theory). The second idea she wanted to test was the idea that the color of the object mixes with the color of the light shining on the object. She planned to test this idea by again shining a blue light on a red object to show that the object does not look purple, as would be predicted by the students' explanation (Activity 8 Testing Mixing Theory).

Having tested common student ideas, Dana planned to introduce the idea that an object reflects the color of light that we see and have students revise their own explanations based on this new scientific information (Activity 10). Finally, she planned to have students apply this new idea to explain the color that is seen when a white light shines on a red object, a red light shines on a red object, and a red light shines on a green object (Activity 11).

This planned instructional approach addressed the two weaknesses Dana noted in her analysis of the curriculum materials. Throughout the unit she planned to engage students in hands-on explorations of phenomena. Furthermore, she planned to test specific common naïve ideas to help students recognize why their ideas do not satisfactorily explain how we see color. Second, throughout the unit, she planned to have students sharing ideas, talking about how their ideas matched their experiences, and revising their ideas in small group and whole class discussions.

Dana's planned instructional approach also reflects strategic sequencing of the activities to fit I-AIM. She planned to begin the unit by establishing a question (light yellow) and then elicit student ideas about the question (dark yellow). While the question she planned to establish did not frame the whole unit because it was about reflection and not about color, it did establish a question for the initial activity using mirrors and flashlights. She planned to follow with opportunities for students to explore and investigate phenomena (green), thus placing the experiences before the explanations (blue), as intended by I-AIM. She also planned, in Activity 5 (Forming a Rule), to have students notice the key pattern that an object placed under a light of a color different from the color of the object appears black. In Activity 6 (Explaining the Rule), Dana planned to have students offer their own explanations for the pattern. Activities 7-9 would provide students with opportunities to test their own ideas (Explore & Investigate – green color). Dana ended the whole sequence with an opportunity for students to apply their new knowledge to explain new situations (purple).

Comparison to the Example Electricity Instructional Approach

In looking at the Dana's planned instructional approach, I thought that her activities and the sequence of activities seemed familiar. I compared Dana's planned instructional approach to an example instructional approach about electricity that Dr. Adams used as an example to introduce I-AIM to the interns. I color-coded the electricity instructional approach using the I-AIM colors. Table 4.2 shows the electricity instructional approach.

Table 4.2

Dr. Adams' example instructional approach for an electricity unit

Activity number	Activity label	I-AIM stage (color code)	Activity function (color code)
1	Exploring a Flashlight	Engage (yellow)	Establish a question (light yellow)
2	Sharing ideas	Engage (yellow)	Elicit student ideas (dark yellow)
3	Investigating a simpler system: Designing a hookup to light a bulb	Explore & Investigate (green)	Explore phenomena (sea green)
4	Testing the designs	Explore & Investigate (green)	Explore phenomena (sea green)
5	Forming a rule	Explore & Investigate (green)	Explore phenomena (sea green)
6	Explaining the rule	Explain (blue)	Students explain patterns (dark blue)
7	Testing the more electricity theory	Explore & Investigate (green)	Explore phenomena (sea green)
8	Testing the positive and negative electricity theory	Explore & Investigate (green)	Explore phenomena (sea green)
9	Testing the complete path theory	Explore & Investigate (green)	Explore phenomena (sea green)
10	Inventing the idea of a "Complete circuit"	Explain (blue)	Introduce scientific ideas (light blue) Compare to & revise student ideas (sky blue)
11	Revising explanations of how a flashlight works	Apply (purple)	Practice with support (model & coach) (violet)
12	Constructing a class book about how a flashlight works	Apply (purple)	Practice with fading support (lavender)

The comparison of Dana's planned instructional approach with the example electricity instructional approach shows dramatic similarities. Dana's plan followed the same sequence as the electricity unit. The activity labels were the same, the activity descriptions were nearly identical, and the activity functions were described in the same words. The only difference was that Dana used words referring to light in place of the words referring to electricity. Table 4.3 shows examples of similarities between Dana's light and color instructional approach and the electricity instructional approach. Similar wording is underlined.

Table 4.3

Comparison of light & color and electricity instructional approaches

Activity number & label	Instructional sequence	Activity description	Activity function
(1) Exploring a flashlight	Electricity	Students examine a flashlight, taking it apart and observing its parts. They construct a first draft explanation of how they think the flashlight works.	Establishes a problem for the sequence, "How do flashlights work?" and elicits student's initial ideas about it.
(1) Exploring a mirror	Light & color	Students examine a mirror, by using a flashlight to reflect light off of it. They construct a first draft explanation of how they think a mirror works or in other words how light is reflected.	Establishes a problem for the sequence, "How is light reflected?" and elicits student's initial ideas about it.
(5) Forming a rule	Electricity	The students report the hookups that worked and those that did not as the teacher records them on a chart or overhead transparency. They then construct a rule for how the battery and bulb must be connected to light the bulb. They check the rule to be sure it covers all of the hook ups that worked and did not work.	Look for patterns in what hookups light the bulb and which do not, recording observations.
(5) Forming a rule	Light & color	The students report their results as the teacher records them. They then construct a rule for how the color of light affects the appearance of the object being viewed. They check the rule to be sure that it covers all of the situations that were experienced.	Look for patterns in light color and color of objects. Record observations.
(8) Testing the positive and negative electricity theory	Electricity	Another theory is that the bulb needs both positive and negative electricity to light. This is tested by connecting the positive contact of one battery to one contact of the bulb and the negative contact of a second battery to the other contact. This does not work either.	Explore phenomena, trying out and testing ideas/hypotheses about electrical flow. Developing conclusions from evidence.
(8) Testing the color of light mixing with the color of the object theory	Light & color	One theory often expressed is that when a colored light illuminates a colored object, the color of the light mixes with the color of the object. This is tested by shining blue light on a red objects. This does not work.	Explore phenomena, trying out and testing ideas/hypotheses about how colored objects are seen. Developing conclusions from evidence.

While the similarities are striking, I do not think that this is a case of an intern simply copying the instructor's example. Translating activities and strategic functions from an electricity unit into a light and color unit in a way that represents the scientific concepts accurately and maintains the intentions of the activity functions required careful thought. For example, Dana had to understand what patterns she wanted her students to recognize in order to develop Activities 5 and 6, she had to recognize the possible naïve conceptions that students might bring to learning about light and color in order to develop Activities 7 and 8, and she had to have the explanations she wanted the students to learn in order to develop Activities 9-11. Furthermore, she had to grasp how the activities in the electricity unit were designed to function together in order to create light and color activities that fit the same functions. Nevertheless, the striking similarities suggest that Dana was using the electricity sequence as a template for designing her unit, something that no other intern in the course did when planning their instructional approaches. I will discuss the implications of this similarity later in this chapter.

In summary of her planning, Dana was assigned to teach about light to her 6^{th}-grade students. While she was responsible for teaching all of the topics about light assigned to the 6th grade curriculum, she focused her planning and teaching for the science methods course on the topic of light and color. She analyzed the textbook adopted by the school district for the middle grades and decided that it did not provide the support she thought was necessary to help students change their misconceptions about light and color. She intended in her unit to provide students with more hands-on experiences with phenomena and more opportunities to share their ideas with each other. She used Dr. Adams' example electricity instructional approach as a template for planning her own instructional approach. In doing so, she used her understanding of students' common naïve conceptions and her understanding of the science content for light and color to translate the electricity example instructional approach into an instructional approach for light and color.

Enacting the Light and Color Sequence

Dana took over the responsibility of teaching science in February, 2007. However, she did not enact her planned instructional approach until March. Prior to beginning her unit on light and color, Dana taught several other lessons on light that were not included in her planned instructional approach. In this section, I will describe Dana's enacted activity sequence, including the activities that she enacted prior to beginning her planned unit. I will then use the analysis framework to examine how well Dana's enacted activity sequence fit the I-AIM and CA&P functions.

Table 4.4 shows Dana's enacted activity sequence, including the pre-unit activities, identified as activities P1-P6. Many of the activities Dana planned in her planned instructional approach are present, and for the most part, the order of the activities in the plans and enactment are the same. The enacted sequence includes more activities than the planned instructional approach, but this situation is probably a function of the difference between my identification of activities in my observations of Dana's enactment and Dana's own identification of activities in her plans. In other words, I often dissected activities that Dana identified as one activity in her plans into two or more activities from her enactment.

Table 4.4

Dana's enacted activity sequence

Activity number	Activity label	I-AIM stage (color code)	Activity function (color code)
P1	White Light	Explain (blue)	Introduce scientific ideas (light blue)
P2	Waves Activity Directions	Explain (blue)	Introduce scientific ideas (light blue)
P3	Sheet Waves Station	Explain (blue)	Introduce scientific ideas (light blue)
P4	Spring Waves Station	Explain (blue)	Introduce scientific ideas (light blue)
P5	Pencil Waves Station	Explain (blue)	Introduce scientific ideas (light blue)
P6	Speed of Waves Station	Explain (blue)	Introduce scientific ideas (light blue)
1	Writing about Light	Engage (yellow)	Elicit student ideas (dark yellow)
2	Exploring a Mirror	Explore & Investigate (green)	Explore phenomena (sea green) Explore student ideas (light green)
3	Sharing - What is reflection?	Explore & Investigate (green)	Explore student ideas (light green)
4	Sharing - What things reflect light?	Explore & Investigate (green)	Explore student ideas (light green)
5	Predicting Colors	Explore & Investigate (green)	Explore phenomena (sea green)
6	Colored Lights	Explore & Investigate (green)	Explore phenomena (sea green)
7	Sharing Results	Explore & Investigate (green)	Explore student ideas (light green)
8	Forming Explanations	Explain (blue)	Develop student explanations (dark blue)
9	Sharing Explanations	Explain (blue)	Develop student explanations (dark blue)
10	Testing Theories: Shining light	Explore & Investigate (green)	Explore phenomena (sea green)
11	Testing Theories: Shining light	Explore & Investigate (green)	Explore student ideas (light green)
12	Testing Theories: Mixing	Explore & Investigate (green)	Explore phenomena (sea green)
13	Testing Theories: Mixing	Explore & Investigate (green)	Explore student ideas (light green)
14	Explaining White Light and Reflection	Explain (blue)	Introduce scientific ideas (light blue) Compare to & revise student ideas (sky blue)
15	Red Strawberry	Apply (Purple)	Practice with support (model & coach) (violet)
16	Green Pepper	Apply (Purple)	Practice with fading support (lavender)

Pre-Unit Activities

Dana enacted at least two lessons prior to beginning her planned instructional sequence. One lesson was on white light (Activity P1 White Light) and the other lesson was on waves (Activities P2-P6). These lessons provided insight into Dana's vision of science teaching unstructured by the requirements of a science methods course or the I-AIM and CA&P tools.

White Light. Dana taught a lesson on the nature of white light. I did not observe this lesson, but Dana explained, "We talked about it and I drew a picture on the board, I think, of all of the colors being in white light" (Dana Interview, 4/21/2007). Students had a diagram that they hand colored showing the order of the colors of the spectrum. Dana also taught the standard mnemonic for remembering the order of the colors. Dana drew on this lesson later in her enactment of her planned instructional approach. At one point, when she was explaining to the students why we see color (Activity 14 Explaining White Light and Reflection), she reminded the students of the order of colors in the visible spectrum. "And how do we remember the colors in white light? Who is the person that we remember? What is that guy's name?" The students answered, "Roy G Biv" for ROYGBIV – Red, Orange, Yellow, Green, Blue, Indigo, Violet. (Dana Teaching Video Transcript, 3/12/2007)

Waves. Dana also taught a lesson on the nature of waves. I observed Dana teaching one day of this lesson. Dana introduced the lesson very briefly by telling the students, "We're going to be working on a science lab station thing… Everyone should have their lab packets. I am going to walk us through each station real quick so we can understand what we need to do." (Dana Teaching Video Transcript, 2/22/07) Dana made no reference to any previous activities, lessons, or content that they were currently studying. Furthermore, she made no presentation of the purpose for the day's lesson or a description of what they were studying (i.e. properties of waves). However, there was a sentence printed in capital letters at the bottom of three of the four pages of the students' lab packets that said "REMINDER: USE YOUR VOCABULARY BOOKLET OR TEXTBOOK IF YOU ARE NOT SURE WHAT THE TERMS MEAN", suggesting that there had been some previous lesson or activity related to entering definitions into a vocabulary booklet.

Dana described the four stations the students would be visiting during the hour. Each station was also listed in the lab packet with directions and questions to answer. I have described the stations here. The names of the stations are the names that Dana assigned.

- Sheet Wave – Students used a large bed sheet to create waves of different amplitudes and were directed to determine which waves required the greatest energy to create.
- Springy Wave – Students used large plastic slinky toys to create waves of different amplitude and frequency. Students were asked what happens to the wavelength of the waves when the frequency is increased.
- Pencil Wave - Students were provided with a drawing of a wave and asked to determine its wavelength and amplitude.
- Wave Speed – Students measured the length of time for a compression wave to travel down the length of a slinky toy stretched out on the floor and then determined the speed of the wave.

Dana assigned the students to groups and then had the groups rotate through the stations. Dana floated from group to group, asking students questions about what they were doing and what they were finding. For example, when visiting a group at the Springy Wave station, Dana had the following conversation with the students (all names are pseudonyms).

1 Dana: Frequency. What is frequency?

2 (Students don't answer.)

3 Dana: You have to know your vocabulary. Frequency. Teddy is researching it.

4 (Teddy looks up the definition of "frequency" in the textbook).

5 Dana: What did you find out?

6 Teddy: It is the number of waves in a certain amount of time

7 Dana: It is the number of waves in a certain amount of time. So if you are making your waves like this (Dana gets down on her knees to demonstrate a wave with the slinky toy), then it says what is the amplitude? What's the amplitude?

8 Students: Uninterpretable

9 Dana: Right, high or low. So it is going to be how high? So the question is what do you have to do to increase the amplitude? What did you have to do? You were making this wave, then what did you have to do?

Dana leaves the group and moves onto a new group.

(Dana Teaching Video Transcript, 2/22/07)

At the close of the lesson, Dana collected the slinky toys and the bed sheet and asked the students to put their lab packets away in their desks. She told the students that they would go over the lab sheets the next day. Immediately, the classroom focus shifted to the social studies lesson and students took out their textbooks to begin taking turns reading the assigned pages out loud.

Purpose and function of the pre-unit lessons. These two lessons demonstrate the tension that Dana negotiated between Melinda's expectations for covering content and the Dr. Adams expectations for use of the I-AIM framework for planning. Dana thought of these lessons as covering the content included in the list of topics assigned to the sixth-grade curriculum and not as part of the unit she developed for her science methods course. Because she did not think of them as part of her unit, she did not feel she had to meet the requirements or structure imposed by the I-AIM tool. As such, these lessons represent Dana's teaching without the influence of the I-AIM model.

Dana's enactment of the lessons on white light and waves show that she was attempting to meet her stated goals of changing students' misconceptions by providing hands-on experiences with phenomena and providing students with opportunities to construct understanding through sharing of ideas. She stated that her students did not usually get many opportunities to engage in hands-on activity and that such activity was something her students enjoyed.

> And they just really loved to be able to touch things, even at sixth grade. They don't get very many opportunities. So, you know I just really wanted to give them as many opportunities to actually do science as opposed to just read science. (Dana Interview, 4/9/2007)

Therefore, she planned a lesson that rotated students through stations that engaged students with representations of phenomena.

As the above transcript shows, when moving among small groups, Dana often asked students questions and then left the group before the students came up with an answer. She explained this teaching move in an interview.

> I wanted them to try to discuss as much as they could and I didn't want to provide them with a whole lot extra. So. But I mean they were still thinking and willing to share and really were working towards the goal. (Dana Interview, 4/21/2007)

Dana valued students talking about their ideas. She believed that through talking with each other students would revise their initial ideas and come to new conclusions.

Despite Dana's desire to change students' misconceptions by engaging students in hands-on activities and providing them with opportunities to change their ideas by talking with each other, Dana's enactment of these activities did not result in many opportunities for students to engage in sense-making. Dana did not provide a sense of purpose for these activities. Her use of the textbook to look up definitions was similar to the math, reading, and social studies lessons that I observed both Dana and Melinda teach where students had to use their textbooks to find answers to questions on a worksheet. The activities in the lessons were disconnected from each other and from the bigger ideas of science. For example, the waves activities were about properties of waves (i.e. frequency, amplitude), but there was no connection made between these properties of waves and the wave nature of light. The activities resulted in procedural display rather than conceptual change (Anderson, 2003).

Although Dana did not consider the activities in these two lessons to be part of her unit on color, I did include the activities in these two lessons as part of the enacted activity sequence. In the case of the white light lesson, Dana drew on the activities in the enactment of her planned instructional approach. In the case of the nature of waves lesson, Dana stated that the activities provided important information that students needed to understand before learning about light and color. Even though Dana thought of the activities in the white light and waves lessons as separate from the unit on color, her sequencing of these lessons before the activities in her planned instructional approach showed that she had a purpose for covering these topics prior to enacting the light and color activities. During the interviews following her teaching, I asked Dana about the purpose of the waves lesson. She explained,

> I just wanted them to understand that light is a wave. They don't really need to know a lot about waves in depth. But they just need to understand that. I mean, I just want them to know that light is waves. And

we didn't really touch that much about if red has a greater wavelength than violet. We didn't really cover anything that in depth at 6th grade. But I just wanted them to understand what wave lengths were and what amplitude was and just some basic understanding of waves before they started learning about light. (Dana Interview, 4/9/2007)

In Dana's mind, the activities in these lessons functioned to provide students with scientific information (light blue) about white light and waves that she thought was necessary in order for the students to construct explanations for how we see color. Dana wanted students to draw on the information they learned in these activities when they engaged in the later activities about light and color. Therefore, the pre-unit activities are identified in Table 4.4 as Explain stage activities (blue).

Comparison of Dana's Enacted Activity Sequence to I-AIM

After teaching the pre-unit activities, Dana enacted the activities she had included in her planned instructional approach similarly to how she had planned them. She had students use mirrors and flashlights to explore the phenomenon of reflection (Activities 1 and 2). However, rather than having students use colored tissue paper over the ends of flashlights to explore the effect of different colored lights on colored objects, Dana switched to using colored light bulbs. In Activities 5 and 6 (Predicting Colors and Colored Lights), Dana had students place a purple plastic flower and a blue plastic lid under a red light and a white light. She hoped that this activity would show the pattern that the objects under the red light appeared black. From there, she had students develop explanations for what they saw (Activities 8 and 9). Then, in activities 10-13, Dana enacted variations of her planned activities to have students test the idea that the color of the light shining on an object determines the color of the object (Testing Theories: Shining Light) and the idea that the colors of the object and the light mix

(Testing Theories: Mixing). In activity 14, Dana introduced the idea that objects reflect the color that we see and in activities 15 and 16 (Red Strawberry & Green Pepper), Dana had students use the new idea to explain how we see colored objects.

In the next sub-sections, I will discuss how well Dana's enacted activity sequence, including the pre-unit activities, fit the I-AIM analysis criteria of establishing a central question, providing experiences before explanations, making patterns explicit, providing opportunities for application, and taking account of students' intellectual and cultural resources.

Establishing a Central Question. In her learning goals, Dana identified her central question as "Why do we see colored objects?" (Dana Learning Goals Assignment, 2/7/2007) However, in neither her planed instructional approach nor her enacted activity sequence did Dana present this question to the students at the beginning of the unit. In both her plans and her enactment, Dana asked the students, "How is light reflected?" (Dana Planned Instructional Approach, 2/17/2007). In Activities 1 and 2 of her plans, Dana had intended to first have students explore the phenomenon of reflection using mirrors and flashlights, and then elicit student ideas about reflection. In this way, the activity provided a context for the question and a purpose for answering it. However, in her enacted activity sequence, Dana inverted the order of these activities. In Activity 1 (Writing about Light), Dana asked the students to write on a piece of paper what they thought reflection was and to explain how people see. In Activity 2 (Exploring a Mirror), she provided students with mirrors and a flashlight and asked them to observe what they noticed about reflection. As a result, the function of the question "How is light reflected?" shifted from a question used to establish a problem to be investigated to a question that functioned to elicit students' initial ideas about a phenomenon they had yet to explore.

Even though Dana did not explicitly establish the question for the unit at the beginning of her enacted activity sequence, by the end of the unit the central question was implicitly established. In Activities 6 (Colored Lights), Dana had students place a purple flower and a blue lid under a red light and a white light and record the colors of the objects as seen under the different lights. Later, in Activities 10-14, Dana tested student ideas about how we see color. Finally, in Activities 15 and 16, students were focused on explaining how we see a strawberry as red and a green pepper as green. Students were thinking about light and color and using the information they were learning to explain the color of the red strawberry and green pepper. Thus, although the central question of "How do we see color?" was never established explicitly for the students at the beginning of the unit, it did serve as a central organizing theme around which most of the activities were focused.

Experiences before Explanations. In her planned instructional approach, Dana planned to have students explore the color of objects under different colors of light and then systematically test common naïve student explanations for how we see color. Dana enacted these activities in her enacted activity sequence. For example, in Activity 10 (Testing Theories: Shining Light), Dana tested the students' idea that the color of the object observed is the color of the light shining on it by shining different colors of light (blue, red, white) on different colors of construction paper. The students saw that the color of the construction paper did not appear the same color as the color of the light shining on it. In other words, red construction paper did not appear white under the white light or blue under the blue light. Similarly, in Activity 12 (Testing Theories: Mixing) Dana tested the students' explanation that the color of the object and the color of the light mixed to form a new color, as when yellow paint and blue paint mix to become green paint. She used the same arrangement of colored construction paper and different colors of lights to attempt to convince the students that the colors of the lights and construction paper were not mixing as expected.

Up to this point, Dana's enacted activity sequence fit the I-AIM intentions of providing students with experiences before providing explanations. Dana was systematically challenging students' ideas to show them that their ideas did not account for the phenomena they were observing. Students were developing hypotheses, collecting data, and testing their ideas. Dana was creating dissatisfaction among the students for their common naïve ideas (Posner et al., 1982; E. L. Smith, 1991).

Evidence that Dana's enactment did not adhere to the EPE and I-AIM principle of providing experiences before providing explanations came during a whole class discussion with students during Activity 14 (Explaining White Light and Absorption). In her planned instructional approach, Dana intended during this activity to introduce to students the idea that white light contains all colors of the spectrum. Her planned instructional approach for this activity (Activity 10 Inventing the Ideas of Light Absorption and Reflection) stated

> Introduce a scientific idea, the concepts of light absorption and reflection. White light contains all colors of light. In order to see an object of color the light shining on it must contain the same color. That color of light is then reflected, while all others are absorbed. White objects reflect all colors of light, while black objects absorb all colors of light. The class discusses the application of the concept to the examples that we experienced previously. (Dana Planned Instructional Approach, 2/17/2007)

However, in her enactment, it became clear that Dana had already introduced this idea to students during the pre-unit activities and that she expected students to use this idea to explain their experiences. During a whole class discussion, Dana asked students to explain how we see color. She tried to prompt students to think about what they already knew about white light and reflection to come up with the explanation.

1 Dana: So, Cody said that white light contains all colors of light. What does that mean if white light shines on something? White light contains all colors of light. What does that do? What does that allow us to see? We see white light. But if I take every color of everything we have in here, why is it that we are seeing them the color that we are?

2 Mark: Because it doesn't change color.

3 Dana: What happens to the light? Let's think about reflection again.

4 Denise: It let's you see the color of the object.

5 Dana: Ok, but why. Ashley, what were you going to say?

6 Ashley: I was going to say that when the light reflects on the true color, it shows the true color that it is because the white light is all the colors in it, so it makes it that exact color.

(Dana Teaching Video Transcript, 3/12/2007)

Rather than introducing new ideas or building on student ideas, Dana was asking students to use information about white light that she had already introduced in Activity P1 (White Light) to now explain how we see color. She was expecting students to invent the explanation for themselves based on information that she had given them. I asked Dana about this moment.

1 Dana: I wanted them to be able to explain, you know, why the purple lid wasn't purple anymore. And I thought by having them discuss it they would come up with things they wouldn't have thought up on their own.

2 Kristin: So you were looking for the actual, wanted them to come up with the reason for what they were seeing?

3 Dana: Right. Which we had already talked about how, well a little bit, about white light at this point, I believe. So they did have some idea.

(Dana Interview, 4/21/2007)

In her enactment, Dana did engage students in testing their naïve conceptions, a practice supported by I-AIM. However, Dana also undermined the intentions of I-AIM by providing her students with information about white light before they engaged in the exploration of light and color. Rather than provide the information about white light and reflection after the students had explored the purple flower and blue lid under the red and white lights, and after they had looked at the colors of the construction paper under red, blue, and white light, Dana provided her students with the information prior to these activities and then expected them to use the information to invent the explanations she wanted them to have. I-AIM intends for scientific information to be introduced at a point when students can use it to explain their observations and understand their experiences. In this way, scientific concepts have an immediate use (Anderson & Smith, 1987; E. L. Smith, 1991). However, Dana thought that students would not be able to make sense of their observations and invent the scientific explanations she was looking for if they did not have the scientific information about white light first. As a result, she introduced scientific information long before there was a need or context with which to make sense of the information, effectively undermining the experiences-before-explanations intent of the activities she had planned.

Making Patterns Explicit. Dana identified in her planning the patterns that were important for her students to recognize in order to understand why we see color. As she stated in an interview, "I wanted it to show them that when they were placing objects under a colored light that wasn't the color of the object, that it would appear black" (Dana Interview, 4/21/2007). Dana's planned instructional approach included an activity sequence that she specifically intended to illustrate this pattern. In Activities 3 and 4

(Investigating a Simpler System and Testing the Designs), she intended for students to use flashlights covered with colored tissue paper to shine light of different colors on objects of various colors. In Activity 5 (Forming a Rule), she planned to have students report the results of the observations to the teacher and then as a class, "construct a rule for how the color of light affects the appearance of the object being viewed." (Dana Planned Instructional Approach, 2/17/2007) She also described the activity function for Activity 5 as "Look for patterns in light color and color of objects" (Dana Planned Instructional Approach, 2/17/2007)

As described earlier, Dana made some changes to her plans for these activities. Instead of using flashlights and colored tissue paper to shine the different colored lights on different colored objects, Dana had students place a blue plastic lid and a purple plastic flower under a desk lamp with a white light bulb and under a desk lamp with a red light bulb. The overhead lights in the room were shut off and the Venetian blinds on the windows were drawn. Students recorded the colors they observed on their own papers. Then, Dana made a large table on the white board in front of the class and asked students what colors they saw for each object under each light. Table 4.5 shows the colors that they recorded.

Table 4.5

Student observations of the color of objects placed under white & red lights

	White Light	**Red Light**
Flower (purple)	purple light purple	brown brownish orange plum darker purple dark blue/navy
Lid (blue)	light blue blue	purple dark purple brown plum black

Dana had hoped that the students would record that the purple flower and blue lid looked purple and blue, respectively, under the white light but that both looked black under the red light. Table 4.5 shows that the students did not come to consensus on what color the objects appeared under the red light. At least one student thought that the blue lid looked black and a few students thought the purple flower looked a dark shade of some other color. However, there was no agreement that the objects looked black.

Dana recognized that there was a problem with the activity. She explained that the reason it did not work was

> ...because it wasn't dark and there was still natural white light coming in. And, the light bulbs weren't a good choice as far as a light to shine on them. If you manipulated it a lot, you could achieve the results, but it took a lot of work. I did it at home and I got the purple flower to be black. But, I mean I was really, really trying and I couldn't do the same thing as well in the classroom where it wasn't as dark as my house was either. (Dana Interview, 4/21/2007)

Even though the students did not agree on the colors that they saw when the objects were placed under the red light, a pattern was still present. Both objects appeared to be a different color than they appeared under the white light. Yet, this version of the pattern was not recognized or at least was not acknowledged by either Dana or the students.

Dana had planned in her instructional approach to have students develop a rule for how the color of the light affected the color of the object (Activity 5). This was the activity that would have made the patterns explicit to the students. In Activity 6, she planned to have students develop their own explanations for this pattern. In her enactment sequence however, Dana combined these two activities into one activity. She had the students divide into their small groups to develop a rule, but in this case what she described as a rule was really an explanation. She said to the students,

> I need you to work with the people you went to the light with to try to develop a rule as to why it is you saw how it went from being this under the white light (points to chart) to being this underneath the red light. You need to come up with something. There should be 4 pieces of paper that have ideas as to why it is you saw these different colors underneath the red light. (Dana Teaching Video Transcript, 3/6/3007)

In these directions, Dana changed her intended wording for developing a rule for "*how* the color of light affects the appearance of the object being viewed" to developing a rule for "*why* it is you saw these different colors underneath the red light." Even though in both the plans and the enactment Dana was talking about forming a rule, by changing the rule from being about "how" to "why", Dana shifted the focus of the activity from identifying a pattern to developing an explanation. As a result, Dana missed an opportunity to make the essential pattern explicit to her students.

Dana's plans reflected Dr. Adams model, which included an activity designed to make patterns explicit to students. Dana identified the pattern that was important for her students to recognize and developed an activity that was intended to show this pattern. During the enactment, the pattern that Dana intended for students to see was not clear, although an alternative pattern was evident. Dana did not recognize this alternative pattern or make it explicit to the students. Furthermore, while Dana planned an activity that would help students describe any patterns and come to agreement on the patterns in the experiences, Dana's enactment shifted the function of the activity intended to make the patterns explicit to an activity in which students were asked to develop explanations. Nevertheless, despite these problems, Dana did plan and attempt to make a pattern visible to her students, even if she was not successful.

Opportunities for Application. In her enacted activity sequence, Dana provided students with two opportunities to apply what they had learned to new situations. In Activity 15 (Red Strawberry), Dana drew a red strawberry on the white board. As she asked questions and the students responded, Dana used colored dry erase markers to illustrate what was happening to the various colors in the white light that was shining on the strawberry. She drew ray diagrams that showed how the red light was reflected off the strawberry by drawing red lines hitting the strawberry and bouncing back. She showed that the green light was reflected off the top of the strawberry by drawing green lines hitting the strawberry leaves and bouncing back. She showed the other colors of the spectrum being absorbed by the strawberry. The following transcript illustrates this conversation.

1 Dana: But what color do we see it?

2 Students: Red and green

3 Dana: This is where the tricky part is. Why do we see it as red and green? This is what we are trying to work towards.

4 Heidi: Because red and green are reflecting off of it?

5 Dana: So red reflects off of what part of the strawberry?

6 Heidi: The red

7 Dana: Green reflects off what part of the strawberry?

8 Heidi: The green part

9 Dana: The green part. What happens to the other light?

10 Brent: They mix

11 Heidi: They stay. Like they go inside.

12 Dana: Does anyone know from what they learned about light before? Light can be reflected, light can be? What is another word?

13 Cody: Absorbed?

14 Dana: Absorbed. Right. Light can be absorbed. Is that what you meant Heidi? The yellow, orange, blue, indigo, violet, they are actually being absorbed. The red and the green light are actually being reflected back off of the strawberry. (Dana Teaching Video Transcript, 03/12/2007)

In Activity 16 (Green Pepper), Dana used a green dry erase marker to draw a green pepper on the white board in front of the room. She asked the students to work independently to draw a ray diagram and write an explanation for why we see the pepper as green. She referred to the diagram of the strawberry that she had just completed. Activity 15 with the red strawberry and Activity 16 with the green pepper both functioned as application activities. The students used their new understanding of reflection, absorption, and why we see color to explain the phenomena of seeing a red strawberry and a green pepper. In Activity 15 Dana modeled the type of drawing she wanted her students to be able to produce and coached the students in using what they had learned to explain the phenomenon. In Activity 16, she faded her support and let students apply their understanding independently.

Taking Account of Students. Analysis of Dana's accounting for students in her plans and enactment looked at two features: Her use of students' conceptions and her connections to students' cultural resources for learning. While Dana carefully considered her students' conceptions, she missed many opportunities to take advantage of the cultural resources her students brought to learning about light and color.

Dana's plans and enactments carefully considered students' conceptions. Dana clearly identified two common naïve conceptions that students often hold about why we see color and then designed activities that tested these conceptions. She faithfully enacted this sequence of testing student ideas. Furthermore, during her instruction, Dana kept track of students' changing ideas about how we see light. When they did not provide her with answers she expected, she tried to guide them toward the conceptions she wanted they to learn. More explicitly than any other intern in the course, Dana identified and then designed her unit around student conceptions by systematically testing student ideas about why we see color and then providing more scientifically correct alternative explanations for the phenomenon.

However, unlike her use of students' conceptions, Dana did not tap into her students' cultural resources for learning. In her pre-assessment report, Dana's analysis did not include any references to features of student thinking that could be related to consideration of students' funds of knowledge (Gonzalez *et al.*, 2005; Moll *et al.*, 1992), out-of-school experiences, or students' ways of being in the world (Varelas *et al.*, 2002). Her analysis focused solely on students conceptions. This complete absence of any reference to students' cultural resources for learning was different from other interns' pre-assessment reports. All other interns made at least some references to students' prior experiences or interests.

During her enactment, there were many opportunities for Dana to connect to the resources students were bringing to their sense-making in the classroom. However, Dana did not recognize these opportunities. Her focus was solely on student conceptions. For example, in Activity 1 (Writing about Light) in the enacted activity sequence Dana asked the students to write what they knew about reflection and how we see things.

1 Dana: What I want you to write on that piece of paper is what you know about reflection and why it is you think we see things.

2 Alicia: Like dead people?

3 Dana: No, like why do you see this water bottle, why do you see this book?

4 Brent: With our eyes?

5 Dana: I want everyone to be writing what reflection is and why we see things.

6 Carla: Are we talking about reflection like when there is sun or in the mirror?

7 Dana: Whatever you think of reflection.

(Dana Teaching Video Transcript, 3/5/2007)

In line 2, when Alicia asked, "Like dead people?" Dana dismissed the reference to dead people and abruptly refocused the question on common objects in the room. She may have thought the students were being silly or ridiculous with the reference to dead people. However, another possibility is that the students were trying to make sense of the task by connecting the question "Why do we see things?" to the movie *The Sixth Sense* in which the little boy says the now famous line "I see dead people" (American Film Institute, 2005). In line 4, Brent was still trying to make sense of what Dana was asking them to do, so he asked, "With our eyes?" Again, Dana did not acknowledge this possible lack of clarity in her question and simply repeated the directions. In line 6, Carla asked about reflections from the sun or a mirror. Carla was trying to connect the word "reflection" to examples of when she had heard the word "reflection" used, as in association with mirrors. The reference to the sun was clarified later in the lesson when Carla referred to the sun reflecting off the moon. The important connection that Dana did not make here was that two days prior to this classroom discussion, there had been a full lunar eclipse. The class had talked about the event and brought in newspaper clipping about it during their morning discussion of current events. Thus, in this scenario, students were drawing on popular movies, common experiences, and recent events to try to understand the task and develop answers to Dana's questions. However, Dana did not recognize or acknowledge the cultural resources on which the students were relying and did not make connections to these resources that could have possibly helped them make sense of the task.

Both Dana's planned instructional approach and her enacted activity sequence focused on consideration of student conceptual resources for learning. She planned and taught a sequence of lessons that took into account common naïve conceptions and systematically challenged those conceptions before offering the scientific explanation for why we see color. On the other hand, she did not take advantage of many opportunities to connect to students cultural resources for learning, including funds of knowledge or out-of-school experiences.

Summary of Dana's Enactment Sequence

Table 4.6 summarizes the analysis of Dana's enactment sequence.

Table 4.6

Summary of analysis of enactment for Dana

Tool	Analysis Foci	Dana
I-AIM: EPE	• Establish a Central Question • Experiences before Explanations • Patterns made explicit • Opportunities for Application	+/– Central question established implicitly – Front-loaded planned approach with scientific information +/– Unsuccessful attempt to make patterns explicit + Opportunities for Application present
CA&P: Taking Account of Students	• Consider student conceptions • Consider student cultural resources	+ Strong consideration of student conceptions – No consideration of student cultural resources

\+ matches intended use of tool feature – does not match intended use of tool

Dana's enacted activity sequence met some of the I-AIM and CA&P analysis criteria. Dana was successful in providing her students with opportunities to apply what they learned about seeing color to new situations. She first modeled and coached students through drawing ray diagrams to explain how we see colored objects; then she faded her support to allow students to practice drawing the diagrams on their own. Dana also strongly considered students intellectual resources for learning by identifying common naïve student explanations for why we see color and designing activities to systematically test and challenge those ideas.

Dana was partially successful in meeting two other I-AIM and CA&P analysis criteria. Dana did identify and use a central question as an organizing theme for her activities. Although she did not explicitly establish the question early in her enacted activity sequence, she did help students learn how to answer the question by the end of the unit. Similarly, Dana did identify the pattern that was important for students to see in order to understand the answer to the central question. She planned and attempted to enact activities to help students see this pattern. However, she was unsuccessful in making the pattern explicit because the activity did not work as planned, she did not recognize an alternative pattern that was present, and she asked students to explain rather than describe the observations that they made.

Dana was not successful on two aspects of the analysis framework. First, she was not successful in providing experiences before explanations. She front-loaded her enacted activity sequence with activities intended to provide students with scientific information, particularly vocabulary, that she expected students to use later to invent explanations for the phenomena they observed. Second, she did not recognize the many opportunities she had to take advantage of the cultural resources that her students were trying to use to make sense of the tasks in which she was asking them to participate. Dana's enacted activity sequence generally met most of the I-AIM and CA&P analysis criteria, but missed some important aspects that were intended by the I-AIM and CA&P tools and the example electricity instructional sequence that Dana used as a template for her unit.

Mediators for How Dana Used I-AIM/CA&P and EPE

Dana was negotiating three sets of expectations for her teaching. First, Dana was expected to cover the content she was assigned by her mentor teacher and the school district to teach. Second, Dana had her own expectations for how she wanted to teach science. Her vision of good science teaching was partially shaped by her own experiences as a science learner and was partially shaped in opposition to the vision of science teaching portrayed by her mentor teacher. Third, Dana had the science methods course requirements to fulfill. Dana used the example electricity sequence as a tool to help herself meet some of these expectations. She used the electricity sequence as a template in order to meet the expectations of the science methods course. At the same time, there were features of the example electricity sequence that fit her vision for teaching. By writing her unit to fit one small topic that she was responsible for teaching, she could cover the other topics she was assigned to teach without having to go into the detail expected in the science methods course. In this section I will describe Dana's vision for science teaching. I will then describe how the example electricity sequence helped Dana negotiate some of the expectations for her science teaching. I will end with a discussion of the implications of Dana's use of the example electricity sequence for her use of the I-AIM and the practices she engaged in during her planning and enactment of the light and color unit.

Dana's Vision and Goals for Science Teaching

Dana had a strong vision for how she thought science should be taught. She wanted to enact this vision during her internship science lead teaching experience. Dana also had a strained relationship with Melinda, her mentor teacher. Dana did not believe that Melinda taught science well. As a result, Dana also wanted to enact her own vision for science teaching in an effort to demonstrate to Melinda that science teaching could be different.

Dana's vision for good teaching. As an undergraduate, Dana was an Integrated Science major, meaning that her program of study included more science courses than elementary education candidates with other program majors received (approximately 50 credit hours of science compared to approximately 12 credit hours for non-science program majors). Dana wanted to be a middle school science teacher and felt confident about her science content knowledge. Dana thought science was important for all students to learn because she thought science explained the world.

> I mean it is everywhere around us. It is interesting. It helps us explain why things work the way that they do. Everything is science. I don't know. Just saying how this table is made, you know. It once was a tree. (Dana Interview, 1/18/2007)

Dana also valued her childhood science experiences and as a teacher, she wanted to give students opportunities to have the types of science experiences she had as a kid.

> I have shown rabbits my whole life. And my dad takes them down to the state fair which is downtown Detroit. And it is so funny to see the kids who are in awe of these animals because they may have never seen a hundred rabbits at one time. It's really inspiring, I think. And I remember just a couple years ago going down there with him and these kids are all staring at him as he's wheeling his rabbits in. Like I was thinking from a teachers' perspective, these are the kids that you want to instill science into. (Dana Interview, 1/18/2007)

Dana wanted students to learn canonical science explanations for everyday experiences. She recognized that students often bring naïve ideas to learning science and she wanted to students to change those misconceptions. During the first interview, Dana described a previous science lesson about seasons that she had planned and taught to her students that fit her vision for good science instruction.

> Well, we read about it the first day, but then we did the activity the next day and it took us 15 minutes. I am sure that everyone cleared up their misconceptions because we talked about it before hand and then afterwards we revisited it. (Dana Interview, 1/18/2007)

When I asked her how she knew the students had "cleared up their misconceptions", Dana explained that when she asked the class questions, "…they were just like (snaps fingers) giving me back [the correct answers]" (Dana Interview, 1/18/2007). Dana believed that engaging students in hands-on activities with science and then offering them opportunities to talk about their ideas would help them change their misconceptions.

Dana also felt that not all students had equal opportunities to participate in science. For example, she observed that many students did not participate in small and large group discussions.

> I wanted to create an environment in which more people would discuss things. Because there is the handful of students who always speak up, always volunteer to give information. But I wanted everybody to have equal participation…. So I really wanted to try to get some of those quieter types to speak and to have a more active role in the class. (Dana Interview 4/9/2007)

Dana wanted to support all students in sharing ideas in class.

Part of providing equal opportunities to learn meant that Dana thought that all students should be held to the same high expectations. She believed that if all students had opportunities to participate, then they would be successful. She expected all students to participate in all group conversations. This attitude also meant that Dana did not readily make many accommodations for students' differences. For example, one day Dana pointed out to me a long list of names on a paper taped to a closet door. The list reached from the top of the door to the bottom of the door. On the list were students' names and their missing assignments. Dana had students stay in over lunch recess to complete their missing work. Melinda saw this event as an example of Dana's rigorous attitude towards students.

> Dana doesn't like making accommodations for them. No. She's, "You do it." She's a lot harder...She was ready to just fail them. Well now, when she hung up the nine pages of missing assignments, she got a feel. And I said, "Welcome to teaching. You have to make accommodations for those kids that have the ten million missing assignments." (Melinda Interview, 3/22/2007)

Dana's insistence on treating all students the same and holding them accountable to the same expectations may account for her own lack of awareness of the variety of cultural resources that students bring to learning science. She focused only on student ideas because in doing so, she was able to treat all students the same rather than as having diverse resources that needed to be accounted for differentially.

At the end of her instruction, Dana was particularly pleased that one of her quieter students participated in the whole group conversation that resulted in the development of the scientific explanation for why we see color.

> But, it was really great to see that it was Heidi who arrived at the response. I tried not to be too excited about it, and I was like "Yeah, you see me." But, she isn't a student who stands out very often, so it was just really great to see her shine. I mean, she got it. I mean, she did really well

with the whole understanding of everything we did in the class about the light, so that made me happy as a teacher. (Dana Interview, 4/21/2007)

To Dana, this event may have been positive confirmation that expecting all students to participate was a fruitful strategy to help all students learn science.

Dana's strong vision for science was probably influenced by her experiences as a successful science learner, both as a child and as a university student. She found science useful for understanding the world, and so she wanted her students to develop an appreciation for science as well. In her schooling, she successfully learned canonical science, and so she expected her students to learn it too. Furthermore, she may have learned about using hands-on activities to address students' misconceptions in the science content courses for teachers that she took as part of her integrated science program. Therefore, she planned to use similar types of activities in her instruction.

A vision in opposition. One manifestation of Dana's strong vision for teaching science was her disagreement with her mentor teacher's approach to teaching science. Dana and Melinda had a strained working relationship. Melinda was an experienced elementary teacher and had taught for the school district for many years. Dana, however, was her first intern, and Melinda wasn't sure what to expect from having an intern in the classroom.

> This is my first time having an intern. So this is all very new to me as far as what to expect, as far as what was expected of me. What I was supposed to do, what I was supposed to say? (Melinda Interview, 3/22/2007)

Although neither Dana nor Melinda shared the details of their difficulties with me, there were several allusions to the challenges they experienced early in the internship year. Dana said,

> I think that as with all kinds of relationships, there's always going to be bumps along the way...I had some issues that we had to resolve through here [university teacher preparation program] and with my CT [mentor teacher] (Dana Interview, 1/18/2007)

Melinda was more explicit about the situation

> The year started off really rough. It really did. And I mean. I didn't know. I thought it was my fault. And [the university field instructor is] like, "Melinda it is not you. They usually are not like this." And she's very dominant....Because I think she came in with this attitude that she was gung ho and she was going rule the roost and I think she looked down at me." (Melinda Interview, 3/22/2007)

By the time I began observing Dana, she and Melinda had worked out a co-existence that allowed them to function in the classroom. Melinda explained, "I've backed off. I was there. I've done it. I've been a kid. You know, so I've backed off and let her run with it and let her do more than what the others would do." (Melinda Interview, 3/22/2007)

Nevertheless, this undercurrent of opposition came through in some of Dana's assignments and comments about her perceptions of her mentor teacher's teaching. I had the opportunity to observe Melinda teaching a few minutes of social studies a few times, and each time she had the students reading from their textbooks and answering worksheet questions. Dana used this same strategy when I observed her teaching reading or math. I would often enter the room to find Dana visiting individual students as they worked independently on a math or reading worksheet at their desks. However, when she taught science, Dana shifted to hands-on activities. She commented on this explicit shift in activity and contrasted it with the experiences she thought her students had not previously received. "Hands-on science projects were not very prevalent in the classroom prior to this unit. Students could not wait to explore why we see objects" (Dana Learning Community Project Report, 5/6/2007).

Dana was also critical of Melinda's whole-class teaching strategies. Although she never mentioned her mentor teacher directly in her Learning Community Project Report, Dana's comments reveal that she did not approve of Melinda's teaching style and contrasted it with her own intentions for providing more opportunities for students to participate in and learn from student conversations.

> Students have been taught to raise their hand when they would like to speak. They are then to wait to be called on. I want to increase meaningful participation of all students in whole class discussions and the current classroom norms interfere with this goal. With the current classroom discussions there is no conversation that takes place between students. Conversation is teacher to students and student to teacher, not student to student. There is no opportunity for students to build on others ideas or to disagree with students without the teacher talking after each student. (Dana Learning Community Project Report, 5/6/2007)

Dana's strong vision for teaching shaped her goals for her experience teaching science during her internship year. Dana wanted to change her students' naïve ideas about science and she wanted them to see the science connections to their lives. She wanted all of her students to succeed. Dana wanted to teach a unit that involved students in hands-on experiences with phenomena and provided them with opportunities to share their ideas and construct canonical explanations for their experiences. However, her goals were not solely altruistic. Dana also wanted to enact her vision for science teaching to demonstrate to Melinda, whom Dana felt did not teach science well, that her own vision for science teaching could be successful, and possibly, better.

Dana's Use of the Example Electricity Sequence

Dana had to figure out how to manage the many expectations the she and others had for her science instruction. On the one hand, her mentor teacher assigned her to cover all of the topics on light in the school district sixth-grade curriculum. On the other hand, Dr. Adams required her to develop and teach an in-depth unit around a central question. In addition, Dana wanted to enact a unit that fit her vision for teaching and differed from her mentor teacher's science teaching. Dana's use of the example electricity sequence as a template for her unit on light and color allowed her to meet some of these expectations in an efficient manner.

First, the example electricity instructional approach fit many of Dana's ideas about good science teaching. It provided a structure for engaging students in hands-on experiences and for challenging student naïve conceptions. Dana used her strong content knowledge and her previous experiences learning about light and color to help her find activities that would fit into the template. I asked Dana where she got the ideas for the activities she used. Usually, Dana replied that "I just came up with it" (Dana Interview 4/9/2007 and 4/21/2007). However, Dana also noted that she consulted one of her former science content course instructor at the university who provided her with the idea for the activities with the colored lights (Activities 5-7) and the lamps and light bulbs to use to conduct the activities. Dana also used diagrams from the textbook as seeds for her activities. For example, a diagram in the textbook of light shining on a red strawberry became the basis for the red strawberry application activity at the end of her enacted activity sequence (Activity 15). At the end of her teaching, I asked Dana if there were any parts of her light and color unit that she thought were helpful. "I think that the testing of it was very helpful. And them [the students] actually explaining what it was that they had seen. I mean I think that it went very well all together." Because she wanted to engage students in hands-on activities and change student ideas, Dana recognized and used opportunities that the example electricity sequence offered as a way to engage students in activities that would challenge naïve conceptions.

Dana also wanted to engage students in conversations with each other. The electricity instructional approach included activity functions that allowed students to share their ideas with others (i.e. elicit student ideas (dark yellow), students explain patterns (dark blue), and students revise ideas (sky blue)). Dana was able to take advantage of this aspect of the example electricity sequence to design similar activities that engaged her students in small and large group conversations. For example, she had students sharing ideas about the colors of the flower and the lid under the red and white lights (Activity 7), and sharing their explanations about why they saw these colors (Activity 8).

Second, Dana wanted to teach differently from Melinda. The example electricity sequence modeled an approach to planning and teaching that was in marked contrast to Melinda's approach to reading about science from the textbook. If ever confronted about the way in which she may have passive-aggressively tried to teach science in opposition to how her mentor teacher taught science, Dana's use of the example electricity sequence could have helped her legitimately justify her instruction as part of the requirements for her university science methods course. At the end of her instruction, Dana gave herself a lot of credit for changing her students' expectations of science.

> Students in my class had not experienced an inquiry unit prior to my science unit. In the beginning they struggled, because they wanted to know the answer. But who can blame them? That is how they are used to learning. The students went from having a 'tell me' attitude to having an attitude in which they wanted to explore on their own to find the answers. (Dana Learning Community Project Report, 5/6/2007)

Finally, Dana saw using the example electricity sequence as a template as a way to meet the course requirements for the unit as efficiently as possible. Like all interns, Dana had many other demands on her time besides teaching. In addition to taking 12 course credits at the university and planning and teaching all content areas in the classroom, Dana was also working several days a week in an after-school tutoring program, serving as a student representative to the National Education Association (NEA), and actively seeking employment for the next year. Dana talked a lot about the challenges of managing the teaching workload.

> It is hard being a teacher. And it is hard thinking about how long things will take and making those last minute decisions.... It is really hard being a teacher and thinking like I only had this much time, this many days... So it is really hard trying to get the most out of the time that you have. (Dana Interview, 4/9/2007)

Dana had a lot of topics that she was expected to cover, and she did not think that it was necessary or even feasible for her to use the course frameworks to organize her instruction of the other light topics. My description of the light lessons that Dana taught before her planned light and color unit shows that Dana did not use the science methods course frameworks to structure her other science lessons. Furthermore, Dana did not use the frameworks for the lessons she taught following the light and color unit. When asked how she planned and taught the lessons following her unit on light and color, Dana said, "It was just a few days of individual lessons. Nothing that was a big instructional approach format" (Dana Interview, 4/9/2007). Dana saw the planning and teaching of the science lessons on the other light topics as separate from the planning and teaching that she had to do on the light and color unit for her science methods course. The example electricity sequence provided her with a template that allowed her to meet the course requirements and then get back to teaching the rest of the topics in a way that demanded less of her time. She said at the end of her unit, "I just think that it takes a lot of effort and desire, I guess, from the teacher to make something like this [her light and color unit] work." (Dana Interview, 4/21/2007)

Accessing the I-AIM Practices

One interpretation of Dana's case is that she did not use the I-AIM in her planning and teaching. Dana did not talk about using I-AIM or EPE and did not identify the I-AIM stages or refer to experiences, patterns, or explanations when talking about her unit. Rather, Dana used the example electricity sequence as a template for her unit and did not engage with the underlying principles of I-AIM and EPE.

However, this interpretation does not recognize the important ways in which Dana's practice during her enactment of her light and color unit did include key practices that are represented in the I-AIM and CA&P. As Table 4.6 shows, Dana did use a central question as an organizing theme, did identify and attempt to show the key patterns, did provide students with opportunities for application, and did consider students conceptions in her planning and teaching. An alternative interpretation suggests that Dana's use of the example electricity sequence as a template provided her with access to the practices represented by the I-AIM, even though she did not use the I-AIM itself.

The intent behind the development of the I-AIM and the CA&P tools was to scaffold preservice teachers' practices of planning and teaching, including using curriculum materials, in a way that would support students in the practices of inquiry and application. The I-AIM serves as a generalized framework that can support preservice teachers in synthesizing many principles of reform-based science teaching and provide access to the reform-based practices (Cartier *et al.*, 2008; Gunckel *et al.*, 2007; Schwarz & Gwekwere, 2007). These teaching practices include, among others, using a central question to organize activities and establish purpose for students, finding and selecting activities that engage students with phenomena and make patterns in experiences explicit, providing students with scientific information the explain the patterns after they have identified and agreed upon the patterns, providing students with opportunities to compare their ideas to scientific ideas and revised their ideas if necessary, providing students with opportunities to practice using their new understanding in new contexts, and taking account of students intellectual and cultural resources while planning and teaching. As a model or framework, the power of I-AIM lies in its generalized representation of these practices.

In the science methods course, Dr. Adams used the electricity sequence as an example of an instructional sequence that fit the intents of the I-AIM. The example electricity sequence fit many of the activity functions of I-AIM and represented many of the underlying principles of EPE. It established a problem, elicited student ideas, provided students with opportunities to explore experiences for patterns, offered scientific explanations, and opportunities to apply new understandings. However, the electricity sequence was not just an instantiation of the I-AIM. The electricity sequence incorporated additional structures and language that were not particular to the I-AIM. For example, the Explore & Investigate stage of I-AIM includes activity functions that support students in finding patterns in experiences. The example electricity sequence included activities that engage students in exploring different combinations of batteries, light bulbs, and wires to make a flashlight bulb work. Students are then asked to form a rule for how the battery, light bulb, and wires must be sequenced in order for the light bulb to work. This rule in the electricity sequence is the equivalent of what the I-AIM generalizes as a pattern. However, the example electricity sequence did not identify the rule as a pattern. Similarly, the Explore & Investigate stage of I-AIM included activity functions that support students in testing their ideas. The example electricity sequence formalized this function by systematically testing common student ideas for how batteries, light bulbs, and wires have to be arranged to make a light bulb light. The example electricity sequence refers to these student ideas as theories. The sequence tests the student theory that light bulbs need more electricity in order to work and the student theory that light bulbs need positive and negative electricity. However, the I-AIM does not make specific reference to student ideas as theories and does not formally structure how one should organize the testing of student ideas. The I-AIM functions as an abstraction of generalized practices, while the example electricity sequence serves as a specific application of the abstraction.

By using the example electricity sequence as a template, Dana learned the language and specifics of the electricity sequence. In doing so, Dana also engaged in the practices represented by I-AIM. When enacting her pre-unit activities on white light and waves, Dana did not use a central question, did not consider students naïve conceptions, did not identify and attempt to make patterns in experiences visible to students, and did not provide them with opportunities to practice using what they had learned. She was trying to enact her own vision for science teaching by engaging students in hands-on activities and opportunities to share ideas, but her enactment resulted in procedural display. However, while enacting the activities that she planned using the example instructional sequence as a template, Dana did engage, with varying degrees of success, in many of the practices intended by the I-AIM. Thus, for Dana, the example electricity sequence functioned as another tool for accessing the practices that the I-AIM intended to scaffold. As such, the example electricity sequence provided Dana with specific scaffolding that the generalized I-AIM did not. The limitation, however, was that by using the example electricity sequence as a template and not engaging the underlying I-AIM framework, Dana lost the power of generality that the I-AIM represents. She did not access the generalized principles that might guide her in engaging in these reform-based practices when planning and teaching another unit in the future.

Furthermore, she did not develop the language used to talk about these generalized principles in a way that would enable her to participate in a community organized around I-AIM whose members share a common meanings for these practices (Lave & Wenger, 1991; Wenger, 1998).

Summary of Mediators

Dana's planned instructional approach and enacted activity sequence were mediated by her strong vision for teaching science, her desire to teach differently from her mentor teacher, and her negotiation of the tension between coving the topics she was assigned to teach and developing an in-depth unit for her science methods course. Dana's choice to use the example electricity sequence as a template for the light and color unit was mediated by her need to fulfill the requirements for the course in an efficient manner and still have time and energy necessary to cover the rest of the topics she was assigned to teach. Furthermore, Dana used the example electricity sequence to fit her own goals for teaching science, including engaging students in hands-on activities and peer conversations to challenge their ideas and help them construct canonical explanations for phenomena. Using the example electricity sequence also helped her meet her goal of teaching differently from her mentor teacher. Dana's use of the example electricity sequence enabled her to engage in many of the planning and teaching practices that the example electricity sequence and the I-AIM and CA&P tools represented, including using a central question, identifying and attempting to make patterns explicit, providing opportunities for application, and accounting for students' ideas. Dana's vision for teaching, however, also included a belief that students need certain information to make sense of their experiences prior to engaging in those experiences. This belief lead Dana to introduce scientific information in her pre-unit activities, thus undermining the intended I-AIM practice of providing experiences before explanations. Dana also believed that in order to provide all students with opportunities to learn science, all student should be held to the same standards and treated the same way, which may have accounted for her lack of awareness of students' cultural resources for learning science.

Chapter Summary

Dana wanted to be a middle school science teacher. For her internship, however, she found herself in a self-contained sixth grade with a mentor teacher whom Dana did not believe taught science as it should be taught. Dana had a strong vision for how she wanted to teach science, and she intended to teach science in a way that matched her vision. Along the way, she wanted to show her mentor teacher that there were other ways to teach science besides reading from the textbook. Dana also believed that her mentor teacher did not hold students accountable for learning, and she intended to show that by holding all students to high expectations, students who do not usually succeed in science could be successful.

Dana, however, had two issues she had to negotiate. First, she had to figure out how to teach all of the content that she was assigned to teach. She negotiated with Melinda, her mentor teacher, to reduce the number of topics that Melinda had originally wanted her to cover. Rather than teach all of the light and sound topics in the sixth-grade curriculum, Dana negotiated to teach just the light topics. Second, Dana had to meet the requirements of the science methods course in which she was enrolled. As such, she had to plan and teach a unit using the course frameworks. Dana chose to focus her unit on how we see color, one of the topics on light that she was responsible for teaching.

Dr. Adams provided interns with an instructional approach on electricity as an example of a unit that fit the I-AIM and EPE frameworks. Dana used the example electricity sequence as a template for her unit on light and color. Dana used the same activity labels, the same sequencing, and the same words and syntax for the description of the activities and their functions. Although her words were the same, Dana did engage in considerable thought to be able to translate the electricity example into a unit that would work to teach about how we see color.

When Dana took over teaching science from her mentor teacher, she taught at least two lessons on light before she began enacting her instructional approach on light and color. Dana taught a lesson on white light and a lesson on waves. Dana did not consider these lessons to be part of her unit on light and color. However, she did sequence the lessons before her light and color unit because she said they provided information that she thought her students needed to understand before they began learning about seeing color. Dana's teaching of these pre-unit activities enacted her vision for what she thought good science teaching entailed. Specifically, she engaged students in hands-on activities and provided them with opportunities to share ideas about their experiences. She noted that these practices were in marked contrast to the type of teaching that her mentor teacher usually engaged in when her mentor teacher had students read about science in the textbook. However, Dana also placed a strong emphasis on looking up and using vocabulary words in a way that disconnected the vocabulary words from the bigger ideas of science. Furthermore, she did not provide students with a purpose for the lessons or a connection to previous or following lessons. As a result, the lessons stood alone as disconnected examples of procedural display.

When Dana began teaching her planned instructional sequence for the light and color unit, Dana engaged in many practices that she had not engaged in during her enactment of her pre-unit activities. Most of these practices matched the practices I-AIM intended to scaffold. Dana identified and used a central question, "Why do we see color?" to frame her unit and organize her activities. Although she did not explicitly establish this question for her students at the beginning of the unit, by the end of the unit the activities that asked students to explain how we see the color various objects had implicitly established the question as the focus of the unit. Dana also identified a key pattern that was necessary for her students to recognize in order to understand the explanation for how we see color. She designed an activity to make this pattern visible to students. However, the activity did not go as planned and even though there was an alternate pattern visible, Dana did not make it explicit to her students.

In addition, throughout the unit, Dana considered students' conceptions. She specifically planned activities that would allow students to test their common naïve ideas and revise their ideas based on what they learned. Finally, Dana provided students with many opportunities for application by asking students to practice using what they had learned in the unit to explain how we see color in new contexts. She modeled using ray diagrams to explain how we see a red strawberry, and then asked students to use the ray diagram to explain how we see a green pepper.

There were also practices intended by I-AIM that Dana did not engage. First, she did not provide experiences before explanations. Dana provided students with information about white light and waves before she began her enactment of her planned instructional approach. In the case of the white light, she expected students to draw on what she had taught them about white light to construct a new understanding of how we see color. Dana front-loaded her light and color enacted activity sequence with explanations, and thus undermined the experiences-before-explanations activity functions that her planned instructional approach had supported. Second, Dana did not take recognize and leverage the many cultural resources that her students were bringing to learning about light and color. Her students were trying to draw on experiences with popular culture, recent natural events, and common experiences to make sense of the tasks that Dana was asking them to complete. Dana missed these opportunities and sometimes dismissed them as off-task behavior.

Dana's strong vision for teaching science, her desire to teach differently from her mentor teacher, and her managing of the tension between covering the topics she was assigned to teach and meeting the requirements of her science methods course all mediated Dana's choice to use the example electricity sequence as a template for her unit on light and color. Dana's use of the example electricity sequence as a template allowed her to teach science as she envisioned and in opposition to her mentor teacher's approach to science teaching. It also allowed her to meet the requirements of the science methods course in an efficient manner, with time and energy left over to teach the other light topics she was assigned to teach in the manner that she wanted to teach them. Dana's vision for teaching science also mediated her inclusion of the pre-unit activities, which undermined some of intent of the example electricity sequence and the I-AIM framework that it represented. While Dana did not engage the I-AIM and CA&P directly, using the example electricity sequence as a template enabled Dana to plan and teach a unit on light and color that matched some of the intentions of I-AIM. It allowed her access, sometimes more successfully than other times, to many of the reform-based teaching practices that I-AIM was intended to scaffold. However, despite the fact that she did engage many of these practices, Dana's use of the example electricity sequence did not allow her to access the power of generality that the I-AIM provided.

CHAPTER 5

Leslie

Chapter Overview

Leslie faced a challenging situation. She was assigned to teach an advanced topic, the carbon cycle, which was not a part of the fifth-grade curriculum, using curriculum materials that provided only limited support. Despite these challenges, Leslie planned and taught a unit that fit many of the I-AIM intentions. However, Leslie's unit missed two key functions of the I-AIM. The meanings that Leslie made of some components of the I-AIM and the underlying EPE framework mediated her use of the I-AIM and CA&P tools to plan and teach her science unit.

In this chapter I will begin with a description of the challenges that Leslie faced in planning and teaching her unit. In the following section, I will describe the content story she wanted to tell, her planned instructional approach and enacted activity sequence. I will analyze Leslie's plans and enactment for how well they meet the intentions of the I-AIM and CA&P tools and the underlying EPE framework. In the last section, I will explain the mediators that account for how Leslie used the I-AIM and CA&P tools.

Challenges Planning Science

Leslie's field placement had many affordances. Leslie had a positive relationship with her mentor teacher and reasonably well-behaved fifth-grade students. Her school was dedicated to meeting the needs of middle-grades students as they transitioned from elementary to junior high settings. However, when in came to planning and teaching science, Leslie had several challenges that combined to create a difficult situation. In this section I will describe Leslie's teaching situation and the challenges that she faced as she began to plan and teach her science unit. I will begin with a description of the setting and the topic she was assigned to teach. I will then describe Leslie's efforts to identify her learning goals. I will also describe the curriculum materials that Leslie had available and Leslie's own evaluation of the strengths and weaknesses of those materials. I will end with a presentation of some initial evidence for Leslie's lower level of understanding of the topic she was assigned to teach.

Leslie's Teaching Situation

Leslie interned at Peace Middle School. This school served fifth and sixth grade students and functioned to facilitate students' transition between elementary and junior high school. Teachers had their own classroom of students, but they were also paired with another teacher with whom they shared planning and teaching responsibilities. Each teacher in the pair was responsible for planning and teaching two core subject areas. Students in the two classes switched teachers for two subjects each day.

Leslie's mentor teacher, Rebecca, taught fifth grade. She was responsible for planning and teaching language arts and science, while her partner teacher, Hank, taught math and social studies. Rebecca and Hank worked together to build a sense of community both within their own classrooms of students and across the two classrooms together. They met daily during lunch to discuss progress that students were making and to plan upcoming events for both classes.

For Leslie, this arrangement meant that during her internship she worked with both Rebecca and Hank and with both classrooms of students. Some days, Leslie followed Rebecca's students through the day, switching classrooms with them when they went to Hank's room for math or social studies. On other days, Leslie stayed in Rebecca's room and helped teach language arts and science to both groups of students. When she became responsible for planning and teaching science, Leslie enacted her science plans twice each day, once with Rebecca's students and once with Hank's students. For the science methods course assignments that required her to assess student conceptions and learning, Leslie focused on Rebecca's students.

Rebecca and Leslie's class had twenty one students, of whom three were African American, one was from the Middle East, and one was Chinese-American. The Middle-Eastern and Chinese-American children spoke English as a second language, although both were considered fluent in English and did not receive ESL services. None of the children in the class received special education services, although one student was identified as having a low IQ and did not qualify for special education. Rebecca explained that the students in the class represented a greater ethnic diversity than the school used to have. She attributed this growth in diversity to school-of-choice students who transferred into the school district from a nearby urban area.

Planning a Unit on the Carbon Cycle

Rebecca assigned Leslie to plan and teach her science unit on the carbon cycle. This topic was not a part of the fifth-grade curriculum, but it was a topic that Rebecca thought was important and to which she thought fifth grade students should receive an introduction. Leslie's challenge was to narrow down a broad, advanced topic into a three-week unit for her fifth-grade students. This was a task that would be challenging to experienced curriculum developers, much less an intern teacher. In this section I will provide some background information on why Rebecca assigned this topic to Leslie and describe how Leslie struggled to define her learning goals.

Selecting the topic. The school district provided teachers with a list of benchmarks for life science, physical science, and Earth and space science to be taught during each grade. In fifth grade, five life science benchmarks were identified:

1. Compare characteristics, food, life cycles, energy, environmental needs of organisms.

2. Observe and describe patterns of interdependence of living things
3. Observing, describe, and explain functions of seed plant parts
4. Describe life cycle of flowering plants
5. Describe flow of energy within a food web.

(School District Curriculum Grid, 2001)

In previous years, Rebecca had taught a unit on food chains and food webs that included energy transfer among organisms. However, this year, she decided she wanted to provide her students with a deeper understanding of where the mass of the organisms comes from. The previous summer, Rebecca had taken a summer science workshop designed to increase teacher science content understanding. This workshop included the carbon cycle and using the carbon cycle to understand global warming. Rebecca felt that adding the carbon cycle to her fifth grade curriculum would enhance her food webs unit. Rebecca explained,

> But we are trying to teach how the energy transfers, and I want to link in where the mass comes from. In the food web, in the food chains. ...And I said I want to give them a little deeper knowledge into, well, what happens when a deer eats a plant? How does a deer grow? And I wanted some deep knowledge in there. (Rebecca Interview, 4/13/2007)

The carbon cycle, however, was not a fifth-grade benchmark. In the school district curriculum, the carbon cycle fit better with the 8th-grade benchmark, "Describe how carbon/nutrients cycle through ecosystems" (School District Curriculum Grid, 2001). Rebecca acknowledged that carbon cycling was not a middle school benchmark. However, she still felt it was an important topic to which fifth grade students should be introduced.

> I thought, "I want to try this this year, right or wrong." ... The carbon cycle itself is more of an upper level benchmark. But I just wanted to try to

introduce it. We just, you know, we did carbon reservoirs one day. You know. Then we took that and did some global warming things. So they are getting a little taste of it. (Rebecca Interview, 4/13/2007)

Rebecca assigned Leslie to plan and teach her unit on the carbon cycle. Leslie thought that this topic was important to teach.

And also, it is to help save the Earth too, because I don't know, it is not doing so well. But, it will get worse during their lifetimes. So, they can use what they know and recycling and all that kind of stuff to help better the Earth and themselves. (Leslie Interview 4/25/2007)

Leslie also had a general understanding of the carbon cycling and recognized it as an example of matter cycling, an important big idea of science. When asked at the end of her guided lead teaching what she had wanted her students to learn, Leslie said,

I am trying to get them to see that everything living uses carbon to grow and that it gives it back to the environment when it dies. I don't know if that is the pattern I want them to see or if it is more of a bigger picture that, in the Earth, matter cycles and carbon cycles and water cycles. There's the rock cycle. They are not really learning about that, but they are starting to get that big idea that things cycle on Earth and everything has an impact on something else. (Leslie Interview, 4/13/2007)

Defining the learning goals. Determining how to take this big idea and turn it into a three-week unit for fifth-grade students turned out to be a difficult challenge. Although she had a big-picture understanding of the concept, Leslie struggled to figure out how to approach the topic and identify the relevant learning goals. She explained,

I was really nervous about teaching this subject to fifth graders because I wasn't sure if they would really understand it and I didn't know exactly how to approach it because the carbon cycle is so big that I needed to narrow it down. (Leslie Interview 4/25/2007)

Table 5.1 shows Leslie's original and revised central question and learning goals. Leslie's first draft of her learning goals identified her central question as "How and why is matter conserved and continuously cycled?" (Leslie Learning Goals, 1/20/2007). Her list of benchmarks, identified from the state curriculum framework, included benchmarks on describing physical changes and a benchmark on describing energy transformations. She also identified two benchmarks that linked to her goals for teaching students about the impact humans have on the environment (LEC III.5.e.4 and LEC III.5.m.5 in Table 5.1 below). Leslie received feedback from her science methods course professor, Dr. Adams, which included suggested revisions to the central question and different benchmarks that more directly related to the big idea of carbon cycling.

Table 5.1

Leslie's original and revised learning goals.

	Original Learning Goals 1/20/2007	**Revised Learning Goals 2/9/2007**
Central Question	How and why is matter conserved and continuously cycled?	*A maple tree starts out as a small helicopter seed. "Where does the weight of the tree come from, what happens to the leaves of the tree that are eaten by deer, and what happens to the tree when it dies?"*
Content Benchmarks	Describe common physical changes in matter: evaporation, condensation, sublimation, thermal expansion, and contraction. (PCM) IV.2.m.1 Describe common energy transformations in everyday situations. (PCM) IV.2.m.4 Describe positive and negative effects of humans on the environment. (LEC) III.5.e.4. Explain how humans use and benefit from the plant and animal materials. (LEC) III.5.m.5	*Describe how organisms acquire energy directly or indirectly from sunlight. (LEC) III.5.m.2* *Describe evidence that plants make and store food.* *(LO) III.2.m.3)* Describe positive and negative effects of humans on the environment. (LEC) III.5.e.4. Explain how humans use and benefit from the plant and animal materials. (LEC) III.5.m.5

Revised content is represented in italics. Benchmark statements are from the Michigan Curriculum Framework (Michigan Department of Education, 2000).

Leslie's revisions focused her learning goals more centrally on the carbon cycle. Dr. Adams suggested specific wording for her central question that Leslie used directly, identified with quotation marks, and acknowledged by citing Dr. Adams as the source of these words in her revised learning goals document. This revised central question had three parts that referred to the processes of photosynthesis, consumption, and decay. The central question was: Where does the weight of the tree come from (photosynthesis), what happens to the leaves of the tree that are eaten by deer (consumption), and what happens to the tree when it dies (decay)? She also revised her benchmark using the two benchmarks that Dr. Adams suggested (LEC III.5.m.2 and LO III.2.m.3 in Table 5.1). These two benchmarks were the only relevant 5th-grade benchmarks in the state curriculum framework (Michigan Department of Education, 2000).

In addition to identifying relevant benchmarks, interns were asked to identify specific practices that described what students would be able to do with the knowledge described by the benchmarks. Leslie's original practices list was not so much a list of practices as a mix of questions she wanted students to be able to answer, concepts she wanted students to understand, and experiences she wanted to provide. They focused primarily on physical and chemical changes. Her revised practices were more clearly statements about what students would be able to do and matched her revised benchmarks. Table 5.2 shows Leslie's original and revised practices.

Leslie's revised benchmark and practices suggest that she was narrowing the focus of her unit to concentrate on photosynthesis and explaining from where plants get their mass. Leslie did not include any practices in her learning goals that related to decay or consumption. This absence may have been because there were no middle school benchmarks in the state curriculum framework that addressed decay or consumption. However, Leslie's newly revised central questions included reference to decay. Her revised learning goals also included benchmarks and practices that related to human impacts on the environment. Although she was beginning to focus on the process of photosynthesis, Leslie's learning goals indicate that she still wanted her unit to connect to the larger picture of matter cycling, global warming, and human impacts on the environment.

Table 5.2

Leslie's original and revised practices

Original practices 1/20/2007	Revised practices 2/9/2007
What do humans do to create more carbon dioxide being released into atmosphere? How does this effect global warming?	Students will tell how plants acquire energy from the sun.
Humans need plant and animal materials in the cycling of carbon. Show this with plant experiment. One plant gets carbon dioxide and the other does not. (Taken from: http://www.promotega.org/ksu30002/carbon_exp.htm)	Students will tell how plants use the energy to make their own food.
Have students think of Legos. Legos that are separated are Legos that are liquid, Legos that are "put in freezer" are Legos that are "frozen" and connected tightly together.	Students will explain what "food" is for plants and how it makes them grow.
Physical change checklist. This involves teacher demonstrations of physical changes. The students must watch and categorize the changes as they are being made.	Students will explain what "food" is not for plants. Students will compare what plants use to grow (water, nutrients) with what causes the actual growth (carbon).
Physical or Chemical change activity stations. The kids go to stations and decide whether each activity is a physical or chemical change.	Students will tell how humans are negatively affecting the carbon cycle on earth. They will give one example.
Cartoon about how water changes states.	Students will give one example of how they can thwart the negative affect on the earth.
Describe how a seed grows into a tree. (Pre-assessment and Post-assessment)	Students will tell how humans are positively affected by plants.
Where does everything on earth come from?	Students will tell how plants are carbon reservoirs.
Carbon Cycle with balloons activity (taken from: http://planetguide.net/cool/carboncycle_activity.html)	Students will tell how plants are part of the carbon cycle.

Curriculum Materials Analysis

Depending on the topic of instruction, the school district sometimes provided teachers with kits and curriculum materials to use to plan and teach science. However, there was no available kit for the food chains and energy flow topic. Because Rebecca was adding carbon cycle to the established school district curriculum, there were also no district resources available to Leslie to use to plan her carbon cycle unit. Leslie did find some curriculum materials, however, that she used to help her plan her unit.

At the summer science workshop that she attended the previous summer, Rebecca received the book *Dr. Art's Guide to Planet Earth* by Art Sussman (2000). This book included an overview of the carbon cycle and had an associated website (http://www.planetguide.net/) with activities. Rebecca provided this resource to Leslie. In addition, I suggested to Leslie that she look at *Food for Plants* (Roth, 1997) to help her with photosynthesis. I made this suggestion because the central question used in *Food for Plants*, (How does a seed grow into a tree?) was similar to the question that Leslie had told me she wanted her students to be able to answer. At the time, *Food for Plants* was available on-line, which is how Leslie accessed it[1].

Leslie analyzed both *Dr. Art's Guide to Planet Earth* and *Food for Plants* for her curriculum materials analysis. Overall, Leslie thought that *Dr. Art's Guide to Planet Earth* provided her with helpful background information but did not include many activities to help teach about the carbon cycle. She identified one activity from *Dr. Art's* website about carbon reservoirs that she thought she could use. She thought the lack of activities in the book meant that the material, which was mostly text, would not support students in learning about the carbon cycle.

> There would be no activities at the beginning of the unit to help support students in generating ideas about growth and carbon. Instead, they

[1] *Food for Plants* is no longer available on-line.

would be pushed into learning about carbon but would not have had to question and use their prior knowledge to build on. They would not make connections with the material they were learning and it would not be meaningful. (Leslie Curriculum Materials Analysis, 2/10/2007)

Leslie's comments suggest that she was considering the book as a text that her students would read in class.

Leslie thought *Food for Plants* provided many useful activities. She liked that it provided a central question that matched the question that she was planning to use. However, she thought that it focused too much on photosynthesis and would not be helpful for teaching about the rest of the carbon cycle.

The focus of the website is food for plants. Although this is the focus, it does not mention the carbon cycle in any of the lessons. The students would not be introduced to this cycle, but would only know one aspect of the carbon cycle, that plants take carbon dioxide in and use it as food. They would not get the understanding that carbon is cycled and reused. (Leslie Curriculum Materials Analysis, 2/10/2007)

From the analysis of her materials, Leslie identified some modifications that she wanted to make in her planned instructional approach. Leslie did not think that either curriculum material provided representations that would help her students understand carbon cycling. In her proposed modifications, she stated several times that she planned to include many different activities to help her students understand how carbon cycles. For example, when asked what modifications she would make to address the identified weakness in the representations of scientific ideas, Leslie said,

I am not sure if the students will be able to understand the concept [carbon cycling] because it is rather abstract. I am going to try to incorporate a movie, activities, charts, pictures, etc. that will help the

> students be able to "see" the cycle with out actually seeing it. I am hoping with these supplemental materials, the students will have a better understanding. (Leslie Curriculum Materials Analysis, 2/10/2007)

Leslie's focus on incorporating many different types of activities in her instructional approach also plays a role in the meaning that she makes of EPE and I-AIM, which I will discuss later in this chapter.

When using the CA&P to analyze the materials for how well they matched students' intellectual and sociocultural resources, Leslie focused her analysis on the ideas she thought her students would bring to understanding the carbon cycle and how interested they would be in learning about the carbon cycle. Through her pre-assessment activities she had identified that because her students had just finished studying about the life cycle of plants, her students would give a life cycle answer to the question "How does a seed become a tree?" Leslie recognized that the activities in the *Food for Plants* materials would elicit this response from her students. Leslie also considered whether students would be interested in learning about the carbon cycle.

> Students must understand growth and how carbon is involved to understand the carbon cycle. This problem is relevant to my students. They see growth each day in plants, animals, themselves, their families. They may wonder how food helps them to grow. (Leslie Curriculum Materials Analysis, 2/10/2007)

Leslie recognized that the curriculum materials she had available provided her with some resources she could use. She also recognized that they left big holes. As she said about *Food for Plants*,

> So, I knew it could help me, but I didn't know how. I knew it was strong and had a lot of good things, but I knew I probably would have to make it

fit my unit and plan my unit around what I had too. (Leslie Interview, 4/13/2007)

Content Knowledge

Leslie's early planning provided the first indications that her level of understanding of the processes involved in the carbon cycle was also a challenge in her planning and teaching. One of the first red flags was the statement in her revised practices, "Students will explain what 'food' is not for plants. Students will compare what plants use to grow (water, nutrients) with what causes the actual growth (carbon)." In her curriculum materials analysis of *Food for Plants*, Leslie stated, "plants take carbon dioxide in and use it as food." (Leslie Curriculum Materials Analysis, 2/10/2007) These statements suggests that Leslie did not fully understand the transformations of carbon that takes place during photosynthesis or the difference between food for mass and food for energy.

Another indication that Leslie might have not held sufficient understanding of the processes involved in the carbon cycle came from her goal-naïve conceptions chart. One of the assignments interns were asked to complete for the science methods course was a pre-assessment of student ideas. Interns were asked to design and administer two tasks to elicit student ideas related to the learning goals. From student responses to the tasks, interns were asked to identify the naïve conceptions that students in the class may have had related to the learning goals. Interns were instructed to pair student naïve conceptions with the goal conceptions they would like students to develop. Leslie identified four common student naïve conceptions. For two of the naïve conceptions, Leslie referenced a research paper suggested by Dr. Adams, "Alternative Student Conceptions of Matter Cycling in Ecosystems" (E. L. Smith & Anderson, 1986) as the source for her statements. The statements from the paper were in quotation marks and properly cited. For three of the four naïve-goal conception pairs, Leslie placed a statement describing a student naïve conception in the goal conception column. For one of the goal-naïve conception pairs, both the identified goal and naïve conceptions were naïve conceptions from the research paper. There were also three statements that Leslie made that suggest that Leslie did not understand the processes of photosynthesis or decay. Table 5.3 lists the problematic statements and the incomplete understandings that they suggest Leslie held about the processes involved in the carbon cycle. These statements and the other problems mentioned suggest that Leslie did not have sufficient understanding of the carbon cycle to distinguish between correct and incorrect statements or understand what was incorrect about naïve statements.

Table 5.3

Problems with Leslie's goal-naïve conceptions chart

Problematic statement from Leslie's goal-naïve conception chart	**Leslie's incorrect conception**	**Correct conception**
The seed grows when exposed to water. It uses the stored food to grow. When it grows leaves, it begins to use photosynthesis to make its own food. The leaves take in the UV rays and carbon dioxide from the atmosphere. A chemical reaction occurs, energy is released, and the carbon packs tightly together. This is what causes the growth in the plant.	During photosynthesis, energy is released in a chemical reaction	Energy is stored during photosynthesis
Students should see food as a form of energy that is "converted into carbon dioxide and water." The carbon dioxide is what helps the animal to grow and build upon itself and the water is either expelled or taken into the cells of the body.	Energy is converted to mass (carbon dioxide and water). Carbon dioxide helps animals to grow & build upon itself	Carbon dioxide is released when food is used for energy and does not help the animal grow.
Students should see that when an animal or plant dies, its matter and carbon is cycled back into the earth, either through consumption or decaying	When a plant or animal dies, matter is recycled back into the earth by consumption	Consumption does not recycle matter unless the animal consuming it uses it as an energy source and carbon dioxide and water are released or the animal dies and decays

Leslie recognized the big idea that carbon cycles through natural systems. However, she was not clear on the details of the processes. This confusion made it difficult for her to recognize the difference between naïve and correct conceptions and to accurately present the science concepts to her students. Leslie was also concerned about this situation.

> I just have this nightmare of going in there and trying to teach science and having them walk out with no understanding whatsoever and being more confused than when they started. Because we are planning this whole unit, this is her [Rebecca's] first time teaching it too. I just feel like it could go bad. (Leslie Interview 4/25/2007)

A significant challenge that Leslie faced was her own understanding of the content she was assigned to teach.

Summary of the Challenges

Leslie had a broad, advanced topic to narrow down into a three-week unit for fifth-grade students. Her mentor teacher had not taught this topic in the past, so there were no established examples for Leslie to use in developing her unit. The state curriculum framework offered some benchmarks related to photosynthesis, but did not include other benchmarks related to other processes involved in the carbon cycle. Leslie's level of understanding of the processes involved in carbon cycling made it more difficult for her to identify and narrow down a central question, benchmarks, and practices to use for her unit. Leslie looked to her curriculum materials to help her figure out what to do. She found the *Planet Guide* book helpful in providing her with background information and she found *Food for Plants* helpful in suggesting activities that she could use to teach about plant growth. She thought that her students would find the *Food for Plants* activities interesting and the materials would elicit and build on her students' ideas about plant growth. However, she was also worried that the materials did not provide enough activities or suggestions for teaching about decay and the rest of the carbon cycle. In the end, Leslie felt left on her own to figure out how to teach the whole carbon cycle to fifth-grade students with limited support from her curriculum materials, limited available guidance from her mentor teacher, and little confidence in her own understanding of carbon cycling.

Leslie's Planned Instructional Approach and Teaching Enactment

Leslie confronted these challenges head-on. She used the resources she had to plan and enact the unit she was asked to teach as best she could. In this section, I will first present the content story that Leslie used to plan and teach her lessons. I will then show how Leslie translated that story into her unit by presenting her planned instructional approach and her enacted activity sequence. Finally, I will analyze both sequences together for how closely they match the intentions of the I-AIM and CA&P tools. This section will show that Leslie had a strong teaching pattern that matched many of the functions of the I-AIM. However, there were also key activity functions that Leslie did not include.

Leslie's Content Story

By the time Leslie began planning her instructional approach, she had constructed the content story about carbon cycling that she wanted her students to understand. Leslie's story of the carbon cycle traced carbon from the air to plants to animals and back to the air. In this cycle, carbon is moved from one place to another. Carbon starts in the carbon dioxide in the air, then becomes part of the plants, part of animals, and finally returns to the air. In her unit, Leslie focused primarily on how carbon becomes part of plants through the process of photosynthesis. This story involved several pieces that Leslie wanted her students to understand. Her focus in her planning and teaching was helping students put the pieces of the photosynthesis story together.

One piece of Leslie's photosynthesis story was that photosynthesis is the process plants use to make their food. Leslie explained this process to the students, using a student to role play a plant performing photosynthesis. "So she [the student role playing a plant] has this carbon dioxide and she has water, she is mixing it up because the sun's energy is helping her change the carbon dioxide and water into food. But remember, food gives us energy" (Leslie Teaching Transcript, 3/22/2770). In Leslie's story, water, carbon dioxide, and sunlight are the ingredients necessary to make food, like flour and eggs are the ingredients necessary to make a cake. She did not distinguish between matter (water, carbon dioxide) and energy (sunlight). Leslie used an energy definition of food. Later, she identified sugar as the food that plants make.

Another piece of Leslie's story was that plants (and people and other animals) are made of carbon. Leslie explained this part of the story to the students, referring to a drawing she had made on the board showing the formula for glucose, written as C + H + O and a leaf filled with the many letter 'C's.

> 'C' by itself means carbon. So the sugar helps the plant pack in these tiny carbons and that is what helps the plant grow. So this formula here 'C' plus 'H' plus 'O', it takes these 'C's and it packs it into itself. Just keeps packing. And it is just the same in you. You take the sugar, the calories that you get, and it takes that carbon from it and it packs inside your legs, and your head, and your stomach everywhere and it helps you grow. So it is kind of interesting to think that your whole body is made up of carbon. Packed with little tiny carbons.
>
> (Leslie Teaching Video Transcript, 3/22/2007)

Here, the carbon is the stuff that makes plants and bodies grow bigger. The carbon that makes up the stuff of the plant comes from the sugar. She implies in this story that because the carbon in the sugar comes from carbon dioxide in the air, the stuff of the plant ultimately comes from the air.

The third piece of Leslie's photosynthesis story was that water and soil are not forms of energy, therefore they are not food. Because they are not food, they do not provide carbon and therefore they do not provide the stuff of the plant. Leslie explained in an interview,

> They needed to know that nothing in soil gives the plant energy. So even the nutrients do not give the plant energy. And nothing in water will give a plant energy…Carbon comes from sugar, I guess, and the carbon dioxide that the plants take in. So, it relates to the carbon cycle too in that we don't get carbon from the soil, we don't get it from water. So I wanted them to be able to, when we put the carbon cycle together, to know that it [the carbon] wasn't coming from the soil, it was coming actually from the food that the plants were making. (Leslie Interview, 4/25/2007)

The important point here for Leslie was that the stuff of the plant does not come from the soil or the water. She noted that the carbon in the sugar, the "food that the plants were making" comes from the "carbon dioxide that the plants take in."

Leslie's story had many features common to a school science narrative of photosynthesis (Mohan et al., 2008). While she was able to explain the pathway that carbon takes as it travels from the air to the sugar to the plant, her story did not include an atomic-molecular-scale model to account for the transformation of materials. She used a macroscopic-level story to describe how the carbon went from the carbon dioxide to the sugar to become the stuff of the plant. She recognized that these materials were all different types of substances. However, there is no evidence that she understood how the atoms were re-arranged during chemical reactions. She could label elements (i.e. carbon, hydrogen, oxygen) and give the chemical formula for substances (i.e. carbon dioxide and glucose), but she did not identify any other substances that make up plants (i.e. carbohydrates, proteins, etc.). Furthermore, she did not attribute mass to any of these materials or to any of the elements other than carbon. While she was able to trace the carbon through photosynthesis, she lost track of the oxygen and hydrogen. They come into the plant through the air and water, but then Leslie left them out of the story once they are used to make the sugar. Finally, Leslie did not include any description of the microscopic parts of plants, such as cells, or their functions.

A significant problem with Leslie's photosynthesis story was that she conflated mass and energy. At one point she said to the students, "What is sugar made of? We know carbon. We have H and we have O - hydrogen and oxygen. So carbon is a part of sugar. So carbon does give energy like sugar" (Leslie Teaching Video Transcript, 3/28/2007). Conflating matter and energy is also a common feature of a school science narrative, as opposed to a model-based understanding of the carbon cycle (Mohan et al., 2008). In Leslie's story, sugar provided energy, sugar was made of carbon, and therefore, carbon provided energy. Water and soil did not provide energy; therefore they did not provide carbon to help the plant grow. In this circuitous logic, mass and energy were the same. Leslie did not recognize that the energy was stored in the molecular bonds and was not in the carbon itself.

Despite these problems, Leslie's story did have some strengths. She was able to trace carbon, show where carbon comes from, and show that carbon is (some of) the stuff that makes plants grow bigger. These were the pieces that Leslie wanted her students to put together. In the next two sections (Planned Instructional Approach and Enacted Carbon Cycle Sequence), I will show how Leslie used this story to plan and enact a unit to help her students put these pieces of the story together.

Planned Instructional Approach

Table 5.4 shows Leslie's planned instructional approach. Leslie labeled and described each activity and gave a rationale for each activity in the sequence. For 4 of the 12 activities she made specific reference to I-AIM functions in her rationale. For the rest of the activities she explained how the activity fit into her sequence, but she did not make specific reference to I-AIM functions. Based on Leslie's written rationale for each activity, I assigned each activity to an I-AIM function. Table 5.4 shows the I-AIM stage and activity function color codes that I assigned.

Leslie planned to begin the unit with Activity 1 Plant 1 vs. Plant 2 by setting up an experiment that she hoped to run through the entire unit. In this experiment, she planned to compare the condition of two plants: a plant placed in a sealed jar and a similar plant left open in the room. Leslie wanted students to make observations of the plants throughout the unit and see that the plant in the jar slowly died. At the end of the unit, she wanted the students to be able to explain that the plant in the jar ran out of carbon dioxide and thus was unable to continue living (Activity 11 Examine the Plant Experiment). Leslie intended for this activity to help students see that plants need air, and more specifically the carbon dioxide in the air, in order to survive.

Table 5.4

Leslie's planned instructional approach

Activity number	Activity label	I-AIM stage (color code)	Activity function (color code)
1	Plant 1 vs. Plant 2	Explore & Investigate (green)	Explore phenomena (sea green)
2	Seed & Log	Engage (yellow)	Establish a question (light yellow)
			Elicit student ideas (dark yellow)
3	What is Food for Plants?	Engage (yellow)	Establish a question (light yellow)
			Elicit student ideas (dark yellow)
		Explain (blue)	Introduce scientific ideas (light blue)
			Compare to & revise student ideas (sky blue)
4	Photosynthesis	Explain (blue)	Introduce scientific ideas (light blue)
5	Forming the Rule	Explain (blue)	Develop student explanations (dark blue)
6	Explaining the Rule	Explain (blue)	Compare to & revise student ideas (sky blue)
7	Carbon Cycle	Explain (blue)	Introduce scientific ideas (light blue)
8	United Streaming Video	Explain (blue)	Introduce scientific ideas (light blue)
9	Cow Activity	Explain (blue)	Introduce scientific ideas (light blue)
10	Draw Carbon Cycle	Explain (blue)	Compare to & revise student ideas (sky blue)
11	Examine the Plant Experiment	Apply (purple)	Practice with support (model & coach) (violet)
12	How are Humans Affecting the Carbon Cycle	Apply (purple)	Practice with support (model & coach) (violet)

Leslie next planned to use an activity from *Food for Plants* that had students investigate a seed and a branch of a tree to develop hypotheses for how the seed could grow into a tree (Activity 2 Seed & Log). She expected students to have many hypotheses, including that the tree takes its mass from the soil to grow bigger. She hoped to disprove this hypothesis later in the unit.

> This experiment is preparing students to think of hypotheses for how the tree got as big as it did, even though it started as a small seed. Students

will begin to think of various hypotheses and will process their prior knowledge to do this. This activity will prepare students to think about this event and learn about it in upcoming lessons and activities. (Leslie Instructional Approach, 2/10/2007)

To help students understand that plants make their food, Leslie planned to have students brainstorm where plants get their food, and then read selected text from *Food for Plants* that would explain that plants make their own food using the sun's energy. (Activity 3 What is Food for Plants?) "This activity will allow students to connect the prior day's experiment [Activity 2 Seed & Log] and hypotheses to decide what food for a plant is." (Leslie Instructional Approach, 2/10/2007)

Leslie planned to use another *Food for Plants* activity to model the process of photosynthesis (Activity 4 Photosynthesis). "This activity has the teacher mix water and a breath [representing carbon dioxide]. The teacher then throws out a sugar cube to represent the chemical change that occurs during photosynthesis" (Leslie Instructional Approach, 2/10/2007). This activity fit Leslie's photosynthesis story by presenting the ingredients that help plants make sugar. In Activity 5 (Forming a Rule) and Activity 6 (Explaining the Rule), Leslie planned to have students use what they had learned about photosynthesis to generate their own explanations for how plants grow. With these activities, Leslie wanted to connect the idea that plants use carbon dioxide to make sugar, with the idea that plants use the carbon in the sugar to grow bigger.

At this point, Leslie planned to introduce the idea of carbon cycling (Activity 7 Carbon Cycle). In her description of the planned activity she stated, "Tell about how carbon cycles through the atmosphere and how plants use carbon to grow. When plants die, the carbon is recycled back into the atmosphere" (Leslie Instructional Approach, 2/10/2007). Leslie planned to follow the explanation with a video that would provide more "examples of how and why carbon cycles" (Activity 8 United Streaming Video) (Leslie Instructional Approach, 2/10/2007).

Next, Leslie planned to use the one activity from *Dr. Art's Guide to Planet Earth* that she thought would be useful. This activity used balloons to demonstrate the relative quantity of carbon in various carbon reservoirs. Leslie labeled this activity the "Cow Activity," even though there were no references to cows in the activity. She may have confused this activity with another activity that Rebecca had suggested that also used balloons but modeled the path of carbon from the air to grass to a cow. Leslie planned for students to be able to draw on their new knowledge of carbon reservoirs and their understanding of where the mass of a tree comes from to draw the complete carbon cycle in Activity 10 (Draw Carbon Cycle).

At the end of the planned instructional approach, Leslie wanted students to revisit the plant experiment and explain why the plant in the jar was dying (Activity 11). In her last activity, she planned to have students discuss how humans affect the carbon cycle (Activity 12).

> I will give a narrative on how humans are affecting the carbon cycle. I will ask students to volunteer if they can think of ways that people are interfering with the cycle and if they can think of any ways that we can stop or reverse the damage to the carbon cycle. (Leslie Instructional Approach, 2/10/2007)

Leslie purposefully considered the sequence of the activities in her planned instructional approach. Her sequencing focused on putting together the pieces of the story she wanted students to learn. Overall, Leslie planned for her instructional approach to provide students with an understanding of how carbon cycles through ecosystems. She focused mostly on photosynthesis. Leslie planned for students to see that plants take in carbon dioxide from the air, not the soil or water, to make sugar and then use the carbon in the sugar to grow bigger. Leslie then wanted students to see where else, besides plants, that carbon resides. She did not include any activities to explore or explain consumption or decomposition. As mentioned previously, the absence of the consumption and decay activities could partly be because there were no middle school benchmarks in the state science curriculum framework related to decay. It could also be partly because there were no activities in either of her curriculum materials to support her in including consumption and decay in her planned instructional approach. Her own level understanding of the specific processes of both photosynthesis and decay may have also contributed to this absence. However, the fact that she did plan to include an introduction to the complete carbon cycle and planned to use several different representations of it (video, drawing) suggests that she did want to provide an overview of the complete picture and was not purposely choosing to leave out consumption and decomposition. Most likely, she was just not sure how to include these processes given the time that she had and the limited resources and support that were available.

Leslie also had a purposeful approach to how she wanted the activities to function to support student learning. She described her approach in her summary of her plans.

> The unit provides students with many activities to work through and explore, therefore practicing scientific methods and creating hypotheses and questions about the unit topic. They are asked to explain their thoughts and hypotheses in their work and will have to participate in a class discussion that is looking for theories of plant growth backed by facts we know about growth. This will lead into the carbon cycle and how it cycles through the atmosphere and is the basis for growth. Students are asked to apply their knowledge to other situations on earth, such as animal growth and the carbon balance of the atmosphere which is

currently unbalanced because of human activities. (Leslie Instructional Approach, 2/10/2007)

Leslie began the unit with a question (light yellow), then planned for students to develop their own hypotheses and ideas to explain phenomena (dark yellow). She planned to introduce scientific ideas (light blue) that would help students revise their hypotheses (sky blue). Then, she wanted students to apply (purple) what they had learned about photosynthesis to the idea of carbon cycling and relate that to the impact of human activities. This pattern is present in Leslie's enacted activity sequence as well.

Enacting the Carbon Cycle Sequence

Leslie enacted her unit over the course of six weeks beginning in mid-March, 2007. Leslie taught two classes each day. She usually taught science in the afternoons several days a week, although not always on the same day each week. Science usually lasted one hour. I observed six of her enactments. I dissected Leslie's enactments into an activity sequence, assigned functions to the activities based on my observations, and color coded the functions in the enactment sequence. I also filled in the activities for the days that I was not able to observe based on interviews with Leslie. Table 5.5 shows Leslie's enacted sequence. In this table, groups of activities with a similar theme are identified. These activity groups were identified during the analysis and become important below in the discussion of Leslie's main teaching pattern.

Leslie's enacted sequence appears much longer than her planned instructional approach. This apparent length is partly because I designated activities at a finer grain-size than did Leslie. Many of the activities that she identified as one activity in her planned instructional approach I dissected in to two or three smaller activities. However, Leslie's enactment was also longer than she planned because she added new activities during her enactment. For example, Leslie added the activities in the Food Stations activity group when she realized that students were not convinced that plants do not get food from water. She also added activities into the Photosynthesis activity group, including a group task to make and present posters explaining the process of photosynthesis. Leslie substituted the Tree activity (Activity 25) in place of the United Streaming video after she decided that the video she had planned to show presented photosynthesis in more detail than she thought necessary for her students. The Cow Activity became the Balloon Activity (Activity 26).

Table 5.5

Leslie's enactment sequence

Activity Group	Activity number	Activity label	I-AIM stage (color code)	Activity function (color code)
Plant Experiment	1	Plant 1 vs. Plant 2	Explore & Investigate (green)	Explore phenomena (sea green)
Seed & Log	2	Seed & Log Intro	Engage (yellow)	Establish a question (light yellow)
	3	Seed & Log - small group discussions	Engage (yellow)	Elicit student ideas (dark yellow)
What is Food?	4	What is Food? - Popcorn reading	Engage (yellow)	Establish a question (light yellow)
	5	What is Food? - Writing and small group discussions	Engage (yellow)	Elicit student ideas (dark yellow)
	6	What is Food? - Whole class sharing	Engage (yellow)	Elicit student ideas (dark yellow)
	7	What is Food? - Popcorn reading II	Explain (blue)	Introduce scientific ideas (light blue)
	8	What is Food? - Whole class sharing II	Explain (blue)	Compare to & revise student ideas (sky blue)
	9	What is Food? - Acting out living on water only	Explain (blue)	Compare to & revise student ideas (sky blue)
	10	What is Food ? - Group Discussion	Explain (blue)	Compare to & revise student ideas (sky blue)

Table 5.5 Continued

Activity Group	Activity number	Activity label	I-AIM stage (color code)	Activity function (color code)
Food Stations	11	Intro to Food Stations	Engage (yellow)	Establish a question (light yellow)
	12	Food Stations	Engage (yellow)	Elicit student ideas (dark yellow)
	13	Food Stations Evidence Tally	Engage (yellow)	Elicit student ideas (dark yellow)
Plant Experiment Continued	14	Plant Comparison - Student Observations	Explore & Investigate (green)	Explore phenomena (sea green)
	15	Plant Comparison - Whole class discussion	Explore & Investigate (green)	Explore student ideas (light green)
Food Stations Continued	16	Definition of Food	Explain (blue)	Introduce scientific ideas (light blue)
	17	Revisit Food List	Explain (blue)	Compare to & revise student ideas (sky blue)
Seed & Log Continued	18	T-Chart	Explain (blue)	Introduce scientific ideas (light blue)
	19	Revisit Hypotheses	Explain (blue)	Compare to & revise student ideas (sky blue
Photosynthesis	20	Acting out Photosynthesis	Explain (blue)	Introduce scientific ideas (light blue)
	21	Review Function of Substances	Explain (blue)	Introduce scientific ideas (light blue)
	22	Drawing Photosynthesis	Explain (blue)	Introduce scientific ideas (light blue)
	23	Photosynthesis Posters	Explain (blue)	Compare to & revise student ideas (sky blue
	24	Poster Presentations	Explain (blue)	Compare to & revise student ideas (sky blue
	25	Visit Tree Outside	Apply (purple)	Practice with support (violet)
Carbon Cycle	26	Carbon Cycle Balloon Activity	Explain (blue)	Introduce scientific ideas (light blue)
Plant Experiment Continued	27	Examine the Plant Experiment	Apply (purple)	Practice with support (violet)

Leslie's Teaching Pattern

Analysis of Leslie's enacted activity sequence shows that Leslie had a strong teaching pattern that she repeated several times. In this teaching pattern, Leslie established a question (light yellow), elicited student ideas about the question (dark yellow), then introduced the scientific ideas (light blue), and had students compare their ideas to the scientific ideas in order to revised their initial ideas (sky blue). This teaching pattern matched the overall purposeful sequencing that Leslie used to plan her instructional approach. I will provide three examples of this pattern in Leslie's work.

What is Food? Activity Group. I will start with the What is Food? activity group because it was in both the planned instructional approach and the enacted activity sequence. It is also the example in which the pattern is easiest to see. Table 5.6 shows the sequence of activities for this activity group and the I-AIM stages and functions.

Table 5.6
Leslie's teaching pattern in the "What is Food?" activity group

Activity group	Activity number	Activity label	I-AIM stage (color code)	Activity function (color code)
What is Food?	4	What is Food? - Popcorn reading	Engage (yellow)	Establish a question (light yellow)
	5	What is Food? - Writing and small group discussions	Engage (yellow)	Elicit student ideas (dark yellow)
	6	What is Food? - Whole class sharing	Engage (yellow)	Elicit student ideas (dark yellow)
	7	What is Food? - Popcorn reading II	Explain (blue)	Introduce scientific ideas (light blue)
	8	What is Food? – Small group discussions II	Explain (blue)	Compare to & revise student ideas (sky blue
	9	What is Food? - Acting out living on water only	Explain (blue)	Compare to & revise student ideas (sky blue
	10	What is Food ? - Group Discussion	Explain (blue)	Compare to & revise student ideas (sky blue

In the overall sequence, this activity group followed the Seed & Log activity group. I will describe the Seed & Log activities in the third example. However, in order to understand the role of the "What is Food?" activity group, it is necessary to know how that in the Seed & Log activity group, Leslie established the question, "How does a seed become a tree?" and then elicited student ideas about the answer to this question. Student ideas varied, and included that the tree grows from the soil and from water.

Leslie began the "What is Food?" activity group by having students read out loud a short paragraph from a text selection from *Food for Plants* that asked if juice, water, and sugar are food (Activity 4 Popcorn Reading). Leslie showed a bottle of juice, a bottle of water, and a bag of sugar to the students, had them write in their science notebooks their ideas about whether each item was food, and had them share their ideas with a partner (Activity 5 Writing and Small Group Discussions). Leslie conducted a whole group discussion where students shared their ideas about whether each item was food (Activity 6 Whole Class Sharing). This transcript focuses on their discussion of water.

1 Leslie: Let's talk about water. Nick.

2 Nick: I don't think water is food.

3 Leslie: Ok, why?

4 Nick: Because it doesn't come from any foods.

5 Leslie: Because why? It doesn't come from any food?

6 Nick: Because if you squeeze an apple you get apple juice.

7 Matt: I think he is saying you can't squeeze any food to get water.

8 Leslie: Right. (getting the class attention) Give me 5. Thank you.

9 Nathan: I think water is not a food.

10 Leslie: Ok, let's listen to Nathan.

11 Nathan: Water is not a food because it is a natural resource

12 Leslie: Ok

13 Joel: I disagree with you.

14 Leslie: Those of you who are disagreeing, raise your hands. Lisa.

15 Lisa: I disagree because when I am hungry, and I drink water I am full when I am done.

16 Leslie: So when you drink it you are full?

17 Lisa: Yeah.

18 Sarah: I agree.

(Leslie Teaching Video Transcript, 3/13/2007)

At this point, students have many ideas about whether or not water could be food.

Leslie had students read out loud the next two paragraphs in the *Food for Plants* text that she had provided (Activity 7 Popcorn Reading II). These paragraphs explained that food provides energy. She had students discuss this reading in small groups (Activity 8 Small Group Discussion II). In a large group discussion, Leslie returned to the notion of water as food and had students think about whether water met the definition of food. Leslie had two students, Nick and Robin, stand in front of the whole class and show what would happen to a person if all they had to consume was water (Activity 9 Acting Out Living on Water Only). Both students fell to the ground. Leslie wrapped up the lesson by again asking the students if water could be food (Activity 10 Group Discussion).

1 Leslie: Our definition of food is that it gives us energy. Does water give us energy?

2 Students: No

3 Students: Yes

4 Leslie: Raise your hands to tell me why or why not. Robin.

5 Robin: Yes

6 Leslie: How does it give you energy?

7 Robin: Because it has nutrients inside of it.

8 Leslie: Nutrients. Matt?

9 Matt: Yes, I know it gives you energy because like I said, if you didn't have energy, you wouldn't be able to live for a month. And you can live for a month without water.

10 Student: I could live for 30 years without school.

11 Leslie: So we're thinking yes. Is that our answer? Does anyone think no? Why do you think no? I think it is no. Here's why I think it is no. Could we live on water alone? Nick and Robin came up here and they fell to the ground dead.

12 Student: They didn't die. They just fell to the ground.

13 Leslie: So, I am thinking that water, I think it is something that you need to keep you hydrated, to keep water in your cells. But when I drink water, you might feel full, Lisa, like you said, but I think it is just because there is a lot of water in your stomach. Do you think if you drank too much water you would gain any weight?

14 Student: No, because when you go to the restroom (uninterpretable).

15 Student: Sometimes people die when they get over hydrated.

16 Leslie: They get too much water. Water doesn't give us energy. Believe it or not, it won't give us energy.

(Leslie Teaching Video Transcript, 3/13/2007)

Leslie had planned that by this point in the sequence, students would understand that water is not food. She had introduced the question (light yellow), elicited student ideas (dark yellow), and presented them with scientific information that challenged their ideas (light blue). Then, she asked them to compare their ideas to the scientific idea in hopes that they would revise their ideas (sky blue). However, as the above transcripts illustrates, the students still struggled with the notion that water could not provide energy. They were not yet convinced that water was not food.

Food Stations Activity Group. The Food Stations activity group followed the "What is Food?" activity group. Leslie decided that because her students were not convinced that water was not food, she needed to continue to address the food-as-energy issue. She added several activities that were not a part of her original planned instructional approach (Activity 11 Intro to Food Stations through Activity 17 Revisit Food List but excluding Activities 14 & 15 Plant Comparison). Table 5.7 shows this activity group.

Table 5.7

Leslie's teaching pattern in the Food Stations activity group

Activity group	Activity number	Activity label	I-AIM stage (color code)	Activity function (color code)
Food Stations	11	Intro to Food Stations	Engage (yellow)	Establish a question (light yellow)
	12	Food Stations	Engage (yellow)	Elicit student ideas (dark yellow)
	13	Food Stations Evidence Tally	Engage (yellow)	Elicit student ideas (dark yellow)
	16	Definition of Food	Explain (blue)	Introduce scientific ideas (light blue)
	17	Revisit Food List	Explain (blue)	Compare to & revise student ideas (sky blue

Leslie introduced this activity group in Activity 11 (Intro to Food Stations) with the question, "Is it food or isn't it?" She had students consider how they might tell if an item was food. Then, Leslie had students read the labels of many common grocery products, including juice, water, spices, noodles, crackers, vitamins, and vegetable oil and look for evidence for whether or not each product was food (Activity 12 Food Stations). Students made notes and wrote down their ideas. Because students were making and recording observations from the food labels, I considered coding Activity 12 as an Explore & Investigate activity (green). However, because the students did not know on what basis to decide if an item provided energy, students were just recording their hypotheses about whether or not items were food and thus were not exploring a phenomenon. Students were only recording their hypotheses about whether or not the item was a food and why, and were not recording any other data from the labels.

In Activity 13 Food Stations Evidence Tally, Leslie had the students share their ideas about which items were food. There was agreement that crackers, noodles, and juice were food, and that water was not food (possibly because Leslie had told the students that water was not food the day before and not because they were convinced that water would not provide energy). There was disagreement on whether vitamins, spices, and vegetable oil were food. Leslie asked the students what criteria they had used to decide if the products were food. One student said that you don't eat oil, while another claimed that the vegetable oil was a food because you use it to make chicken. Several students offered that anything with protein was a food. Another student said that food had vitamins in it and one student said that she counted as food anything that had food starch in the ingredients list. One student offered that food would have sugar in the ingredients list.

The next day, Leslie briefly interrupted the flow of the Food Stations activity group with Activities 14 and 15, which I will describe later when I discuss the Plant Experiment activity group. Leslie then resumed the Food Stations activity group in Activity 17 (Definition of Food). Leslie told the students that food had calories in it and she asked them to re-evaluate the list of foods from Activity 13 (Food Stations Evidence Tally) to decide which things had calories.

> So I wanted to give them these definitions and then I wanted them to go back and see if they were right. And I told, I think I told them that, actually what we were supposed to look for was calories and calories can tell us energy because its fat is a form of calories, sugar is a form of caloriês,

and everything else[2]. So, I wanted them to go back and look at what they had done and see if they were accurate or not in deciding if it was a food. And if it wasn't a food, what is its purpose? (Leslie Interview, 4/25/2007)

Food for Plants included an activity similar to Leslie's Food Station activities, in which students use the calories definition to examine food labels and decide it items are food. However, in contrast to the activity in *Food for Plants*, Leslie provided the calories definition after the students had looked at the food labels. Significantly, Leslie did not provide the food labels again during the discussion; students made their re-evaluations based on what they remembered or what they had written in their notes. Students did not have systematic data to which to refer. Therefore, even after she had provided the calories definition, students had no real way of checking to see which foods had calories and which did not.

Like the previous activity group, this activity group followed Leslie's established teaching pattern. Leslie began this activity group with a question about what items are food (light yellow), and then elicited student ideas about the answer to the question (dark yellow). She then recorded student ideas, offered them a scientific definition of food (light blue), and asked them to revise their ideas based on the new definition (sky blue). The students finally agreed that vegetable oil was a food and that spices and vitamins were not food.

Seed & Log/Photosynthesis Activity Group. The What is Food? and Food Stations activity groups illustrate Leslie's teaching pattern within an activity group. The Seed & Log and the Photosynthesis activity groups show that this teaching pattern is also evident across the overall enacted sequence. The pattern is presented in Table 5.8.

[2] Leslie stated that fat and sugar are calories, conflating matter and energy.

Table 5.8

Leslie's teaching pattern for the Seed& Log/Photosynthesis activity groups

Activity group	Activity number	Activity label	I-AIM stage (color code)	Activity function (color code)
Seed & Log	2	Seed & Log Intro	Engage (yellow)	Establish a question (light yellow)
	3	Seed & Log - small group discussions	Engage (yellow)	Elicit student ideas (dark yellow)
	18	T-Chart	Explain (blue)	Introduce scientific ideas (light blue)
	19	Revisit Hypotheses	Explain (blue)	revise student ideas (sky blue)
Photosynthesis	20	Acting out Photosynthesis	Explain (blue)	Introduce scientific ideas (light blue)
	21	Review Function of Substances	Explain (blue)	Introduce scientific ideas (light blue)
	22	Drawing Photosynthesis	Explain (blue)	Introduce scientific ideas (light blue)
	23	Photosynthesis Posters	Explain (blue)	revise student ideas (sky blue)
	24	Poster Presentations	Explain (blue)	revise student ideas (sky blue)
	25	Visit Tree Outside	Apply (purple)	Practice with support (violet)

This pattern begins with Activity 2 Seed & Log Intro, in which Leslie had students work in groups to consider the question, "How does a seed become a tree?" She gave each group a maple seed and a branch of a tree and had students develop group hypotheses about where they thought the mass of the tree came from. She explained why she chose this activity.

> Well, first I thought, I want to introduce them to, or I want them to see the fact that trees don't have soil in them, they don't take the soil in. And they don't use water as food. They use water, but not as food. And that, I wanted them to see that they pull carbon dioxide in and they use the sun's energy and they use water too. … I thought first we will look at the seed and log and hopefully they will notice there is not soil in the log. And I wanted them to just start thinking about the question, "How does a seed

grow into a tree?" So they started, and they had some hypotheses. And that was a good start. (Leslie Interview, 4/13/2007)

This quote is interesting because Leslie seems to imply that students would not see actual soil or water in the logs and that would convince them that soil or water are not the source of the mass of the tree. She also said that she wanted them to see that the trees pull in carbon dioxide and use the sun's energy, which are both phenomena that are not directly observable from examining a tree branch. Nevertheless, this activity served the important purpose of eliciting student ideas about how a seed grows into a tree.

Leslie then asked each group to choose their best hypothesis to share. Leslie wrote down those hypotheses on chart paper in front of the class (Activity 3 Seed & Log - small group discussions). "I took all of their ideas and I was asking about their ideas in class. And they would say, "Well I think a plant grows because of the soil." So I would write it up as a hypothesis" (Leslie Interview, 4/25/2007).

Leslie followed Activity 3 (Seed & Log) with a group of activities designed to challenge student hypotheses about what could be food for plants (What is Food? activity group). She then added the Food Stations activity group to convince students that food provides energy. Having detoured through these two groups of activities, Leslie returned to the Seed & Log activity group in Activity 19 (Revisit Hypotheses). Having established that food has calories and that since water has no calories it cannot be food, Leslie reposted the hypothesis list generated in Activity 3 (Seed & Log) and led the class through a systematic reconsideration of whether or not each hypothesis was correct. The class eliminated many hypotheses because they included water or nutrients from the soil as the source of mass. Leslie was proud of this moment.

I tried to help them use it to disprove what they had thought. Use all the activities they had done and lessons we had done since the first day when we did all the hypotheses. And I tried to help them go back and use their learning to disprove some of those. We know that soil doesn't make a seed grow. It does use nutrients, but is nutrients energy? Will it give it mass? Well, no, we learned that. So we went through and crossed out a few of them. So that was kind of cool that they could do that. (Leslie Interview, 4/25/2007)

Now, having finally established that plants do not get their food from water or soil, Leslie returned to her original planned instructional approach and conducted a group of activities about photosynthesis that spanned four days (Activity 20 Acting out Photosynthesis through Activity 25 Visit Tree Outside). Leslie provided students with the explanation for photosynthesis that she wanted them to have. She modeled the process using an activity from *Food for Plants* that involved students' role playing a plant getting carbon dioxide from the air and turning the carbon dioxide into sugar (Activity 20 Acting out Photosynthesis). She had students draw the process, identifying the ingredients (carbon dioxide, water, sunlight) and where they came from (Activity 22 Drawing Photosynthesis). In this activity, Leslie explained that sugar is made from carbon, even providing students with the chemical formula for glucose. In the drawing that Leslie drew on the overhead projector and had students replicate in their science notebooks, Leslie illustrated that the water, made of hydrogen and oxygen, came in through the roots and the carbon dioxide came in through the leaves. This discussion was where she introduced the idea that plants and bodies are made of carbon.

1 Leslie: And then, we are left with this question, well, "How does that sugar help it grow?" The plant stores this energy from the sugar and it helps it grow by packing the carbon, the carbon part of the sugar, into its leaves. So pretend this leaf is filled with little 'C's of carbon (draws 'C's on the picture of the leaf on the overhead projector).

2 Student: Little ‘C’s?

3 Leslie: Little ‘C’s. Because what does ‘C’ mean?

4 Student: Carbon

5 Leslie: Carbon. ‘C’ by itself means carbon. So the sugar helps the plant pack in these tiny carbons and that is what helps the plant grow. So this formula here ‘C’ plus ‘H’ plus ’O’, it takes these ‘C’s and it packs it into itself. Just keeps packing. And it is just the same in you. You take the sugar, the calories that you get, and it takes that carbon from it and it packs inside your legs, and your head, and your stomach everywhere and it helps you grow. So it is kind of interesting to think that your whole body is made up of carbon. Packed with little tiny carbons.

(Leslie Teaching Video Transcript, 3/22/2007)

After providing the information that she wanted students to understand about photosynthesis, Leslie created a small group task for her students. She assigned each group of four students to make a poster that answered two questions: 1) How does a plant make food? 2) How does a seed grow into a tree? (Activity 23 Photosynthesis Posters) She had each group present their poster to the rest of the class (Activity 24 Photosynthesis Posters). These activities took two days to complete and were rather chaotic at times as students planned and drew their posters. The following is a transcript of one group presenting their poster to the rest of the class, with Leslie asking them specific questions about their poster.

1 Student Presenters: A seed grows into a tree by nature and carbons. They make their own food by the sun’s energy, carbon dioxide and H_2O. H_2O plus CO_2 equals sugar.

2 Leslie: So tell me again, what makes sugar? What are the three things that make sugar?

3 Student Presenters: water

4 Leslie: Ok water

5 Student Presenters: Sun's energy

6 Leslie: Sun's energy

7 Student Presenters: Carbon dioxide

8 Leslie: Carbon dioxide. So that makes sugar. How does sugar help a plant to grow?

9 Student Presenters: They eat sugar?

10 Leslie: So it has sugar inside of it because it is making sugar.

11 Student Presenters: It makes it grow?

12 Leslie: Do you remember when we were talking about certain parts of sugar packing itself into all of the leaves, all of the branches, everything in the tree. The bark, the roots, everything. What part of sugar packs itself to help a plant grow and to help you grow too. Do you know?

13 Student Presenters: Carbons?

14 Leslie: Carbons. So isn't that true that carbons help a seed grow into a big tree since that is what is being packed into a big tree?

15 Student Presenters: Yeah

16 Leslie: That's good. More applause.

(Leslie Teaching Video Transcript, 3/28/2007)

Leslie coached groups during both the poster construction and presentations, reminding them what they had learned about food and photosynthesis. As the above transcript demonstrates, however, after a while, students started to guess at what Leslie wanted them to say. Leslie continued to try to reinforce her story about how the plants make food and grow.

Leslie ended this activity group with an opportunity for application. In Activity 25 (Visit Tree Outside), Leslie took the students outside to look at a living tree and discuss how it grew from a seed. This activity provided students with an opportunity to practice using their new understandings. Leslie provided coaching support.

> The goals of that were first to get them outside because they were just crazy and it was a really nice day and they really wanted to go outside. And second it was to help, hopefully if they were in partners they could talk back and forth with each other and reason about how a tree grows from a small seed into a huge tree. And also how it makes its own food. And they could use their notebooks again, so I was giving them another chance to hit that chart. (Leslie Interview, 4/25/2007)

The Photosynthesis activity group completed the overall pattern of ask questions (light yellow), elicit ideas (dark yellow), present information (light blue), revise ideas (sky blue) that was begun with the Seed & Log activity group. Leslie provided scientific information to help students revise their original ideas about plant growth that they expressed at the beginning of the unit after looking at the seed and branch. She hoped students would reconsider and revise their initial ideas while they made and presented their posters. They practiced using the scientific ideas when they went outside to look at the tree.

What I have shown here is that Leslie had a story about photosynthesis, made up of several pieces that she wanted her students to understand. She planned and enacted a unit to help her students understand these parts and put them together to explain how plants make food and how plants grow. She then wanted her students to use that information to understand that carbon cycles through ecosystems and that people's actions impact the balance of the carbon cycle. To help her students put the content pieces of the story together, Leslie repeatedly used a teaching pattern that provided a central question, elicited student ideas, provided scientific information, and asked students to revise their ideas based on this information. In the next section I will compare this teaching pattern to the intended functions of the I-AIM and CA&P tools.

Comparison of Leslie's Teaching Pattern to I-AIM

Comparison of Leslie's teaching pattern with I-AIM shows that Leslie's teaching pattern fit many of the functions in the I-AIM but missed others. In this section I will show which functions she used and which she left out.

Engage, Explain, & Apply Functions. First, Leslie's teaching pattern fit both Engage functions. Leslie established a central question for the unit in Activity 2 Seed & Log. She established several other framing questions in Activity 4 What is Food? and Activity 11 Food Stations. In each of these examples, Leslie elicited students' ideas about answers to the questions and recorded students' ideas for later use.

Leslie's teaching pattern also fit two Explain functions. She repeatedly provided students with scientific information and then had students compare their ideas to the scientific information and revise their ideas to the central/framing question. Leslie explained that in her teaching, she tried to elicit student ideas, which she called hypotheses, and then introduce scientific ideas to help students disprove their original ideas.

> I tried to help them use it [list of hypotheses] to disprove what they had thought. Use all the activities they had done and lessons we had done since the first day when we did all the hypotheses. And I tried to help them go back and use their learning to disprove some of those. (Leslie Interview 4/25/2007)

Finally, Leslie's teaching pattern also occasionally included opportunities for application, as seen in the Photosynthesis activity group when she took the students outside to explain how the tree got its food and where the mass of the large tree came from.

Experiences with Phenomena. While Leslie's teaching pattern fit many important functions of the I-AIM, one important feature of the I-AIM was missing. Key to the I-AIM is providing students with experiences with phenomena. In Leslie's enacted sequence (Table 5.5), she provided few activities with phenomena (sea green). The only experiences with phenomena that Leslie provided were experiences in the Plant Experiment activity group.

Leslie introduced the plant experiment at the beginning of the unit by showing the students two similar plants and then sealing one plant in the jar (Activity 1 Plant 1 vs. Plant 2). She placed the two plants near the window to receive sunlight. Leslie stated that she did not tell the students why she placed one plant in the jar.

> I didn't tell them why we were doing it. I said, "We are just going to watch both of the plants to see kind of how they do. They are both the same plant. But one is going to be trapped in this jar and it has enough water." Because I didn't want them to think that it was being starved of water and that was why it would die. (Leslie Interview, 4/25/2007)

Immediately after placing the plants by the window, Leslie moved on to Activity 2 (Seed & Log). Leslie did not make reference again to the plant experiment until Activities 14 and 15 (Plant Comparisons). One day in the middle of the unit, Leslie started the science class by showing the two plants to the students. The leaves of the plant in the jar were beginning to look a little whitish. Students recorded their observations in their science notebooks. Leslie asked for students to share their observations with the whole class. She then put the plants away and began Activity 16 (Definition of Food), described earlier. There was no connection made between the plant experiment (Activities 14 & 15) and the definition of food (Activity 16). Again, Leslie did not tell students why they were looking at the two plants or what she hoped they would notice about the plants.

At the end of the sequence, Leslie returned to the plant experiment in Activity 27 (Examine the Plant Experiment). In this activity students were asked to apply what they had learned in the previous activities to explain why the plant in the jar was dying. In this position in the sequence, Activity 27 functioned as an application activity. Leslie explained "And they were able to at the end say, "Well it was because of the carbon dioxide because a plant needs carbon dioxide to grow. So it was kind of cool" (Leslie Interview, 4/25/2007).

The plant experiment activities did provide students with opportunities to make observations and explore a phenomenon, but the experiment stood alone and was not integrated with the other activities in the enactment sequence until the end of the unit. Thus, Leslie's overall enactment sequence did not fit the important I-AIM intention of providing experiences before explanations. In fact, she provided few experiences at all and instead relied heavily on providing students with scientific explanations.

Making Patterns Explicit. In her unit, Leslie was trying to help her students understand that plants get much of their mass from the air and that they do not take significant matter from the soil. However, she provided students with few experiences with phenomena to help them understand these patterns. The *Food for Plants* curriculum materials included experiences with phenomena that would have been helpful but which Leslie did not use. For example, *Food for Plants* included an activity that summarized Van Helmont's 1600's experiment in which Van Helmont planted a tree in a known mass of soil, grew the tree for 10 years, and then reweighed the soil. He determined that the weight of the soil was unchanged and therefore that soil could not be the source of mass for the tree. The *Food for Plants* version of this experiment presented students with data and asked students to use the data to deduce whether soil is the source of mass for a tree. Dr. Adams suggested that she use this activity, but Leslie did not. Leslie relied on the authority of scientific definitions to teach about patterns and thus to the students, the patterns became new information to memorize rather than patterns from experiences that the scientific information later helped explain.

As described above, the plant experiment did provide one direct experience with a phenomenon. Leslie set up this experience at the beginning of the unit (Activity 1 Plant 1 vs. Plant 2) and then returned to it later in the sequence. In activities 15 & 16 (Plant Comparisons), Leslie began class one day by having students look closely at the two plants and record their observations. Leslie did not tell the students what to look for or why they were doing the plant experiment. However, she did have the students share what they were observing.

1 Leslie: What were you starting to notice about either of the plants? What were some of the things that you noticed? What was one of your observations, Anna?

2 Anna: One of the plants, the plant in the jar, had a flower on it.

3 Leslie: So one of the plants, the plant in the jar, had a flower on it. And it was dead, or it was dying. What else did you notice? What else did you notice about the plants? Ron?

4 Ron: They both are green.

5 Leslie: Yeah, they both are green. (Leslie holds up the plant in jar). Did anyone notice something about the color of this one, though. Although it is green. Thanks for raising your hand Natasha.

6 Natasha: It is also, way at the bottom, its leaves are turning white.

7 Leslie: Yeah, it's also turning white. Does anyone notice another color that we can also see?

8 Matt: Purple.

9 Leslie: Thanks for raising your hand Robin.

10 Robin: A little bit of brown

11 Leslie: A little bit of brown. That is something I noticed too. A little bit of brown. What do you notice about the plant that is not in the jar?

12 Nick: It is standing up straight.

13 Leslie: It is standing up straight. It is pretty strong.

(Leslie Teaching Video 3/22/2007)

In this example, Leslie had an opportunity to begin to make one pattern visible to the students – that plants sealed in jars die. However, Leslie was relying on students to discover the pattern. While students provided observations that Leslie could have used to help them see that the plant in the jar was not as healthy as the other plant, Leslie did not take the conversation to that end. Instead, the activity ended with many observations offered, but no patterns identified from the experiences and no understanding of the purpose of the experiment or how it fit with the rest of the activities the students were doing.

Thus, Leslie's enactment sequence did not provide the experiences necessary for students to see patterns in experiences. When there were opportunities for students to see patterns in experiences, Leslie stopped the activity before the patterns were identified. As a result, despite the fact that she used activities whose functions aligned with I-AIM, Leslie's enacted activity sequence did not provide the experiences or patterns accounted for by the explanations she wanted them to learn.

Taking Account of Students. Analysis of how Leslie took account of her students included examination of her account of students' conceptions and her account of students' cultural resources for learning. Leslie was able to consider students on both accounts when planning and enacting her science unit.

In her pre-assessment, Leslie identified several conceptions that students would bring to learning about the carbon cycle. She realized that students had just finished learning about the life cycle of a plant, and so she was not surprised when students answered her pre-assessment question about how a seed becomes a tree by referring to the life cycle of a tree. She also recognized that students would likely think that the stuff of a tree came from soil or water. She planned her instructional approach to address these conceptions.

During her enactment, Leslie paid close attention to students' conceptions. This attention was what prompted Leslie to add the new activities in the Food Stations activity group. She recognized that students were not yet convinced that water was not food, and so she added new activities to try to address that issue. As she noted in her lesson plans for the Food Stations activities

> They will be able to relate this to plants and the fact that plants do not get their "stuff" from the water they suck in or the nutrients from the soil, like so many of them think. With this lesson, I will instead be able to transition easily into photosynthesis, then to carbon. (Leslie Lesson Plans, 3/20/2007)

Leslie's accounting of students' cultural resources focused mostly on student ways of being. For example, in the Photosynthesis Activity Group, Leslie asked the students to prepare a poster to present to the class (Activity 23 Photosynthesis Posters). Along with the poster, she told students that they could present a song or a skit if they wanted. In Activity 24 Poster Presentations, all of the groups presented posters, one group also presented a song, and two groups also created skits. To Leslie, connecting to student ways of being and youth genres was an important strategy to helping students learn. She explained her reasons for encouraging students to do skits and songs as well as posters in their presentations.

> They really love rap. Just the whole classroom loves rap. So during that one activity, the group activity that they did, a lot of them chose to do a rap. And it helps them learn. And even one girl. I don't know if you were in the classroom but one girl the other day said, "That rap really, I can remember it to this day." And it was a couple weeks ago or maybe a week ago that they did it. And she was like, "I just can't forget how a tree makes its own food now." (Leslie Interview, 4/13/2007)

Thus, in this activity, Leslie was able to allow students to merge their own youth genres and ways of being with the science content they were learning (Calabrese Barton & O'Neill, 2008; Calabrese Barton *et al.*, 2008; Varelas *et al.*, 2002). Other examples of Leslie's consideration of students' ways of being include her use of a skit to model photosynthesis (Activity 20 Acting Out Photosynthesis), and taking the class outside to investigate the tree (Activity 25 Visit Tree Outside) when they were overly energetic.

Summary of Leslie's Enacted Activity Sequence

Leslie used a particular teaching pattern designed to help students put together the pieces of the photosynthesis story that she wanted them to learn. This teaching pattern matched some of the intended I-AIM activity functions, and missed others. Table 5.9 summarizes the comparison of Leslie's enacted activity sequence to the I-AIM functions.

Leslie's planned instructional approach and enacted activity sequence matched the intentions of the I-AIM framework for two of the four analysis foci. She established a central question that framed most of the activities she presented. She also included two opportunities for students to apply new understandings in familiar contexts. However, Leslie did not provide sufficient experiences with phenomena, she did not integrate experiences with phenomena into her main teaching pattern, and she did not make patterns in experiences explicit to her students. Providing experiences with phenomena and making patterns explicit are important because they align the instructional model with the inquiry practices of scientists' science. Providing a central question and eliciting and challenging student ideas are important parts of the model too. However, Leslie's teaching pattern relied on scientific information, rather than patterns in experiences, to push students to revise their ideas.

Table 5.9

Summary of analysis of enactment for Leslie

Tool	Analysis Foci	Leslie
I-AIM: EPE	• Establish a Central Question • Experiences before Explanations • Patterns made explicit • Opportunities for Application	+ Central question established – Teaching pattern relied on explanations and did not integrate experiences with phenomena – Patterns not made explicit + Opportunities for Application present
CA&P: Taking Account of Students	• Consider student conceptions • Consider student cultural resources	+ Consideration of student conceptions + Consideration of student ways of being/youth genres

+ matches intended use of tool feature – does not match intended use of tool

Leslie was able to take account of students' conceptual and cultural resources for learning. She paid attention to student ideas and made modifications to her planned instructional approach while teaching to address the struggles that her students were having with the concepts. She also took account of students' ways of being both when planning and modifying her lessons. Thus, Leslie's planned instructional approach and enacted activity sequence fit many intentions of the I-AIM and CA&P tools, but missed two key functions that were important for engaging students in and the inquiry practice of learning from experiences.

Mediators for How Leslie Used I-AIM/CA&P and EPE

The previous section showed that Leslie used many features of the I-AIM and CA&P but that both her plans and enactment missed other key features of the frameworks. Leslie, however, did not recognize that she missed these features. In this section, I will present Leslie's view of her work and accomplishments. I will then discuss the reasons for the discrepancy between how Leslie thought she used I-AIM and the underlying EPE framework and her actual planned and enacted use of the tools.

Talking about Using EPE & I-AIM

Leslie's planned instructional approach and her enacted activity sequence fit some of the intentions of the I-AIM, but did not provide sufficient experiences with phenomena or make patterns explicit to students. By missing these two key features, Leslie's plans and enactment did not engage students in the inquiry practices of the EPE framework. However, when Leslie reflected on her unit, she claimed that she did use EPE to sequence her activities.

> Students were able to create solid theories from recognizing patterns that they saw from the experiences they were having. Most students could look back at his/her original hypothesis and explain how that hypothesis was flawed. (Leslie Post Assessment Analysis and Reflection Paper, 4/24/2007)
>
> I used the Experiences-Patterns-Explanations model to develop and plan the unit. I tried to make sure that each aspect of that model was accounted for in my unit plan. I focused on assisting kids to think of prior knowledge they have that relates to the carbon cycle and I allowed the students to have more experiences to add. The students then focused on

the experiences they had to develop patterns. (Leslie Post Assessment Analysis and Reflection Paper, 4/24/2007)

In the above quotes, Leslie referred to the Experiences-Patterns-Explanations model and not the Inquiry-Application Instructional Model. The I-AIM was designed to help teachers sequence lessons in a way that fit the EPE framework, but the EPE framework itself is not an instructional model. To Leslie, however, they both held the same status as distinct instructional models. She spoke frequently of how she saw her activities fitting EPE, but was not able to explain how they fit I-AIM. When asked how Activity 13 (Food Stations) fit I-AIM, Leslie said, "I am not as familiar with the I-AIM as I am with the EPE, but I think it fits in." (Leslie Interview, 4/25/2007).

At the beginning of the unit, Leslie was unsure about teaching her unit. She was not confident teaching science, and she realized that the carbon cycle was a challenging topic.

> At first I was nervous about it because I haven't had that much experience teaching science. Just with the first grade. So I was nervous...It is different because I am a social studies major too, so I don't have too much background in science. (Leslie Interview 1/22/2007)

After teaching her unit, Leslie thought that the EPE "model" helped her succeed and gave her confidence in teaching science. When reflecting about what her students learned in the unit she said,

> They now knew that soil was not a food because the nutrients in it did not give the plant energy. I realized that by learning about the EPE model, I gained a valuable tool in learning how to teach science. This was an exciting day for me. (Leslie Post Assessment Analysis and Reflection Paper, 4/24/2007)

Leslie also claimed that she would use EPE again in her future teaching. In her science philosophy statement she said,

> Students will be expected to observe, question, reflect, and explore nature and the world they live in. My classroom will do this through having experiences in and out of the classroom, noticing patterns about these experiences, and explaining the patterns observed. This method for teaching science has been proved effective and meaningful to the learning that occurs in the science classroom. (Leslie Science Philosophy Statement, 4/19/2007)

These statements suggest that Leslie thought that she understood the EPE framework. However, when pressed, she had a hard time explaining how her plans and enactment fit EPE.

> So, explaining, well patterns also going outside would be a pattern. No, that would be an experience and we used it to think about our patterns. But, I think experiences were, would be drawing the carbon cycle, I want to say. And then seeing a pattern would be the actual balloon activity we did with the carbon cycle, I think. And then examining the plant experiment, the plant in a jar would be explaining. And the assessment will be explaining. I don't know. (Leslie Interview, 4/13/2007)

She had difficulty distinguishing between experiences and patterns (i.e. going outside or the balloon activity would both be experiences), and experiences and explanations (i.e. drawing the carbon cycle would be an explanation).

Leslie incorporated the language of EPE into her reflections and other course assignments. Yet, her plans and enactment show that she did not use the I-AIM and the underlying EPE framework as intended and she did not have a robust understanding of the frameworks. This situation raises two issues that need to be addressed. First, why did Leslie make reference to using the EPE framework, especially if she did not understand it? Second, why did she think she was using the EPE framework when her plans, her enactment, and her responses in the interview show that she was not using the EPE framework as intended?

Adopting the Language of the Course

That Leslie included mention of the EPE framework in her written reflection of her unit and her science philosophy statement submitted at the end of the semester is important. Not all interns used EPE or I-AIM to frame their reflections. That Leslie made mention of EPE suggests that she recognized that EPE was a central organizing framework of the course. As a conscientious student, Leslie incorporated the language of the course into her work.

Leslie was a careful student who always tried to do her best. Rebecca noted that this quality was one of Leslie's strengths. "Now that unit [carbon cycle] I definitely would not give to someone else. But I knew she [Leslie] could really do her best at it" (Rebecca Interview 4/13/2007). In class, Leslie's always turned her work in on time. Leslie's work often exceeded the requirements. For example, interns were asked to write notes on the social status and funds of knowledge for five students. Leslie turned in a table with comments on all 21 students in her class. Her lesson plans and reflections were detailed and thorough. Furthermore, she paid attention to the suggestions that Dr. Adams made in his feedback, sometimes quoting his suggestions in her revised assignments and citing him as the source.

In the course, EPE and I-AIM were important elements of the classroom discourse. The course met 10 times during the semester. EPE and/or I-AIM were major foci in 7 of the 10 course meetings. Both Dr. Adams and the interns referenced EPE and/or I-AIM in lecture, whole class discussions, and small group meetings. The course assignments were designed to scaffold interns in using EPE and the I-AIM. Interns were asked to identify experiences, patterns, and explanations in their learning goals and use the I-AIM to structure their planned instructional approach. As a careful student who always tried her best, Leslie recognized EPE as a central focus of the course and incorporated the classroom language into her course assignments because that is what she had learned that successful, good students do.

Experiences as Many Types of Activities

Leslie's incorporation of the course language into her work was not merely a case of knowing what Dr. Adams was looking for and then making sure that she used that language in her assignments. Leslie engaged in sense-making around the EPE framework and the components of the framework. Lemke explains in *Talking Science* (1990) that people make meanings of words based on the relationships among words and contexts. Within a given contexts, these relationships, called thematic patterns, signal certain socially-constructed meanings. Lemke explains, "making sense of anything we hear means somehow connecting it up with something else we have heard before. And those connections can go on and on" (p. 92). The thematic patterns, or the connections that one makes, influences the meanings that one makes of words. Therefore, two people can use the same words, but because they make connections to different thematic patterns, they come to different meanings.

Leslie thought that she was using the EPE framework, but the thematic pattern she accessed to make sense of the word "experience" led her to a different meaning for the word than the meaning intended by the EPE and I-AIM frameworks. In EPE and I-AIM, experiences must be about or involve phenomena. Experiences can be either direct or indirect, but they must relate to an event or occurrence. In order to use EPE and I-AIM as intended, a teacher must understand this thematic relationship between experiences and phenomena. Leslie, however, connected the word "experience" to a different thematic pattern. To her, an experience could be any number of different types of activities.

Leslie purposefully tried to include many different types of activities in her sequence, including videos (planned instructional approach only), skits, group tasks, talking with partners, drawing, songs, going outside, writing in notebooks, and hands-on experiences. She believed that she needed to include many different types of activities to accommodate students' various learning types and needs. In the first interview, she explained how she would use curriculum materials to plan a unit.

> I would try to use this book and adapt the lessons that it has in it to materials that I have or lessons that I know that would work well for the kids. Try to develop lessons that have a lot of abilities. (Leslie Interview 1/22/2007)

I asked her what she meant by this statement and she replied, "Just maybe movement, visual learning, written learning. I would try to put technology into it. I would definitely try to find something online" (Leslie Interview 1/22/2007).

Later, when talking about her planned instructional approach and enacted activity sequence, Leslie made many references to needing to provide many types of activities in order to keep her students interested and motivated.

> They also needed different activities that got them out of their seats because they just couldn't sit in their seats and learn for a while. They could for a certain, for some of the day, but they couldn't for all of it. So they needed to get up...So they need different ways to learn. They need to be able to process what they are learning to help them. And I think they need discussion too. (Leslie Interview 4/13/2007)

Leslie's focus on including a variety of types of activities in her instruction was supported by her mentor teacher, Rebecca. Leslie and Rebecca had a close working relationship. They often co-planned and co-taught both language arts and science lessons.

> And like Rebecca would help me plan literacy and she would give me information that she had from the past and activities that she used in her experience to help with that. And that really helped me to develop a whole big picture. And then I added things and used some of the things that she used. So, I think we just really collaborated on it. I think that is what we will do in science too. (Leslie Interview 1/22/2007)

Leslie also looked to Rebecca when she was teaching science.

> I watched Rebecca teach and tried to pay attention to her big ideas of teaching, like the notebook and observations are very important and relating it to the kids prior knowledge. I felt more comfortable and I knew kind of how to go. I kind of know how to relate it more to their lives. And she is helping me a lot to with it. (Leslie Interview 1/22/2007)

Rebecca confirmed that Leslie looked to her for guidance.

> She's always asked a ton of questions, watched how I set things up, watched how I planned units. When she planned her unit she was just with me all the time. Like, "What do you think about this?" And then I'm. "That's a little too passive; you need to get them active a little more." ...We talked about every unit she taught. Every lesson she taught, not unit, every lesson she taught we'd reflect. (Rebecca Interview, 4/13/2007)

Rebecca modeled using many different types of activities in her own teaching, in both science and language arts. The day I observed her teach science, she had the students labeling plant diagrams, playing a science game, and performing rap songs to review for an upcoming science test on plant parts. Rebecca also had student use science notebooks, which replaced a textbook in her science class. Students used the notebooks to record observations or hypotheses and make drawings. Often, students would staple copies of text from a reference into their science notebooks. Students were expected to refer back to their science notebooks when developing or learning to use explanations. Furthermore, Rebecca incorporated many group tasks into her instruction. She and her partner teacher, Hank, attended a workshop on incorporating group tasks and complex instruction (Cohen, 1994) into their practice. Rebecca was the person who suggested to Leslie that she do the group poster-making and presentation task at the end of her photosynthesis unit.

While Leslie's planned instructional approach and enactment sequence included only one experience with a phenomenon, her plans and enactment included many different types of activities. She believed teachers need to provide many different types of activities to keep students interested and to help them process what they were learning. She also saw her mentor teacher using many activity types in her own teaching. Rebecca suggested to Leslie that she include a variety of activity types in her instruction as well. Leslie made sense of the word "experience" by connecting it to a thematic pattern in which providing experiences meant providing many different types of activities. Because she used many different types of activities in her instruction, she thought she was providing students with many different experiences and thus was using the EPE framework.

Developing Explanations from Pieces

Leslie also made different sense of the words "patterns" and "explanations" than the ones intended by the EPE framework. To Leslie, patterns were the pieces of an explanation. She called the explanation a "theory." Generating a theory was Leslie's notion of helping students put the pieces of the story together.

A conceptual change orientation. Leslie came to planning her science unit with an orientation toward conceptual change teaching (Anderson & Smith, 1987; Magnusson *et al.*, 1999; Roth *et al.*, 1987). A teaching orientation refers to a teachers' knowledge and beliefs about the purposes and goals of teaching science (Magnusson et al., 1999). A conceptual change orientation involves identifying and considering students conceptions, and planning and teaching in such a way as to guide students to revise their ideas to more correct scientific ideas (Anderson & Smith, 1987; Roth et al., 1987). Early in her first interview, prior to receiving an introduction to I-AIM, Leslie brought up the importance of paying attention to students' misconceptions when planning and teaching science.

> You can prove how a misconception is actually wrong and while you are proving that you can help the kids see the actual big idea, or I don't know, the conception that you are trying to get them to see. They [misconceptions] can help you plan your units. (Leslie Interview, 1/22/2007)

When I asked her to how she would do this, she said,

> Design experiments that show and model the actual way that the Earth works and not the way that they [the students] think it works. And also prove to them that their misconception is wrong. (Leslie Interview, 1/22/2007)

Lemke (1990) explains that thematic patterns serve several important functions that help us make meaning. These functions include enabling us to make representations, interact with each other, organize ideas and actions, and establish an orientation or point of view. In her planning and teaching, Leslie was making sense of the I-AIM stages from the point of view of her conceptual change orientation. Her teaching pattern leveraged those aspects of the I-AIM model that most closely match a conceptual change orientation to teaching, specifically establishing a question, eliciting student ideas, presenting scientific ideas, and having students compare their ideas to the scientific ideas in order to revise their initial ideas. However, Leslie's conceptual change orientation did not help her make sense of the elements of the I-AIM that move beyond conceptual change teaching to engage students in inquiry and application practices (experiences with phenomena and making patterns explicit). For Leslie, the goal was to help students tell the scientific story. To do this, she worked to help students understand the correct pieces of the story, and then put those pieces together in a coherent way.

Patterns as pieces of explanations. Activity 6 (Forming a Rule), and Activity 7 (Explaining the Rule) provide an example of Leslie's understanding of patterns as pieces of explanations. In her planned instructional sequence, Leslie described these two activities (Table 5.10). The activity labels matched activity labels in the example instructional sequence that Dr. Adams provided the class when modeling a unit on electricity. Leslie used the activity labels, but wrote original activity descriptions and functions. In these descriptions of activities and functions, Leslie used the words "rule", "theories", and "patterns". In Dr. Adams' model instructional approach, rules were intended to be patterns and theories were testable explanations. However, Leslie equated both rules and theories with explanations. For example, in Activity 6 (Forming a Rule), Leslie described generating theories "for the way in which plants grow and add mass to themselves." By describing generation of theories but labeling it "forming the rule", Leslie equated theories and rules. Furthermore, Leslie stated in the activity function for Activity 7 that students will be "looking for patterns and forming a rule that has all patterns that were observed." Here, patterns were pieces of rules.

Table 5.10

Leslie's planned activities 6 & 7

Activity number	Activity label	Activity description	Activity functions
6	Forming the Rule	Based on the hypotheses, experiments, and text that the students have read, they will begin to generate theories for the way in which plants grow and add mass to themselves. They will be looking for patterns in plant growth.	Students will look for patterns in what they have learned so far. They will try to generate a theory in which we can test and discuss.
7	Explaining the Rule	I will ask the students, "What do we know about plant growth based on the activities we have done in this unit so far?" We will create a chart with information and a class theory that includes all of the "facts" we know about growth.	Students will have to use all the information we have to create a solid theory in which we can test. This activity has them looking for patterns and forming a rule that has all patterns that were observed.

Furthermore, in the mention of patterns in the activity function for Activity 7, Leslie used the word "observed." It is not clear whether she intended to mean that patterns emerge from empirical data or rather that patterns can be drawn from across all information and facts. In the activity functions for Activity 6, Leslie stated that, "Students will look for patterns in what they have learned so far." This statement implies that patterns be found not just in empirical data (either experienced first hand or described), but can also be drawn from information and facts given. In her summary of her planned instructional approach, Leslie said that students would "explain their thoughts and hypotheses in their work and will have to participate in a class discussion that is looking for theories of plant growth backed by facts we know about growth" (Leslie Planned Instructional Approach, 2/10/2007). Thus, Leslie made no distinction between explanations based on empirical evidence and explanations based on authoritative knowledge (Abell & Smith, 1994; D. C. Smith & Anderson, 1999). Patterns were pieces of explanations that could be found in both empirical data and authoritative knowledge.

Putting together the pieces of explanations. Leslie wanted her students to put together the pieces of the explanations to develop a new understanding. For example, when talking in an interview about Activity 3 (Seed & Log), Leslie articulated her goal of helping students put together the correct pieces of the explanations she wanted them to learn. In this activity, she had groups offer their best hypothesis, which she wrote on the board. Later, in Activity 19, the students revisited those hypotheses to "disprove" some of them. However, in Activity 3, after all the students had offered their ideas, Leslie added an additional hypothesis, of her making, to the list. She explained,

> And at the end I tried to make a hypothesis that was accurate and I tried to help them think it through. And I said, "Well we know that it has to do with sunlight, and you know it needs water and some of us know that it needs something from the air." So I tried to help them form different pieces of their hypotheses into one hypothesis that I knew was mostly accurate and that we could go from in the future when we were developing a new theory. (Leslie Interview, 4/25/2007)

Leslie saw the "new theory" as the explanation, or story, that she wanted students to learn about photosynthesis, and she was setting up the situation so that she could make sure they had the correct pieces that went into that story.

Summary of Mediators

While Leslie did plan and teach a unit that fit many important I-AIM functions, the meanings that she made of the EPE framework mediated her use of the I-AIM tool. The connections to thematic patterns that Leslie made helped her make sense of experiences as activity types, rather than experiences with phenomena. Furthermore, her conceptual change orientation to teaching helped her take advantage of the features of I-AIM that matched a conceptual change approach to teaching. However, this orientation did not help Leslie to understand that explanations account for patterns in empirical data. Instead, she saw patterns as pieces of explanations, or theories, and her role as a teacher was to make sure students put together the correct pieces of the scientific story rather than to engage them in the scientific practices of inquiry and application.

Chapter Summary

Leslie was an earnest intern. She wanted to do what people asked of her and to be a successful teacher. Leslie had a supportive field placement and a good working relationship with her mentor teacher. She also had a positive attitude and a willingness to try new ideas. When it came to teaching science, she was faced with a challenging situation. She was assigned to teach the carbon cycle, an advanced topic that was not part of the grade level curriculum to fifth-grade students in a three-week unit. Her mentor teacher had no previous experience teaching the topic, and the curriculum materials she had available provided limited support. Furthermore, she had a narrative rather than model-based understanding of the processes involved in carbon cycling, including photosynthesis

Leslie tackled this challenge head on. She recognized that the challenge was big and she was anxious about a potentially poor outcome. She recognized that she had some tools that she could use, including some activities from the *Food for Plants* curriculum materials and the EPE framework. Her planned instructional approach and her enacted activity sequence included a strong teaching pattern that met many important functions of the I-AIM. She established a central question, elicited student ideas about the answer to the question, presented scientific information, and had students compare their ideas to the scientific ideas in order to revise their answers to the question. She also provided students with opportunities to practice applying their new understanding in new contexts with support. Finally, she took account of students' intellectual resources and provided opportunities for students to merge their youth ways of being with scientific practices. Given the challenges that she faced, Leslie's planned instructional approach and enacted activity sequence represent a considerable accomplishment.

Nevertheless, Leslie's planned instructional approach and enacted activity sequence missed two key functions of the I-AIM. First, she did not provide sufficient experiences with phenomena and the experiences that she did provide were not integrated into her teaching pattern. Second, she did not help students see patterns that were present in the experiences she provided. Students were left to discover the patterns for themselves or learn patterns as scientific information. As a result, students did not engage in the inquiry practices intended by the I-AIM and underlying EPE framework.

Leslie, however, thought that she had met the intentions of the EPE framework. Leslie saw the EPE framework as an instructional model and described how she had provided students with experiences and helped them to see patterns. Her insistence that she used the EPE framework suggests that Leslie recognized EPE as an organizing framework for her course. However, her sense-making of the various components of the framework resulted in meanings for the framework that were different from the intended meanings.

First, the thematic patterns that Leslie made connections to when making sense of the word "experiences" helped Leslie equate "providing experiences" with "using a variety of activities." She believed that teachers must provide a variety of types of activities to students to accommodate diverse learning needs and styles. Her mentor teacher, to whom she looked for guidance, modeled and reinforced this practice, which in and of itself is a worthy practice. However, Leslie did not recognize that providing experiences with phenomena is one type of activity that is necessary to help students engage in inquiry learning. The other types of activities which she used better fit the Explain and Application functions of the I-AIM.

Second, Leslie took a conceptual change orientation to making sense of patterns and explanations. Her goal for planning and teaching science was to help student correctly put together the pieces of a scientific story. To do that, she had to identify students' ideas, and then present them with the scientific pieces of the story to help them disprove and revise their initial ideas. Leslie saw the patterns as the scientific pieces of the story, either empirical data or authoritative knowledge, and the explanations as the scientific theories that she wanted her students to learn. Thus, the thematic patterns that Leslie had access to helped her make meanings of the words "experiences", "patterns," and "explanations" that were different from the meanings the EPE and I-AIM intended. As a result, Leslie thought that she was using EPE in her work, and although she was consistently accessing and using the conceptual change features of the I-AIM, she was not engaging students in the inquiry practices that I-AIM was intended to support.

CHAPTER 6

Nicole

Chapter Overview

Nicole was a high achieving intern who held herself to high expectations. She planned and taught a second-grade unit on sound that met all of the intended I-AIM functions. Nicole's unit focused on helping her students recognize two important patterns: 1) that objects that make sounds vibrate and 2) that one thing vibrating can make another thing vibrate. Nicole provided her students with many opportunities to experience examples of objects vibrating and objects making other things vibrate. She then helped students use these patterns to explain how people hear sounds.

Nicole's case is interesting because her interpretations of the I-AIM and CA&P tools mediated her successful use of the tools to select activities from curriculum materials, design some new activities, and then sequence these activities to support students in learning the specified learning goals, engage them in the scientific practices of inquiry and application, and leverage students' intellectual and cultural resources for learning science. Nicole received converging support from Dr. Adams and her mentor teacher that helped her interpret the I-AIM in ways that often matched the intentions of the I-AIM stages and functions.

In this chapter, I will begin by describing Nicole's teaching situation and the process that she went through to plan her instructional approach. In the next section, I will analyze Nicole's enacted activity sequence for its fit with the I-AIM and CA&P tools. In the last section, I will explore Nicole's interpretation of the I-AIM stages and discuss how these interpretations may have mediated her use of the tools.

Planning a Unit on Sound

Nicole had a positive and supportive internship placement. She worked with an experienced mentor teacher. She was also in a team-teaching situation with the first-grade intern, Dominique. She and Dominique worked together to plan the unit on sound. In this section I will describe Nicole's teaching situation and then describe Nicole and Dominique's work to identify their learning goals, analyze their curriculum materials, and plan their instructional approach.

Nicole's Teaching Situation

Nicole interned at Turner Elementary School. This school served approximately 330 K-4th grade students. The school was located in a formerly rural agricultural area that was becoming more suburbanized as development from the nearby urban area expanded. 82% of the students at the school were white, 8% were Hispanic, 6% were African American, and 3% were Asian. 34% of the students were eligible for free or reduced lunch.

Nicole was placed in a second-grade classroom. Her mentor teacher, Annette, team-taught with the first grade teacher, Cindy. They had adjoining rooms separated by a sliding curtain wall that they could open to make a double-wide room for the two classes together. Annette and Cindy usually taught math and reading to their own students, but planned and taught their science and social studies units together. Students in Cindy's first-grade class moved to Annette's second grade class the following year. As a result, the science and social studies curriculum followed a two-year cycle. One year the two teachers taught the district first-grade science and social studies curriculum and the following year they taught the second-grade science and social studies curriculum.

Cindy also had an intern, Dominique. Because of the team-teaching arrangement between Annette and Cindy, Nicole and Dominique co-planned their science and social studies units. Nicole and Dominique worked well together. They were both high achieving students and creative teachers. They supported each other and challenged each other when appropriate. Nicole often gave credit to Dominique for the ideas and activities that they used in their unit.

Although Nicole and Dominique planned their science unit together, they enacted their units with their own students. Annette and Cindy usually taught science and social studies to mixed age-groups of first and second grade students. Originally, Nicole and Dominique had wanted to teach science to mixed age-groups of students as well. However, Nicole and Dominique ran into logistics problems with a shortage of supplies they needed to share for their instruction. They solved the problem by each teaching science at a different time of the day. As a result, they each enacted their science lessons with their own students.

Nicole and Annette's classroom was a busy place. There were 23 active second grade students representing all economic classes, six countries of origin (Thailand, China, Bosnia, Haiti, Vietnam, and France) and all ability levels. Several students had special needs and were pulled out of class regularly to receive special services. The classroom was equipped with a microphone and speaker system. The teacher wore a wireless microphone around her neck and her voice was broadcast from speakers in the corner of the room.

Annette was a practiced teacher with over 30 years of experience teaching in the school district. She had participated in many university professional development programs, including working closely with Dr. Adams in past professional development school partnerships. As a result, she was familiar with both the university teacher preparation program and many of the science teaching principles that Dr. Adams emphasized in the science methods course.

Identifying the Learning Goals

Annette and Cindy assigned Nicole and Dominique to teach the state and district benchmark: Explain how sounds are made (Michigan Department of Education, 2000). Nicole and Dominique struggled at first to figure out what content this benchmark covered.

During the previous year, Nicole had been placed in a fifth-grade classroom where she planned and enacted several lessons on sound. Nicole felt that because of this previous experience she was a step ahead. She and her fifth-grade teaching partner had done quite a bit of research to learn about sounds so that they would be prepared to teach about sound. As a result, Nicole felt comfortable with the science topic she was assigned to teach.

> So it was like lots of research and we, I mean we read books, we read children's books, we read books for college level. We were on the Internet. We, you know, we talked with our CT [mentor teacher] a lot. We talked with my SME [university science content course] instructor. It was really important that we got to know the content. And that was like the biggest thing I learned last year was if you don't know it, you are not going to be able to teach it. So we got to the point where we were really comfortable talking about it and talking about it to each other. (Nicole Interview, 1/17/2007)

Although she was comfortable with the content, Nicole struggled to translate the content she taught to fifth-grade students the previous year into a unit for second-grade students. Nicole and Dominique's first draft of their learning goals listed the following benchmarks.

1. Describe sounds in terms of their properties. (PWV) IV.4.e.1
2. Explain how sounds are made. (PWV) IV.4.e.2
3. Explain how sounds travel through different media (PWV) IV.4.m.1
4 Classify common objects and substances according to observable attributes/properties (PME) IV.1.e.1

(Michigan Department of Education, 2000)

The third benchmark in this list is a middle school benchmark and the fourth learning goal was included to clarify the word "media" in the third benchmark (i.e. solids, liquids, gases).

Nicole and Dominique also identified the patterns they wanted students to learn and the explanations that accounted for their patterns. In their first draft, they identified 20 individual patterns and five explanation statements. They cited their notes from their university science content course as the source for their explanation statements.

By the second week of the semester, before Dr. Adams had assigned them to do so, Nicole and Dominique had laid out their entire unit to address their learning goals. They had their experiences picked out and the sequence they wanted to use. However, as they worked through the process of more clearly defining their learning goals, frustration set in. Nicole recognized that while she had used a molecular model to explain sound to her fifth-grade students, she could not use that explanation with her second-grade students. She and Dominique struggled to figure out how they could explain how sounds travel through solids, liquids, and gases if they could not include molecules in their explanations.

> The first couple of weeks were really a struggle for me and I know Dominique probably had a hard time working because I was thinking fifth

grade, like what we did with them and try to bring it down to second grade and I think it was probably like bringing us down. And I was just frustrated. (Nicole Interview, 4/11/2007)

The breakthrough came in the third week of class during a workshop that Dr. Adams designed to bring the interns together with their mentor teachers to learn about the EPE frameworks and I-AIM/CA&P tools and work together on planning the science unit. Nicole and Dominique were sharing with Annette and Dr. Adams what they wanted to do. Nicole and Dominique described some of their ideas for helping students understand how sounds travel through solids and liquids, but they were still struggling with trying to figure out how to explain how sounds travel through air. Dr. Adams pointed out that they were using a middle school benchmark and offered some suggestions for the learning goals that he thought were more appropriate for second-grade students.

1 Dr. Adams: Well, explain how sounds are made. And here the idea I think, and this is what I am looking for, in your explanations and patterns. What I'm thinking about is that whenever a sound is made, the thing that is making it is vibrating.

2 Nicole: Right

3 Dr. Adams: That is a pattern to me. Because what you investigate here is another object and you can somehow detect a vibration.

4 Nicole: So that is what we want them to be able to verbalize.

5 Dr. Adams: And I think that the idea that we are not going to explain how you hear by the vibrations vibrating the air and that is making your ear drum, I don't think you are going there, right?

6 Nicole: Not like to the ear part. [Turns to Annette] You are covering the ear, aren't you? But we are not covering it.

7 Annette: We have a health unit about the ear, and we teach that just before the sound unit. So, they've learned about an ear drum and they've learned about vibrations, but we don't talk about, you know, the vibrations in the air.

8 Dominique: Though, Cindy was saying that she thought it would be nice if at the very end of the lesson we went through and kind of talked about the vibrations with the ear to what we learned.

9 Dr. Adams: Well, what. One thing that is vibrating can cause another thing to vibrate that is not, that is nearby but not necessarily touching. That would be the drum vibrating can cause our ear drum to vibrate. So you've got the patterns.

(Nicole Workshop Transcript, 1/23/2007)

In their revised learning goals, Nicole and Dominique narrowed the focus to two elementary benchmarks:

1. Explain how sounds are made. (PWV) IV.4.e.2
2. Describe sounds in terms of their properties. (PWV) IV.4.e.1

(Michigan Department of Education, 2000)

They reduced their patterns list to seven patterns.

1 Sounds are heard everywhere (indoors and outdoors)

2 When one object vibrates, it causes another object to vibrate.

3 Through reading multiple children's texts on sound, content from science time is reinforced.

4 The more water a glass has in it, the lower the pitch.

5 The less water a glass has in it, the higher the pitch.

6 The bigger the object (glass of water, rubber bands, straws, musical instruments) the lower the pitch is.

7 The smaller the object (glass of water, rubber bands, straws, musical instruments) the higher the pitch.

The first two patterns related to explaining how sounds are made; the last four patterns related to describing properties of sounds, particularly pitch. The third pattern was a teaching strategy, not a pattern.

Nicole and Dominique also identified their central question as, "How does a drum you see in a parade make the sound you hear?" (Nicole Learning Goals, 2/7/2007). Nicole later rephrased the central question as, "How are you able to hear the drums that you see played like in a marching band?" (Nicole Interview, 4/11/2007). The emphasis in the first question is how sounds are made and the emphasis in the second question is on how we hear sounds. Both of these emphases played a role in Nicole's enacted activity sequence, as I will describe later.

Nicole and Dominique continued to refine their learning goals throughout their planning and teaching. In particular, they continued to narrow down the patterns so that by the end of the unit students recognized that all objects that make sound vibrate and one thing vibrating makes another thing vibrate. The pitch patterns were also refined and received reduced emphasis in both the planned instructional approach and enacted activity sequence. At the end of the semester, Nicole reflected back on the struggles she and Dominique had identifying what they wanted to teach.

> Initially, initially, initially, when I first found out we were teaching sound, it was just like we came up with a unit that was not a second-grade unit. It was not second grade. We worked really hard on it but it had benchmarks above and beyond. It was so compacted, it was not good. I look back on that and I'm just like, "What were you thinking?" And I know a lot of it was me pushing Dominique to like, include this, include this, include this.

> Because I was the one who had taught fifth graders last year. So I felt like I kind of knew what I was doing. But I didn't. (Nicole Interview, 4/11/2007)

Curriculum Materials Analysis

The school district usually provided curriculum materials and kits to support teachers in meeting the district benchmarks. However, for the sound unit, the school district provided materials developed by the Battle Creek Mathematics and Science Center that were written for third grade students. Annette and Cindy had long ago decided the Battle Creek materials were too advanced for their first- and second-grade students. They did not provide the Battle Creek materials to Nicole and Dominique. Instead, they gave the interns a thick folder of activities that they had collected over the years. Some of the activities came from *AIMS Primarily Physics* (Hoover & Mercier, 1994) and some of the activities came from previous interns' unit plans.

Nicole and Dominique went through the folder looking for activities they wanted to do with the students. As Nicole explained, they looked for activities that would provide students with experiences that would help them understand the two key patterns that they had identified and be able to answer their central question.

> Once we had the central question, we were like, ok how are we going to get them to be like, one object causes another to vibrate. First of all they have to know that something is vibrating to make a sound, something can vibrate and make a sound. We're like, we have got to start off with something like a tuning fork. It vibrates, it is making a sound, they can feel it, they can hear it at the same time. Then, the next step is like they have to know if they touch that tuning fork to something, it can make something else vibrate. And then we had to do things with like in pairs. Two tuning forks, two drums. (Nicole Interview, 4/11/2007)

When Nicole and Dominique encountered an activity that they did not think related to the central question or did not help students understand the key patterns, they did not include the activity in their unit.

> So then we came up with all of these activities that could potentially be fed into our unit. But then we are like, "Well which ones are really pertinent to what we are doing and which ones are going to like derail them from?" So, like "Eggs Full of Sound." That is like they shake a plastic Easter egg and there is something inside and they have to, you know, "Is it a coin, is it rice?" Well, you know, we know what certain sounds are so we can detect them. Well, that wasn't really, had really nothing to do with getting to our central question. (Nicole Interview, 4/11/2007)

Nicole and Dominique completed the curriculum materials analysis assignment using the CA&P questions. However, when they answered the questions they considered their intended instructional approach, rather than the complete set of available activities. As a result, they used the CA&P to think about how well their planned instructional approach fit the I-AIM and considered student cultural and intellectual resources, rather than using the CA&P to help them identify strengths and weaknesses of the materials prior to planning their unit.

> Yeah, well when we found out we had to do the curriculum material analysis, we really already knew what we wanted to do. We already had pulled what we wanted to do…And then we did this. So, we did not rank or really heavily critique the packet of stuff. We knew where we wanted to go, we pulled what we wanted, we got rid of what we didn't. Then we sat down and did the curriculum materials analysis. (Nicole Interview, 4/11/2007)

Nicole and Dominique used the CA&P questions to identify the strengths and weaknesses in the activities that they had selected. Their answers to the CA&P questions sometimes showed that they had additional criteria that they thought were important that were not necessarily part of the CA&P tool. For example, the CA&P asked if activities were likely to be relevant to students' lives. Nicole and Dominique's response to this question shows they only considered real instruments and equipment to be relevant. In other words, it was the equipment, not the context, that was important.

> We do not feel that every activity is relevant to the students' lives. A concern arises that for example, after constructing the fish line and plastic cup phones, the students may have the misconception that all phones operate exactly as the ones they made do. (Nicole Curriculum Materials Analysis, 2/12/2007)

Similarly, Nicole and Dominique wanted experiences that would be authentic science experiences. By "authentic", Nicole and Dominique wanted students to engage in scientific practices. For example, the CA&P asked if the scientific practices in the activities would be relevant to students. Rather than consider if the activities would be familiar to students, as the CA&P intended, Nicole and Dominique considered whether the activity provided a relevant scientific practice. "The activities that do not ask the students to record are not relevant [authentic] because a scientist must always record their findings and represent them to share with the scientific community." (Nicole Curriculum Materials Analysis, 2/12/2007)

Nicole and Dominique also used the CA&P questions to identify the modifications to their chosen activities that Nicole said they used in their enactments.

> Ok, well we planned to center this unit around our central question. So like whatever we do has to go around this central question. So anything we use from *Primary Physics* [sic] we're going to revamp and put it

> around the central question. And like making the materials more suitable to the grades we were teaching, we did that too. We had to change certain things, put it in different wording. And then you know they didn't always provide like how you would instruct the students in pairs or in groups and that is something we wanted to do. So, a lot of these [identified modifications] we went back and we did. We actually made the modifications and we actually incorporated them. (Nicole Interview, 4/11/2007)

Nicole and Dominique's curriculum materials analysis shows that they had specific criteria that they used to decide what activities to use in their instructional approach, including whether or not it matched the benchmark or provided experiences that would help students understand the patterns. They also wanted activities that provided real as opposed to represented experiences, and that engaged students in authentic scientific practices. Although they used the CA&P to analyze their intended instructional approach rather than as a way to evaluate potential activities, Nicole and Dominique were able to identify places where they should modify the activities that they had selected to include in their unit.

Planned Instructional Approach

Table 6.1 shows Nicole and Dominique's planned instructional approach. Nicole and Dominique described their activities in detail and provided a rationale for the function of each activity. Most of the time, their descriptions, and rationales matched the I-AIM functions. However, they also sometimes identified more focused functions that matched the intents of the I-AIM functions but were not necessarily identified in I-AIM. To preserve Nicole and Dominique's ideas and intents, I assigned color codes using their descriptions. When Nicole and Dominique's descriptions and rationales identified specific functions not explicitly included in the I-AIM, I color-coded these activities in shades of brown and orange.

Table 6.1

Nicole and Dominique's planned instructional approach

Activity number	Activity label	I-AIM stage (color code)	Activity function (color code)
1	Introduction: Sounds in our Community	Engage (yellow)	Set the scene and provide purpose (light brown)
2	Journal Entry	Engage (yellow)	Engage in authentic science writing practice (light orange)
3	Classroom Discussion	Explore & Investigate (green)	Explore student ideas about patterns (light green)
4	Exploring the Snare Drum	Explore & Investigate (green)	Explore phenomena (sea green)
5	Predicting: How does a Drum make Sound?	Engage (yellow)	Establish a question (light yellow) Engage in authentic science writing practice (light orange)
6	Sharing Predictions	Engage (yellow)	Elicit student ideas (dark yellow)
7	Creating A Rice Drum	Explore & Investigate (green)	Explore phenomena (sea green)
8	Journal Entry	Explore & Investigate (green)	Engage in authentic science writing practice (light orange)
9	Sharing their Observations	Explore & Investigate (green)	Explore student ideas about patterns (light green)
10	Tuning Fork	Explore & Investigate (green)	Explore phenomena (sea green)
11	Discussion: Establishing A Pattern	Explore & Investigate (green)	Explore student ideas about patterns (light green)
12	Demonstration with Two Drums	Explore & Investigate (green)	Explore phenomena (sea green) Explore student ideas about patterns (light green)
13	Modeling of and Exploration with Two Tuning Forks	Explore & Investigate (green)	Explore phenomena (sea green)
14	Vibrating Ear Drum Discussion	Explore & Investigate (green)	Explore student ideas about patterns (light green)
15	Modeling of & Exploration with Fish Line & Plastic Cup Phones	Apply (purple)	Practice with support (model & coach) (violet)
16	Fish Line and Plastic Cup Phone Discussion	Apply (purple)	Practice with support (model & coach) (violet)
17	Introduction to Pitch	Engage (yellow)	Set the scene and provide purpose (light brown) Establish a question (light yellow)

Table 6.1 Continued

Activity number	Activity label	I-AIM stage (color code)	Activity function (color code)
18	Listening to Music/Sounds with Different Pitches	Explore & Investigate (green)	Explore phenomena (sea green) Explore student ideas about patterns (light green)
19	Modeling of and Exploration with Water Xylophones	Explore & Investigate (green)	Explore phenomena (sea green)
20	Discussion: High and Low Sounds Produced by the Water Xylophone	Explore & Investigate (green)	Explore student ideas about patterns (light green)
21	Distinguishing between High and Low Pitches Using Straw Flutes of Varying Lengths and Shoe Box Guitar Construction	Explore & Investigate (green)	Explore phenomena (sea green) Engage in authentic science writing practice (light orange)
22	Discussion: Recognizing Patterns Within Each of Our Pitch Activities	Explore & Investigate (green)	Explore student ideas about patterns (light green)
23	Field Trip: *Marshall Music*	Apply (purple)	Practice with support (model & coach) (violet)
24	Journal Entry and Discussion	Apply (purple)	Engage in authentic science writing practice (light orange)
25	Wrap Up and Preparation for Sound Museum	Apply (purple)	Practice with fading support (lavender)

Nicole and Dominique relied heavily on two I-AIM functions: Explore phenomena and Explore student ideas about patterns. They planned to provide students with many experiences with phenomena and use the experiences to make patterns explicit. For example, when describing Activity 7 (Creating a Rice Drum), Nicole explained,

> This is one of many upcoming experiences the students will have from which to start formulating patterns. They feel more a part of the experience and more like scientists when they are given the opportunity to construct the object they are working with. The rice enables the students to see that something is occurring when the drum is struck. (Nicole Instructional Approach, 2/19/2007)

Similarly, when describing Activity 20 (Discussion: High and Low Sounds Produced by the Water Xylophone), Nicole explained, Using what the students learned about pitch in our previous lesson, students will begin developing patterns about how different levels of water affect the pitch produced by the xylophone. (Nicole Instructional Approach, 2/19/2007)

Nicole and Dominique also included three other I-AIM functions: Establish a question, Provide practice with support, and Provide practice with fading support. They planned to establish the central question about how a drum makes sound in Activity 5 (Predicting: How does a drum make sound?) and in Activity 17 (Introduction to Pitch) they planned to ask the students, "Did all of the sounds we heard sound exactly the same?" At the end of the sequence about vibrations, Nicole and Dominique planned to have students apply the patterns they had learned to explain how the sound that someone makes talking into a cup connected to a fishing line can be heard by someone holding the cup attached at the other end of the fishing line (Activities 15 and 16). Similarly, at the end of the sequence on pitch, Nicole and Dominique planned to take students on a field trip to a music store to use what they had learned about sound to explain how the instruments made sound (Activity 23 Field Trip: Marshall Music). Finally, at the end of the entire unit, they planned to have a Sound Museum where students would serve as tour guides to explain to their visiting parents how drums, tuning forks, and other objects make sound (Activity 25).

Sometimes, Nicole and Dominique placed a special emphasis on certain aspects of the I-AIM stages that were not specifically highlighted in the I-AIM functions. For example, as part of their introduction to the unit, Nicole and Dominique wanted to establish a broad purpose for the importance of studying sound. In Activity 1 (Introduction: Sounds in our Community), they planned to take the students on a sound hunt to listen for both new and familiar sounds inside and outside of the school. They explained, "We want students to become aware of the sounds that are always around them in an effort to establish a rationale for why it is important to study sound." (Nicole Instructional Approach, 2/19/2007). This activity function matches the intent for the Engage stage because it provides experiences that are necessary for understanding the central question, introduced later. However, setting the scene and providing purpose (light brown) is not a specific function included in the I-AIM. Nicole and Dominique purposely identified an additional function that elaborated on the Engage stage of the I-AIM.

In addition, Nicole and Dominique purposely planned activities that would engage students in writing in journals. Nicole wanted her students to "attain a feeling of being a scientist through working on their writing skills in science." (Nicole Learning Community Inquiry Project, 3/26/2007) Journal writing is one type of activity that can fit many of the I-AIM stages/functions, including eliciting student ideas (Engage, Explore & Investigate, Explain, Apply), looking for patterns in experiences (Explore & Investigate), or explaining patterns (Explain). Furthermore, I-AIM is designed to engage students in scientific practices, including writing. In coding their planned instructional approach, I highlighted the journal writing as a separate activity function (light orange) because Nicole and Dominique placed special emphasis on journal writing as an authentic scientific practice.

Finally, examination of Nicole and Dominique's planned instructional approach shows that they did not identify any activities as Explain stage (blue) activities. In places where it would seem that Nicole and Dominique might identify an Explain function, they specifically describe Explore & Investigate stage (greens) functions instead. For example, in Activity 7 (Creating a Rice Drum), one might expect Nicole and Dominique to introduce the scientific idea of a vibration. However, in Activity 7, Nicole and Dominique wrote,

> This is one of many upcoming experiences the students will have from which to start formulating patterns. They feel more a part of the

experience and more like scientist when they are given the opportunity to construct the object they are working with. The rice enables the students to see that something is occurring when the drum is struck. (Nicole Instructional Approach, 2/19/2007)

Another opportunity to introduce the scientific idea of a vibration occurs in Activity 10 (Tuning Fork.)

Students need a more tangible way of experiencing vibrations. The tuning fork is a way for students to feel the vibrations in holding the fork and placing up to their cheek (skin) and to see the vibrations in action when placing it in the water. The qualities of this activity may make the vibrations less abstract to the students. (Nicole Instructional Approach, 2/19/2007)

At this point, Nicole and Dominique used the term "vibrations" in their descriptions of what students will see and experience, but at no place so far have they identified where students learn to label their experiences as vibrations. Rather, Nicole and Dominique specifically use phrases like "need experiences" or "formulating patterns" which fit Explore & Investigate functions and not Explain functions.

Similarly, in Activity 17 (Introduction to Pitch), and Activity 18 (Listening to Music/Sounds with Different Pitches), one might expect Nicole and Dominique to introduce the term "pitch." Nicole and Dominique's rationale for Activity 17 said,

Now that the students have been made aware of vibrations, we want to see what differences students are able to notice between sounds. We would like to generate an awareness that sounds are composed of different properties and do not all sound the same. (Nicole Instructional Approach, 2/19/2007)

For Activity 18, they said,

> We wanted to allow the students an opportunity to hear different pitches without the specific vocabulary as a way of seeing if they would be able to detect the differences in the sounds on their own. Using their descriptions, we will build an understanding of high and low pitch. Due to starting a new subtopic within sound, we wanted to play music as a way of piquing student interest. (Nicole Instructional Approach, 2/19/2007)

Nicole and Dominique focus on student experiences and not on introducing scientific ideas. In Activity 18 they specifically noted that they did not want to introduce a scientific ideas (in this case identified as vocabulary). Nicole believed that science was about discovery. She also thought that science instruction should follow a logical flow. "I just want it to be in like a logical order...It has to be systematic but at the same time I have to catch myself because there's got to be flexibility too because of the discovery aspect" (Nicole Interview, 1/17/2007). Nicole and Dominique intended in their planned instructional approach to provide specific experiences and opportunities to process the experiences in such a way that the sequence would lead students to discover the important science concepts without providing explanations directly. To Nicole, teaching science was about "trusting the students to be serious scientists and really process it." (Nicole Interview, 4/11/2007)

In summary, Nicole and Dominique struggled in the beginning to define the content they wanted to teach. Nicole's previous experience teaching sound to fifth-grade students became a stumbling block because she was unsure how to translate her fifth-grade experience to a unit appropriate for second grade. However, Dr. Adams provided a clear articulation of the key patterns necessary to explain how sounds are made, how sounds are heard, and what makes sounds different from each other. Nicole and Dominique latched on to those patterns and used them to guide their selection of activities from the folder of activities their mentor teachers provided. They selected activities that provided experiences related to those key patterns and engaged students in scientific practices. They sequenced the selected activities to provide students with many experiences, guide students to seeing the patterns, engage students in scientific writing practices, and present students with opportunities to apply what they learned. While many of the activities in Nicole and Dominique's planned instructional approach fit I-AIM functions, they did not specifically identify any activity functions that fit the Explain stage of the I-AIM.

Enacting the Sound Unit

Nicole enacted her sound unit in early February, 2007. Nicole taught science for 40 minutes two to three times per week. I observed four of her lessons. I dissected Nicole's activity sequence into activities, assigned functions to the activities based on my observations, and color coded the functions in the enactment sequence. I also filled in the activities for the days that I was not able to observe based on interviews with Nicole. Table 6.2 shows Nicole's enacted activity sequence.

Table 6.2

Nicole's enacted activity sequence

Activity group	Activity number	Activity label	I-AIM stage (color code)	Activity function (color code)
Introduction	1	TWL Chart	Engage (yellow)	Elicit student ideas (dark yellow)
	2	Exploring Whistles	Engage (yellow)	Establish a question (light yellow)
			Explore & Investigate (green)	Explore phenomena (sea green)
				Explore student ideas (light green)
	3	Sound Hunt	Explore & Investigate (green)	Explore phenomena (sea green)
	4	Whole Class Sharing	Explore & Investigate (green)	Explore student ideas (light green)
Vibrations	5	Snare Drum	Explore & Investigate (green)	Explore phenomena (sea green)
				Explore student ideas (light green)
	6	Coffee Can Rice Drums	Explore & Investigate (green)	Explore phenomena (sea green)
				Explore student ideas (light green)
	7	Review Snare Drum	Explain (blue)	Develop student explanations (dark blue)
				Introduce scientific ideas (light blue)
	8	Exploring Tuning Forks	Explore & Investigate (green)	Explore phenomena (sea green)
				Explore student ideas (light green)
	9	Group Sharing	Explain (blue)	Develop student explanations (dark blue)
				Introduce scientific ideas (light blue)
	10	Two Tuning Forks	Explore & Investigate (green)	Explore phenomena (sea green)
				Explore student ideas (light green)
	11	Group Sharing	Explain (blue)	Develop student explanations (dark blue)
				Introduce scientific ideas (light blue)
	12	Cup Phones	Apply (purple)	Practice with support (model & coach) (violet)

Table 6.2 Continued

Activity group	Activity number	Activity label	I-AIM stage (color code)	Activity function (color code)
Pitch	13	Explore Pitch	Engage (yellow)	Establish a question (light yellow)
			Explore & Investigate (green)	Explore phenomena (sea green)
				Explore student ideas (light green)
	14	Explore Pitch	Explain (blue)	Introduce scientific ideas (light blue)
	15	Bottle Xylophones	Explore & Investigate (green)	Explore phenomena (sea green)
				Explore student ideas (light green)
	16	Group Sharing	Explain (blue)	Develop student explanations (dark blue)
				Introduce scientific ideas (light blue)
Application	17	Marshall Music	Apply (purple)	Practice with support (model & coach) (violet)
	18	Journal Writing	Apply (purple)	Practice with fading support (lavender)
	19	Invented Instruments	Apply (purple)	Practice with fading support (lavender)
	20	Sound Museum	Apply (purple)	Practice with fading support (lavender)

Nicole's enacted activity sequence was slightly shorter than the planned instructional approach because Nicole ran into time constraints and had to reduce her emphasis on pitch. Most of the activities I identified matched the activities that Nicole and Dominique identified in their planned instructional approach. In contrast to my coding of the planned instructional approach, however, I assigned functions to the enacted activities based on my observations. In doing so, I was able to consider how the enacted activities functioned within the I-AIM framework. Thus, for several activities, the observed function is different from the function intended by Nicole and Dominique. For example, many activities that Nicole and Dominique identified as Explore & Investigate stage (green) activities actually functioned during the enactment as primarily Explain stage (blue) activities. That is not to say that activities did not also function to meet Nicole's desired functions too, such as providing opportunities to engage in scientific writing practices. The emphasis of this analysis will be how the activities functioned during the enactment.

I identified four activity groups within Nicole's enacted activity sequence. In the Introduction activity group (Activities 1 – 4), Nicole introduced the unit to the students, conducted a pre-assessment, and elicited students' initial ideas about sound. The Vibrations activity group (Activities 5 – 12) focused on exploring and explaining vibrations. The Pitch activity group (Activities 13 – 16) focused on properties of sounds. Finally, the Application activity group (Activities 17-20) provided students with many opportunities to practice using what they learned in the Vibrations and Pitch activity groups.

In this section I will describe how the four parts of Nicole's enacted activity sequence met the analysis criteria of establishing a central question, providing experiences with phenomena prior to explanations, making patterns explicit, providing opportunities for application, and considering the intellectual and cultural resources of her students.

Establishing a Central Question

Nicole began the Introduction activity group with a TWL chart (Activity 1) in which students shared in a whole class setting what they thought they knew about sound (T) and what the wanted to learn about sound (W). They were supposed to return to the chart at the end of the unit to share what they had learned about sounds (L). Nicole then gave students plastic whistles to explore (Activity 2 Exploring Whistles). She asked the students to figure out how the whistles made sound. After a loud 10 minutes in which students were blowing their whistles in the classroom, Nicole had the students write down their ideas about how the whistles made sounds and then share their ideas with the whole class. She explained that she wanted the whistles activity to be a pre-assessment. "It was really to get them thinking about, "What's that ball doing inside the whistle?'" (Nicole Interview, 4/13/2007) Activity 2 (Exploring Whistles) was also important in the Vibrations activity group, as I will describe later.

Next, Nicole led the students on a sound hunt (Activity 3). The class walked silently around the school and then outside the school, recording all the sounds, both new and familiar, that they heard. After returning from the sound hunt, Nicole held a whole class sharing session in which the students made a master list of all the sounds that they heard on their walk (Activity 4 Whole Class Sharing). Activity 3 is the activity that Nicole and Dominique identified in their planned instructional approach as functioning to provide a sense of purpose to the unit. Nicole said she wanted the activity to get the students thinking about all of the sounds that they hear and begin getting used to writing in science.

> I just wanted them to just like write down everything. I just wanted them to just do it [write] constantly because I wanted them to pick up on minute sounds that they are not used to. Like I really wanted to get past the, "Oh, I heard talking, and I heard." I wanted to get like to the ones [sounds] with the fan in the lunchroom and the boiler room. Those were the ones that we really wanted them to get. (Nicole Interview 4/13/2007)

In the enacted activity sequence, Activity 3 functioned to familiarize students with the phenomena they would be exploring in more detail in the unit. It provided the context of the sounds they hear everyday in which students could later situate the specific instances of whistles blowing, tuning forks humming, and drums beating. I coded Activity 3 as an Explore & Investigate stage activity (green) because it involved exploration of a phenomenon and collection of data. I also coded Activity 3 as an Engage stage activity (yellow), because the exploration also met Nicole's intention of providing a broad context and purpose for the unit. Providing experiences to serve as a context for understanding a central question does fit the intentions of I-AIM.

Throughout these four activities, Nicole did not ask the students the central question about how the drum in a parade makes a sound that she and Dominique identified in their learning goals. However, in Activity 2 (Exploring Whistles), Nicole did ask the students to try to figure out how the whistles made sounds. In subsequent activities in the sequence, Nicole would ask the students variations of the question she asked in Activity 2. In a generic form, the questions were, "How are sounds made?" and "How do we hear sounds?" These questions were always asked in the context of a particular object making a sound. For example, "How does that [trumpet, tuning fork, whistle, guitar, etc.] make a sound?" and "How can we hear the [trumpet, tuning fork, whistle, guitar, etc.]?" Furthermore, all of these specific examples fit together to support the overall task of figuring out how sounds are made. By the end of the unit, most students, when asked, would readily describe how a trumpet or a guitar or a drum made sound. Their ready response suggests that they had come to understand that they were expected to be able to answer these types of questions. When I asked Nicole about this situation, she explained,

> I don't think that we ever really came out and were just like, asked them to answer that one thing… We started with one tuning fork, we started with one drum and like how it affected other objects like the rice or what not. And we started with 2 tuning forks, and we started with two drums, and we started with cups. And then by the time they understood one thing makes another one vibrate, it was like, not only could we give them the drum question, it was like, well we could talk about anything, like how am I hearing the chime that we ring for making a line, or whatever. So it was like we could apply it to anything. So I think because we took it pretty

systematically like, there wasn't a day when we really just dropped the question. We arrived at it, I think. Which I don't know if that was what was supposed to happen, but we just kind of came to it. And then they could apply it to the drum, but they were able to apply it to a bunch of other stuff. (Nicole Interview, 4/11/2007)

Later, in the Pitch activity group, Nicole established a new question, "How are sounds different from each other?" In Activity 13 (Exploring Pitch), Nicole played audio clips of various sounds she downloaded from the Internet and asked students to describe how the sounds were different. Like Activity 2 (Exploring Whistles), Activity 13 asked students a specific question in the context of the exploration of a phenomenon. Nicole was then able to springboard from this activity to explore the property of pitch.

At the beginning of her unit, Nicole emphasized engaging students in the topic of study by piquing their awareness of sounds and eliciting their ideas about sound. She did not explicitly establish the central question she wrote in her learning goals, but through her teaching of the unit, she repeatedly established two variations of the question within the context of specific sounds and drew connections across these instances to establish the tasks of figuring out how sounds are made and explaining how we hear sounds. Similarly, in her activity group on pitch, Nicole established a question in the context of the exploration of a specific phenomenon.

Experience – Patterns- Explanations

The Vibrations activity group (Activities 2, 5-12) addressed how objects make sounds and how we hear the sounds that objects make. Activity 2 (Exploring Whistles) was also part of the Introduction activity group. However, the activity played an important role in explorations of vibrations, so it is also included in the Vibrations activity group. The Pitch activity group (Activities 13-16) addressed identifying high and low pitch. In both activity groups, the activities Nicole included followed the pattern of providing experiences with phenomena, followed by providing opportunities to learn the patterns and develop and understanding of scientific ideas. Tables 6.3 and 6.4 show the I-AIM activity function pattern these activity groups.

Table 6.3

Vibrations activity group of Nicole's enacted activity sequence

Activity group	Activity number	Activity label	I-AIM stage (color code)	Activity function (color code)
Vibrations	2	Exploring Whistles	Explore & Investigate (green)	Explore phenomena (sea green)
				Explore student ideas (light green)
	5	Snare Drum	Explore & Investigate (green)	Explore phenomena (sea green)
				Explore student ideas (light green)
	6	Coffee Can Rice Drums	Explore & Investigate (green)	Explore phenomena (sea green)
				Explore student ideas (light green)
	7	Review Snare Drum	Explain (blue)	Develop student explanations (dark blue)
				Introduce scientific ideas (light blue)
	8	Exploring Tuning Forks	Explore & Investigate (green)	Explore phenomena (sea green)
				Explore student ideas (light green)
	9	Group Sharing	Explain (blue)	Develop student explanations (dark blue)
				Introduce scientific ideas (light blue)
	10	Two Tuning Forks	Explore & Investigate (green)	Explore phenomena (sea green)
				Explore student ideas (light green)
	11	Group Sharing	Explain (blue)	Develop student explanations (dark blue)
				Introduce scientific ideas (light blue)
	12	Cup Phones	Apply (purple)	Practice with support (model & coach) (violet)

Table 6.4

Pitch activity group of Nicole's enacted activity sequence

Activity group	Activity number	Activity label	I-AIM stage (color code)	Activity function (color code)
Pitch	13	Explore Pitch	Explore & Investigate (green)	Explore phenomena (sea green)
				Explore student ideas (light green)
	14	Explore Pitch	Explain (blue)	Introduce scientific ideas (light blue)
	15	Bottle Xylophones	Explore & Investigate (green)	Explore phenomena (sea green)
				Explore student ideas (light green)
	16	Group Sharing	Explain (blue)	Develop student explanations (dark blue)
				Introduce scientific ideas (light blue)

Experiences. The Vibrations and Pitch activity groups relied on providing experiences with phenomena (sea green). The Vibrations activity group began with the students exploring plastic whistles (Activity 2 Exploring Whistles). Nicole asked the students to play with the whistles and figure out how the whistles made sound. The whistles were made of clear plastic, so the ball inside was clearly visible. While this activity functioned as one of Nicole's preassessment activities, Nicole also recognized that the whistles played an important role in providing experiences with vibrations that her students could later draw on when identifying the key pattern that objects that make sounds vibrate.

> They eased into vibrations so much more because they had that little preassessment with the whistle before we moved in and throughout the whole lesson we kept referring back to the whistle. "Remember when we first gave you that whistle? Remember? How is it like the tuning fork? How is it like the drum? What is going on?" So it was able to not be part of the main unit, but yet it kept being filtered back in. (Nicole Interview, 4/13/2007)

Nicole followed the whistle activity with many additional experiences with sounds and vibrations. They investigated the sound of a snare drum (Activity 5). Nicole had the students place their hand on the drum so that they could feel the vibrations the drum made when it was hit with a drumstick. One student said that the drum felt, "Like little worms going through your body." (Nicole Teaching Video Transcript, 2/20/2007). The students then made their own drums from coffee cans and plastic wrap (Activity 6 Coffee Can Rice Drums). They put rice on top of the drums to see how the rice bounced when the drums were hit with the drumstick.

Nicole then transitioned into experiences with tuning forks (Activity 8 Exploring Tuning Forks). First, they explored what happened when one tuning fork was hit. They listened to the tuning forks, explored what was needed to make it hum, and watched what happened when a vibrating tuning fork was placed in a cup of water. Nicole considered the tuning fork experience to be a pivotal for the students.

> They need to be able to hear the sounds and feel the vibrations at the same time to know that they are existing in the same, you know, frame. So, a tuning fork just does such a great job of doing that. (Nicole Interview, 4/13/2007)

Next, students explored sounds using two tuning forks (Activity 9 Two Tuning Forks). They tapped one tuning fork to hear it hum, and then held it near another tuning fork until that tuning fork also began to hum. Nicole explained,

> That was the next step. We were like, if they are going to make it to how does one thing cause another thing to vibrate, then we've got to baby step it up. So we went from how a tuning fork can vibrate on its own, now we are going to test the effect of it on something else. So that is when we, they worked with two tuning forks.

In the Pitch activity group, Nicole was running short of time, so she abbreviated her planned instructional approach. However, she still included important experiences with pitch in Activity 13 (Explore Pitch) and Activity 15 (Bottle Xylophones). In Activity 13, Nicole collected from the Internet many digital recordings of various sounds. She played the sounds for the students and asked them how the sounds were different from each other. In Activity 15 students explored the pitch of the sounds made by a real xylophone, and then made a model xylophones out of bottles filled with various volumes of water.

In both the Vibrations and Pitch activity groups, Nicole provided students with many examples of the phenomena. Students explored many examples of objects vibrating when they make a sound, one vibrating object making another object vibrate, and sounds with various pitches.

Patterns. In both the Vibrations and Pitch activity groups, Nicole elicited student ideas about their experiences with phenomena (light green) by having students write about their experiences in their science journals. She then brought the students together to share what they had observed. In these group sharing activities (Activities 7, 9, 11), Nicole had students share their ideas about the experiences and then she carefully guided students to seeing the patterns in their experiences. For example, after sharing their experiences with one tuning fork, Nicole lead students to identify the pattern that sounds make vibrations (Activity 11 Group Sharing).

1 Nicole: Ok, now, what happened when you hit it [tuning fork] and you put it in the cup of water? Annie, what happened?

2 Annie: It comes out everywhere.

3 Nicole: It came out everywhere. And Annie had a good example. She hit it and she put it in the cup of water and it splashed everywhere. Why did it splash everywhere? I should see everyone's hands up.

Why did the water splash everywhere? What was happening to make the water splash everywhere? Dean?

4 Dean: It was vibrating and but it felt like I was in a race car. Starting a car.

5 Nicole: So, Dean just said it was vibrating. So, when it was vibrating in the water, the vibrations caused the water to splash everywhere. So, that is how we know that the vibrations are really there because we can feel them and we can see the water splash. Ok, we have to go back over things. We've had vibrations happening to us a lot. So, what happened with the whistle?

6 Students in chorus: It vibrated

7 Nicole: What happened with the drum?

8 Students in chorus: It vibrated

9 Nicole: What just happened with the tuning fork?

10 Students in chorus: It vibrated

11 Nicole: Ok, so there is something with sound

12 Students in chorus: Vibrations

13 Nicole: There is something with sound that involves vibrations.

(Nicole Teaching Video Transcript, 2/22/2007)

In these discussions, the class came to agree on the two patterns in the Vibrations activity group: 1) Something that makes a sound vibrates and 2) one thing vibrating can make another thing vibrate. The students were able to agree on these patterns because they had had many opportunities to explore phenomena and see the patterns across many examples. The same thing happened in the Pitch activity group in Activity 16 (Group Sharing) following the exploration with the xylophone instrument and the bottle xylophone.

> The pattern [we] are pushing the students to arrive at is, "The less water in the glass, the higher the pitch and the more water in the glass, the lower the pitch." In order for students to arrive at the pattern themselves as scientists, they must be provided with an array of different learning experiences that promote a similar pattern. (Nicole Lesson Plan, 3/20/2007)

Explanations. Nicole's use of and work with explanations was subtle. She focused on helping students use patterns to answer questions about sound. Her teaching style involved subtle moves to connect student ideas to scientific ideas.

In the EPE framework, scientists' science explanations are the big ideas, models, and theories that account for many patterns from millions of data points and experiences (Anderson, 2003). In I-AIM instructional approaches, the explanations required to answer the central question often explain what happens in a particular instance of a phenomenon. Especially at younger levels, the goal is not to necessarily develop the scientists' science explanations, but rather to help students understand and use the patterns. The explanations involved are really the introduction of scientific ideas to help frame and establish the patterns. In Nicole's case, she was working to help students learn how to use patterns about vibrating objects to answer questions about how certain objects make sounds and how we hear particular examples of sounds. As she came to realize while clarifying her learning goals, she was not intending, at the second grade level, to explain the molecular model that accounts for the patterns, or even to explain the idea that air can vibrate to transmit sounds. These ideas would be explained later in the K-12 progression. Nicole's focus was to help students understand and use the patterns that some day would help them make sense of the scientific models that explain sounds. However, even though it was not her purpose to provide high level scientific explanations, Nicole's unit did involve helping students identify and use scientific ideas, both functions which fits the Explain stage (blue) of the I-AIM model.

Students do not usually invent scientific explanations directly from experience. They need guidance and sometimes explicit instruction to help them see patterns in experiences and understand how explanations account for patterns or how patterns can be used to explain particular instances of a phenomenon. Nicole was serving this function in her teaching by leading students to a group consensus on what the patterns were and how the patterns could be used to explain how we hear sounds. During the whole class discussions that followed each exploration, students shared their ideas about the patterns, but they were also beginning to put the patterns together in a way that would answer the questions about how sounds are made and how we hear sounds (dark blue). At the same time, Nicole was picking out the important points that the students made, labeling them (i.e. vibrations), and elaborating on the phenomenon or the pattern. In this way, she was introducing scientific vocabulary and making scientific ideas explicit to the students, helping them to make sense of their experiences (light blue).

Although Nicole sometimes did challenge and test student ideas, her teaching style relied on these subtle moves to help students make important connections. These moves were so subtle, in fact, that Nicole herself did not recognize that she was serving the Explain stage functions, a situation I will explore further later in this chapter. The important point here is that in the planned instructional approach, Nicole and Dominique did not identify any activities that fit the Explain stage functions. Yet, in her enactment, Nicole was taking the necessary teaching steps to help students connect their ideas to scientific ideas. By the end of the sequence of activities, Nicole had helped students connect the patterns they had learned about vibrations to what they had just learned about the ear drum in a recent health unit on the ear in order to explain how we hear sounds. During a class discussion, Annie offered this explanation, "Because after something you hear goes to your ear drum it vibrates and then it goes into your brain." (Nicole Teaching Video Transcript, 2/20/2007)

Opportunities for Practice

Nicole provided many opportunities for students to practice using the patterns they had learned to explain how many different objects make sound and how people hear the sounds. The first opportunity for practice came at the end of the Vibrations activity group. In Activity 12 (Cup Phones), Nicole had students play with "telephones" made from two plastic cups strung together with fishing line. A student holding a cup to her ear could hear clearly the voice of another student talking into the cup at the other end of the taut fishing line. Nicole then had the students use the patterns they had learned about vibrations to explain how the first student could hear the second student talking. By this point in the unit, students had learned how to use the patterns to explain how we hear sounds. This activity provided students with an opportunity to practice using the patterns in a new situation. Nicole coached students as they worked through the development of the answers together in a whole group setting.

Later, in the Application activity group (Activities 17-20), Nicole provided additional opportunities for students to practice explaining how sounds are made and we hear sounds. In Activity 17 (Marshall Music), Nicole and Dominique planned a field trip to a large local music store. The music store staff gave the students an introduction to and performed many types of instruments. Then, in small groups with adult chaperones, the students toured the store. I was able to participate in the field trip and chaperoned a group of five girls as we looked at pianos, guitars, drums, and many other instruments. At each instrument, I asked the girls how the instruments made sound. At the guitars the girls told me the strings vibrated. At the drums they told me that the top of the drum vibrated. Nicole explained how she thought this field trip functioned in the I-AIM model.

> I think the best part was the fact that they let us go around that entire store. Like the kids couldn't really touch the instruments, but that we took the small groups and we just talked about them. So, like the kids could look inside the piano and then I would just quiz them. "Well, ok, they just said this hammer hit this string. Well what is the string going to do?" They are like, "Vibrate." And I was like, "If that is happening what else is happening?" They are like, "Our eardrums vibrate, that is how we hear." You know, and just to be able to go around and point to all the instruments. We saw a maraca, we saw a cymbal, we saw that little boy that got to play the electric guitar. That to me was the biggest part of the application process. (Nicole Interview, 4/13/2007)

Upon returning to the classroom, Nicole had students write in their journals about the instruments they saw, how the instruments made sound, and how we could hear the sound of the instruments (Activity 18 Journal Writing).

In another practice opportunity, students were assigned to build an instrument at home and bring it in to share with the class (Activity 19 Invented Instruments). Some students made guitars out of shoe boxes and rubber bands. One student made a trumpet from a straw and a paper cup. When he blew into the straw, the cup on the end of the straw made a kazoo-type buzzing. Many students made drums; one student made a gong. The students then had to present their instrument to the class and explain how the instrument made sound and how a person could hear the sound.

The culminating activity of the unit was the Sound Museum (Activity 20). Nicole and Dominique set up their classrooms as a museum. In the evening, students showed up at school with their parents to visit the sound museum. Inside the museum were all of the experiences with which the students had engaged during the unit, including the snare drum, the rice drums, the tuning forks, the cup phones, the xylophone and bottle xylophone, and all of the instruments that students had invented. Students received official scientists' name tags and a clip board with a checklist of fifteen experiences listed. Students were supposed to take their parents around to the different experiences, explain each experience, and then check the experience off their checklist.

About twelve students and their parents and siblings showed up at the sound museum. The students proudly showed their parents what they had done in their science unit and explained how the various objects made sound. Several students showed up with real instruments. Dean's dad brought a trumpet that several students tried to play. Dean was successful, after much blowing and puffing, at making the trumpet make noise. I asked Dean how he made the sound. He told me that he vibrated his lips, which made the air inside the trumpet vibrate and the vibrations came out the other end of the trumpet. He showed me that pushing the buttons on the trumpet made the trumpet make different pitched sounds. I asked him what happened next and he told me that the vibrations made his eardrum vibrate and then the sound went to his brain.

Annie's parents were interested in the cup phones. They were using the cup phones to talk to each other. At the same time, Annie was playing with a tuning fork. She hit the tuning fork on the table, then turned around and touched the tuning fork to the taut fishing line. Both parents had the cups to their ears and when Annie touched the fishing line with the tuning fork, both parents jumped back suddenly and said, "That was loud." They held the cups away from their ears and asked Annie to touch the tuning fork to the string again. This time, everyone in the room could hear the sound. I asked Annie what happened. She told me that the tuning fork vibrated, then that made the fishing line vibrate, which made the cups vibrate, which made our ear drums vibrate so we could hear.

Nicole was pleased with the results of the Sound Museum. Originally, she intended the Sound Museum to be just a celebration of the completion of the unit. However, she also recognized that the sound museum was an assessment of the students' learning.

> But then here is the test - can you talk about it? You know, like, we never gave them a written test. It was, bring your family, and then the families got to see what they were doing...But I think that was the true test. Like can you talk about it? You are the tour guide. Like if you didn't believe you were a scientist then, then you are now. You know, you've got this clip board, you've got this badge, and you've got to go do it. So, that is cool. Like can you talk about it. (Nicole Interview 4/13/2007)

Taking Account of Students

Nicole was able to take account of students' intellectual and cultural resources in her enacted activity sequence.

Accounting for students' conceptions. One of the naïve conceptions that Nicole identified from a preassessment that she did with tuning forks several weeks prior to beginning the unit was that many students believed that you would only get a sound from a tuning fork if you hit it on something hard. While this idea was not the main focus of her unit, Nicole did want students to understand that tuning forks made a sound when they vibrated. Furthermore, she wanted students to use the tuning forks to show that one thing vibrating can cause another thing to vibrate. In other words, she wanted the students to realize that the tuning fork did not have to be hit at all to vibrate if there was something else vibrating nearby that could make the tuning fork vibrate too. Nicole did not want the students to become distracted from this idea by focusing on how the tuning fork was made to vibrate.

During Activity 9 (Group Sharing - following Activity 8 Exploring Tuning Forks), Nicole asked her students what made the tuning forks vibrate. Several students insisted that the tuning forks only made a sound when hit on a hard object. Nicole gently challenged the students on this claim. First she asked the students if anyone had tried hitting their tuning fork on something that was not hard.

1 Nicole: Kevin says that he hit his tuning fork on something hard and that is why it made a sound. Did anybody hit it on something that wasn't hard? Emily?

2 Emily: My hand and a chapter book.

3 Nicole: Emily hit it on her hand and a chapter book.

4 Emily: Yeah and I hit it on a hard, big book.

5 Nicole: But it is softer than hitting it on a desk, right? And, Emily, what did you experience, what happened when you hit it on your soft chapter book?

6 Emily: It made a sound.

7 Nicole: So even though she hit is on something softer, it vibrated and she still heard a sound. Did anyone hit is on anything softer? Something else that was different from our desk?

8 Amy: Ashley's hair

9 Nicole: You hit it on Ashley's hair? And what happened?

10 Amy: It vibrated.

11 Nicole: So there we go Kevin. So when you hit it on something hard it vibrates. But Amy and Emily hit it on something soft and it did what?

12 Amy: It vibrated.

However, even after this careful guidance using evidence from students' experiences, the students were not convinced that hitting the tuning fork on something soft would also make the tuning fork vibrate. Amy continued,

13 Amy: But I meant like layers of soft things, not like one.

14 Nicole: Ok, you are saying the chapter book might have been a little bit harder just because it was layers. But what about Ashley's hair?

15 Amy: Yeah, well that is more like, that is more thicker than fluffy.

16 Nicole: So you are saying if we hit it on something fluffy we might not hear anything?

Finally, Nicole decided they should test the tuning fork by hitting it on something soft.

17 Nicole: Should we try it?

18 Amy: Like a pillow.

19 Nicole: Do you think if we hit it on Mandela [a large stuffed animal dog on the shelf] up there, that it would? Well, we gotta test it. I'm not sure if I could get through the whole day not knowing if we hit is on something soft. So we are bringing over our look alike dog [stuffed animal dog] and we are going to test it. Ok, Ms. Thomas, would you?

Nicole's mentor teacher, Annette Thomas, brought the stuffed dog over to the front of the room. Dramatically, she struck the tuning fork on the stuffed dog. Then, she held the tuning fork to the classroom microphone. A soft buzzing sound came through the classroom speakers.

20 Nicole: Did you hear it? Ok, Amy, what does that sound like?

21 Amy: I hear kind of a buzzing sound.

22 Nicole: She heard a buzzing sound. And that was hitting it on a soft stuffed animal. So, what do we know? Tyler?

23 Tyler: It can vibrate if it is on hard or soft things.

(Nicole Teaching Video Transcript, 2/20/2007)

In this example, Nicole carefully considered the students' naïve conceptions and then helped them test their ideas to revise their understanding of what needs to happen to make a tuning fork vibrate. Nicole had not planned to test the tuning fork on hard and soft objects, but once she realized that the students were not yet convinced that tuning forks did not need to be hit on a hard object to vibrate, she pursued their line of thinking by spontaneously creating experiences that would convinced the students otherwise.

In addition to considering students' naïve conceptions, Nicole also valued students' congruent conceptions as contributions to the class. She explained that the students went beyond her expectations several times by making conceptual connections she did not expect. For example, the students asked how we recognize the sounds that we hear. During a previous unit, students had learned about how the brain uses schemata to help it recognize and remember certain things. While Nicole would have been satisfied if students could explain that we hear sounds by using the pattern that one thing vibrating can make our ear drums vibrate, the students added that after the ear drum vibrates, the brain uses schemata to recognize and label the sounds. Nicole even went so far at that point as to invent an activity in which she played a bunch of sound clips and asked the students to identify the sounds.

> And my kids came up with the fact that well, "How do we know that when a bird's chirping, even though our eyes are closed we know it is a bird?" And then we brought in the whole idea of the brain. So I was like, "Well we've got to have some activities about that." So, that is when we brought in the whole play familiar sounds and try to guess... But, you know, they just came up with it. (Nicole Interview, 4/11/2007)

In these examples, Nicole carefully considered students' ideas and experiences in her teaching. When students were not convinced yet that tuning forks could start vibrating after being hit on something soft, Nicole challenged the students' ideas. Rather than contradict students, she valued their ideas and developed an experience to help them revise their ideas. When students made a connection that she was able to leverage, she took advantage of the situation.

Accounting for students' cultural resources for learning. Nicole also took advantage of many cultural resources that students brought to learning about sound. When I asked Nicole about what funds of knowledge she thought she was able to leverage, her first response was that she was able to leverage students' family relationships (Moje *et al.*, 2004).

> That was one of our biggest successes was the fact that we had so much family support. I don't know if that fits into that category, but lots of parents willing to take the time to come and basically go through all the activities. But they brought in instruments, they offered things, they were talking about it with their children. Because the children would come in and be like," Well I was talking to my mom or dad about such and such and you know." And they were talking about vibrations and stuff. So I was like, "Ok, so obviously they are continuing their work at home." So that is good. So we had a lot of family. (Nicole Interview, 4/11/2007)

Nicole also said she connected to students' interest in and knowledge of popular culture (Moje et al., 2004). For example, in Activity 13 Explore Pitch, Nicole found numerous sound clips from the Internet that she played for the students and then asked them how the sounds were different. Many of the sound clips she chose were from music with which the students were familiar.

> You could play them sound clips and ask them," What do you hear?" I mean you could take a favorite piece of music of theirs, and be like,

> "What sounds do you hear in it? Are they high, are they low?" (Nicole Interview, 4/11/2007)

In addition, Nicole was adept at incorporating experiences that students brought to learning. For example, in Activity 10 (Two Tuning Forks), students did lots of experimenting on their own with their tuning forks. One student stuck a tuning fork in a cup of popcorn left over from snack and was amazed when the popcorn jumped out of the cup. Another student held a humming tuning fork next to a sheet of paper and was surprised when the paper buzzed. A third student touched the tuning fork to the plastic whistle and noticed that the ball inside the whistle moved. Nicole quickly incorporated those experiences into the list of experiences that the whole class used to identify that one thing vibrating could make another thing vibrate. In fact, Nicole included all of these experiences in the Sound Museum and expected the students to explain the phenomena to their parents. At the end of the unit, Nicole noted that she learned to value what her students contributed and came to expect that her students would make contributions she never considered.

> Like that is what I took away with me was, [you] gotta raise the bar. Don't underestimate like even a second grader, even a first grader...They are going to come up with stuff you never thought of, even if you sit there planning for an hour what they could come up with, and then you'll get to that like final goal like the way you intended. (Nicole Interview, 4/13/2007)

Summary of Nicole's Enacted Activity Sequence

Table 6.5 summarizes the analysis of Nicole's enacted activity sequence compared to the intentions for I-AIM and CA&P.

Table 6.5

Summary of analysis of enactment for Nicole

Tool	Analysis Foci	Nicole
I-AIM: EPE	• Establish a Central Question • Experiences before Explanations • Patterns made explicit • Opportunities for Application	+ Central question established + Many experiences with phenomena + Explanations after experiences + Patterns made explicit + Many opportunities for application
CA&P: Taking Account of Students	• Consider student conceptions • Consider student cultural resources	+ Consideration of student conceptions + Consideration of student funds of knowledge and experiences

+ matches intended use of tool feature – does not match intended use of tool

Nicole met all of the criteria for meeting the intentions for the I-AIM and CA&P frameworks. Although she did not explicitly establish the question she and Dominique identified in their learning goals, she did repeatedly ask the students how sounds are made and how we hear sounds in the context of specific examples of phenomena. Nicole provided many experiences with phenomena, helped her students learn the patterns that the experiences illustrated, and provided scientific information about the phenomena only after the students had engaged in the experiences. Nicole used subtle guidance to lead her students to see the patterns and use the patterns to describe how various objects make sounds and how we hear the sounds. Furthermore, she carefully and respectfully considered students ideas, both naïve and congruent, and incorporated their ideas into her instruction. She developed activities to either challenge their naïve ideas or reinforce their congruent connections. She was also adept at incorporating students' conversations with family, knowledge of and interest in popular music, and experiences with phenomena into her activity sequence. In the next section I will consider some reasons why Nicole was able to use so many of the I-AIM features in her instruction.

Mediators for How Nicole Used I-AIM/CA&P and EPE

Nicole's unit was a success. Her activities matched many of the I-AIM functions and intentions. The students were engaged in the learning and contributed to the direction and content of the activities. Nicole chose to use the Activity 19 Invented Instruments as her post-assessment. She evaluated the instruments and the students' explanations of how the instruments made sound and how people hear the sound.

> The results of this post-assessment were outstanding. There were several sub-categories, including the actual instrument construction (including something that vibrates), a demonstration, and a description. One-hundred percent of the students included a vibrating element in their instruments. One-hundred percent of students were able to demonstrate how their instruments produced vibrations and describe those vibrations. Eighty-five percent of the class was able to discuss the effect of the instruments' vibrations on our eardrums and the resulting sounds we heard. (Nicole Post- Assessment Assignment, 5/6/2007)

Analysis of Nicole's case suggests that the interpretations that Nicole made of the central question and the I-AIM stages facilitated her successful use of I-AIM in her planning and teaching. Some aspects of Nicole's meaning for the I-AIM stages did not match exactly the intended meanings of I-AIM. However, Nicole's meanings were not at cross-purposes with the I-AIM meanings and in many cases were close enough to the I-AIM meanings that she was able to plan and teach science activities in a way that matched both her purposes and the intentions for the I-AIM. Nicole's mentor teacher also played an important role in supporting Nicole's interpretation and implementation of

I-AIM. In this section I will discuss Nicole's interpretation of the central question and the I-AIM stages and how they mediated her successful teaching of her unit.

Grasping the Role of the Central Question

The learning goals assignment that Dr. Adams had interns complete asked the interns to identify the unit benchmarks from the state curriculum framework, the associated practices that described what students would be able to do with the science content knowledge, an Experiences-Patterns-Explanation chart for the benchmarks, and a central question with model response that would frame the unit. For many interns, the relationships among these parts of the learning goals assignment were not always evident. They may have seen them as discrete parts of the assignment. Nicole, however, recognized how the parts fit together.

> There's got to be focus. There has got to be this core thing that you are working at. It is your central question, but it is your goal, it is your, it is what you want to assess, it is what you want your kids to know by the end. This central question, it is like huge. So I would say central question. And everything has to be really pertinent to that central question. Don't include anything that is not. It is like your engage, your explore, your apply, it is all gotta be tied into that central question. Don't like throw some "Eggs Full of Sound" in there if it has nothing to do with your central question. (Nicole Interview, 4/11/2007)

To Nicole, the central question represented the learning goals and the key patterns all wrapped together. She explained that the central question helped her and Dominique figure out what content to teach and how to focus their instructional approach. She credited Dr. Adams with helping them identify the central question and key patterns.

> But really it made sense when he [Dr. Adams] was like, "Start with a central question." And that is when we figured out, by the time these students walk out of here, that when one thing vibrates, it causes another thing to vibrate. So then, everything started to working around that. We'll start with vibrations, then we'll do more and more experiences with vibrations, then finally, you know we'll do, ok, making another drum vibrate. A tuning fork make another tuning fork vibrate. Then we are going to substitute in the ear model for one of the drums or one of the tuning forks. So that is when, that is when, once we had the central question, that became when we wanted them to know. Before that, at least for me, and Dominique might have had a different vision, but mine was really fragmented, really fragmented. (Nicole Interview, 4/11/2007)

Nicole's mentor teacher, Annette, also provided important guidance. Annette emphasized the importance of the central question and the learning goals in planning and teaching science. She explained the importance of the central question in her own planning and teaching science,

> I really like to come back to a central question. We really like still beginning with a central question instead of, "These are the objectives we're going to cover." It is a question that we think is relevant to the kids and connects really directly to what the objectives are. (Annette Interview, 3/9/2007)

Annette also emphasized how closely she followed the learning goals, which she calls "objectives" during her own instruction.

> We really keep those objectives out in front of us. We really stay really focused on those objectives. Because you can go off and put a lot of time

> into a lot of activities that don't contribute to the objectives. So that really is our guiding light. (Annette Interview, 3/9/2007)

Furthermore, Annette explained, she had specific expectations for Nicole's science unit.

> That it would very specifically address the, the activities that they did develop would very directly support the objectives. And that none of the time, none of the activities would be peripheral, off on a tangent from the objectives just because they were related but fun. None of that. (Annette Interview, 3/9/2007)

Thus, Nicole had converging support from her science methods course instructor and her mentor teacher to help her develop a sophisticated understanding of the central question. She recognized the role that the central question provided in focusing a unit on the learning goals. She also recognized how the key patterns fit with and supported the ideal response to the central question. These understandings helped Nicole plan and enact a science unit in which all of the activities fit together cohesively and coherently into a tidy package that supported students in achieving the learning goals.

Interpreting Engage as Creating Excitement

Nicole stated in an interview that one of the things she learned from her experiences planning and teaching her science unit was the importance of the Engage stage.

> So like having those first few days where we just got them really excited about sound. We weren't even doing the exploration yet. We were just experiencing sound, and making predictions and getting them excited and being like, this is what we are going to start on tomorrow. And so they got totally pumped for it. And we took the time to get them excited and the time to get them ready for what we were going to do. We weren't just like,

yeah, we're studying sound...It has to be Engage is just a whole separate thing. (Nicole Interview, 4/11/2007)

Nicole's meaning for the Engage stage reflects a common desire among elementary preservice teachers to make science fun and exciting for students (Abell *et al.*, 1998; Schwarz et al., 2008). It also was also a meaning that was supported by Annette. Although her first criterion for selecting and using activities was that it had to meet the learning goals, one of her other criteria was that activities should be fun and exciting. For example, Annette described the types of curriculum materials she liked to use when selecting activities for her own science units.

> You know you can get thematic unit books and you can thumb right away and tell if it's got relevant, fun, good activities that will be easy for the kids to visually understand as opposed to something that looks like these Battle Creek books. I mean, really, look at these Battle Creek books. Now this AIMS, you look in here and you think, "Oh, look at that. Oh my gosh, that would be fun. And the kids could do that." You know, we pick and choose. We do this Little Brown Seed. We sing songs, we do. And then you open up this [Battle Creek] and think how much fun is this? I mean, just look. (Annette Interview, 3/9/2007).

Furthermore, Annette said her expectations of Nicole's unit were, "That it is hands-on, that it is fun." (Annette Interview, 3/9/2007).

The Engage stage of the I-AIM functions to establish a question to investigate during the unit. This question is intended to establish for students a purpose for learning (Kesidou & Roseman, 2002). As described above, Nicole did introduce a central question in the Introduction activity group when she asked the students how the whistle makes a sound, but to Nicole, that was not the only purpose of the Engage stage. Nicole also interpreted the Engage stage as important for creating a sense of excitement about the unit. Creating a sense of excitement and establishing a purpose are not necessarily the same functions. One could create excitement without establishing a purpose for being excited. However, in this case, possibly because she also had a solid grasp on the importance of aligning all activities with the central question and learning goals, Nicole's interpretation of the Engage stage enabled her to include activities in her planned instructional approach and enacted activity sequence that functioned to create excitement and interest, and establish the central question.

Interpreting Explore & Investigate as Authentic Science

Nicole interpreted the Explore & Investigate stage as involving her students in authentic science. She wanted her students to be scientists and she placed a high value on engaging students in real science activities. For example, when the interns were assigned to develop a project that focused on fostering a science learning community, Nicole chose to focus on incorporating writing into her unit because she saw writing as an authentic scientific practice.

> And, we really wanted them to understand like that it is what real scientists do. You've got to get it down on paper…Like that is so important. And just realizing that they are real scientists, they are out there exploring, so if you are coming up with those ideas, you gotta get them down. And kind of just making them more confident, I guess. You know, like making them more just feel better about what they are doing. And really taking science more seriously. (Nicole Interview, 4/11/2007)

Nicole also incorporated the field trip to Marshall Music into her unit was because she saw field work as something that scientists do.

> And to get them [the students] to the idea that scientists do field experience. And they have got to go out there. And it doesn't matter that

> you are in second grade. We are going out there. (Nicole Interview, 4/11/2007)

During the Science Museum, Nicole gave each student a name tag that said "Scientist Dean" or "Scientist Amy" or "Scientist Todd." She said she wanted them to be able to talk to their parents like scientists. "Like if you didn't believe you were a scientist then, then you are now. You know, you've got this clip board, you've got this badge and you've got to go do it." (Nicole Interview 4/13/2007)

Closely associated with positioning students as real scientists and engaging them in scientific practices was Nicole's insistence on providing realistic experiences, instruments, and materials. For example, Nicole was at first reluctant to use the Coffee Can Rice Drum activity (Activity 6) because she did not think that drums made from coffee cans were real drums. She solved this problem by having the Coffee Can Rice Drum activity follow the Snare Drum activity (Activity 5).

> [Using the snare drum was] putting it in a real context where it was something they had seen before, something they had probably used in music class, that sort of thing. And it was something where the kids could construct an activity that resembled an actual drum. So like, we had an actual drum there, the actual snare drum. And then the kids were able to construct something that resembled it closely, so it is like their activity wasn't that far off from the real deal...I think you can have the real drum there and the fake, the home made one. Then it is cool because they can parallel them. But if you are just making rice drums, like, it is not as realistic. (Nicole Interview, 4/13/2007)

Similarly, Nicole liked using the tuning forks because they were "real scientific device[s]" (Nicole Interview, 4/13/2007).

Nicole's emphasis on positioning her students as scientists, engaging them in scientific practices, and providing realistic experiences influenced the types of experiences she provided for her students in the Explore & Investigate stage of I-AIM. The Explore & Investigate stage of I-AIM is founded on the EPE principle that in inquiry, experiences should involve explorations of phenomena. Although Nicole never used the word "phenomenon" or defined experiences with reference to events that can be observed or sensed, her insistence on real examples and real practices meant that the experiences she provided were experiences with phenomena. Furthermore, EPE and I-AIM are about engaging students in the scientific practices of inquiry and application, as well as the other scientific practices involved in inquiry and application, such as asking questions, making hypotheses, designing experiments, making observations, etc. Nicole's insistence on having students write as scientists fit the intentions for the EPE framework and the I-AIM tool perfectly.

Resisting Explain

Nicole's focus on engaging students in scientific practice meant that Nicole quickly grasped the difference between school science and scientists' science. Throughout her planned instructional approach and enacted activity sequence, Nicole always provided students with experiences before they discussed patterns or used the patterns to explain phenomena. However, Nicole's version of scientists' science also had an element of discovery.

> Instead of school science it is scientists' science so they are actually doing the exploration before they are asked to like, define it. We are not going to define it before we experience it. So, as much as I wanted to tell them, like, "Hey pitch is this", it had to be like, "Let's listen to like 10 different pitches" and then, you know, really hoping, like ok, trusting the

students to be serious scientists and really process it and they did. One little girl was like, "That one is high. That one is low." There is one student out of all of them. We were doing it for like 15 minutes and finally one was like, "That one is higher." And what does that make the other ones? I didn't give it to them. And then for the rest of their lives it was their own. It started as their own thing. So I feel like school science, scientists' science. Don't define it right away, don't give them the textbook terms, don't spew the information out. Just set them free for the exploration with some structure, some guidance and then. (Nicole Interview, 4/11/2007)

A common naïve conception of the nature of science is that explanations stem directly from the data (Abd-El-Khalick & Akerson, 2004; Abd-El-Khalick *et al.*, 1998; Lederman *et al.*, 2002; E. L. Smith & Anderson, 1984). Contrary to the intentions for I-AIM, Nicole believed that scientists discovered explanations. She wanted her students to also make discoveries, and in this way, they would come to own their new understandings.

Nicole also placed an emphasis on logical organization of experiences. She believed that a good instructional sequence would provide the structure to help students make connections among the activities to understand the underlying concept. "It has to be systematic, it has to be step by step. Everything has to be clear and concise and it has got to make sense" (Nicole Interview, 4/11/2007). In her first interview, Nicole spoke of wanting the activities to be laid out in a logical sequence so that at the end of the unit, students could trace how they got from one idea to the next.

What would be so cool if like they learned like all the different pieces of sound and just were kind of able to, I guess, just to put them in a order. Maybe not like this is what we learned day one, this is what we learned day two. But like, at the beginning of our timeline we have our radio at home and then next comes that we know that it is vibrations. Like sound is vibrations. And then the next part is, you know, just kind of having them piece together a puzzle of the content we talked about. Like with something being produced. Like this is the timeline of it being produced. This is what it starts off as and here's when it goes on. (Nicole Interview 1/17/2007)

In I-AIM, the Explain stage functions to provide scientific explanations for the patterns that students learn through their explorations with experiences. Sometimes, teachers explicitly provide the scientific explanations. At other times, teachers may be able to carefully build on student ideas to guide students to a new understanding. Nicole preferred the second approach and resisted the former approach. Even when she was challenging student ideas, as she did when she had the students test whether or not the tuning fork would make a sound when struck on something soft, Nicole saw herself as guiding student ideas to discovery rather than offering explanations for experiences.

I wanted my role to be that I was just the facilitator. Really just being like, "Oh, so who agrees, who disagrees? Say more about that." But like, I felt like I was trying to guide them to recap as much as what happened during that exploration time when they were all over the room...So really trying to just get as much, like into the boat, like, "What did you experience? What did you experience? What did you experience?" So that we could work our way to the patterns...So my, I felt my role was just to maximize the student response... And then...use like the probing questions, "Well, what do all those have in common? You know, what did so-and-so's have in common that yours had in common? Well how is that related to this next person?" So I felt like I was, I felt like I was funneling them towards what I wanted them to get at...I was just kind of guiding them towards the

> door that I was hoping they'd reach...So, they got themselves there, not me. So, they deserve the credit. (Nicole Interview, 4/13/2007)

Nicole resisted providing explicit information to explain student experiences. For example, in Activity 12 (Cup Phones), students were supposed to use the patterns that they had identified to explain how "telephones" made from plastic cups and fishing string worked. Students initially said that there was a hole in the string through which the sound traveled. Nicole was frustrated because as long as the students believed there was a hole in the string, they would not use the pattern of one thing vibrating can make another thing vibrate to explain how the telephones worked. Nicole finally told the students that there was no hole in the string. She believed she had made a grave teaching error in doing so.

> I didn't like telling them that. I didn't like saying that, "I was going to find out, prove you're wrong, right now." Because with the other stuff if was like we had so many experiences that were guiding us to the pattern. And then here, it was like, "Oh boy, well I am just going to come out and tell them that there is no hole." It just kind of felt like I was putting the kibosh on it. You know, like, "I hate to break it to you, but." Where as with the tuning forks, they pretty much led themselves with my questions towards the pattern. (Nicole Interview, 4/13/2007)

Nicole's focus on providing a logical flow of activities that facilitated student discovery and her resistance to providing explicit explanations explains why she and Dominique did not identify any Explain stage functions in their planned instructional approach. Nicole thought that explanations had to be explicit telling, and since she did not plan to provide any explicit explanations, she did not identify any of her activities as Explain stage activities. She did not recognize that the guidance she planned to facilitate student thinking was a form of explanation that fit I-AIM. In Nicole's teaching, she did provide some of the scientific information that was necessary to help her students connect their experiences to scientific information, but these moves were subtle and Nicole may not have recognized how they were serving the Explain functions. In a more complex unit at a higher grade level, Nicole might not be as successful if she resists explicitly offering scientific information when necessary.

Understanding Apply as Real Life

Nicole's focus on providing students with real experiences also influenced the meanings she made of the Apply stage. For Nicole, the Apply stage was about connecting science to and helping student use their new science knowledge in the world outside of school. In her science philosophy statement, Nicole stated, "Science teaching must allow opportunities for application, particularly to aspects of the outside world so that students see how science relates to them" (Nicole Science Philosophy Statement, 4/26/2007). Similarly, in her post-assessment and post-teaching analysis and reflection, Nicole stated that the "'application' phase of I-AIM is of a higher caliber. Students are pushed to test their knowledge by using it in reference to a real world experience and make connections. As a result, they expand their knowledge" (Nicole Post-Assessment Assignment, 5/6/2007). Furthermore, when talking about taking students on the field trip to Marshall Music, Nicole said,

> We're like take them some place where they are going to be at home talking about like this is how it really applied to their everyday life. A field trip should take them out of the school setting. And even though I am trying to bring as much as I can into the classroom, this is how it applies to real life. Unless I can really get them out there and be like "Ok, look at this. This is what is happening in your real life," then it is going to make that connection so much stronger. (Nicole Interview, 1/17/2007)

In I-AIM, the main function of the Apply stage is to provide students with practice using explanations in new contexts (Collins *et al.*, 1989). Nicole recognized the importance of practice in student learning. She also interpreted the Apply stage as functioning above and beyond merely providing practice.

> They have to explore and have like experience after experience after experience after experience and then towards the end of your unit you have to say, "You know, our expectation is that you can take all this information and then go to Marshall Music and just walk around the store and just talk about instruments we've never even covered, but yet you have an idea of how those instruments work." And so that was, that was just really different. Like apply wasn't just something daily. They were exploring daily, they were practicing daily, they were getting immersed in it and then applying was coming. (Nicole Interview 4/13/2007)

Nicole's statement points to a perspective that science instruction is not always about the "real world." She voices a perspective that is probably not uncommon among preservice teachers, that the science instruction they received in school and that they may still see in schools is so divorced from experiences with phenomena and connections to students' lives that students do not recognize science as explaining everyday experiences.

> I had been confused as to the difference between experience and application. Because I said, "Well, if you are doing a hands-on activity, then isn't that application?" ...In my grade level experience maybe it was application because we'd sit there and read the textbooks. "Ok, you've got your knowledge, go apply it in the hands-on activity." But now, the hands-on activity is taking the place of the textbook. And the application is this whole other level. Everything has been shifted. I don't want to be like

really confusing, but the textbook is no longer there and the experience is now the hands-on part and the application is just this whole other thing.

This perspective on science instruction matches the description of school science in the EPE framework (Anderson, 2003).

What is interesting here is that within the EPE and I-AIM frameworks, all activities and experiences should be related to phenomena, and thus by definition, would necessarily have to be "real." Furthermore, the CA&P emphasizes connecting science instruction to students' lives, experiences, and funds of knowledge. But for many preservice teachers, like Nicole, who have probably experienced lots of school science and not much scientists' science, connections to the "real" world must be something that to them needs to be purposely added into science instruction. Nevertheless, Nicole's belief that science instruction should connect to students' lives and involve students in real experiences helped her to provide Apply activities, such as the field trip to Marshall Music and the Sound Museum, which made that important connection to the world outside school and also provided students with opportunities to practice using scientific ideas in new contexts.

Summary of Nicole's Interpretations

Nicole's interpretations of the I-AIM stages matched many of the intended meanings for the I-AIM stages and function. Furthermore, the meanings that she made of the stages often supported, or at least in this case did not hinder, her enactment of a unit that met many of the I-AIM functions. She recognized the importance of the central question in focusing the unit. Although she was focused on building excitement for learning, Nicole also recognized the importance of establishing a purpose for learning. Nicole's focus on engaging students in scientific experiences with real instruments, positioning her students as scientists and engaging students in such scientific practices as making observations, writing, and finding patterns, enabled her to provide many experiences with phenomena and make patterns in experiences explicit. Furthermore, Nicole wanted the experiences to fit into a logical flow that would help students discover for themselves, through step-by-step connections, the patterns and explanations that she wanted them to learn. While Nicole did not recognize that she was making teaching moves to help her students connect their experiences to scientific information, Nicole's teaching style did help her students learn how to use the patterns to explain how certain objects make sounds and how people hear those sounds. Finally, Nicole's insistence on providing "real world" connections supported her in providing opportunities for her students to practice using the patterns they had learned to explain how new objects made sound.

Many aspects of Nicole's situation supported her in developing interpretations of the I-AIM stages that enabled her to teach a unit that fit the I-AIM functions. Unlike Leslie, the thematic patterns that Nicole accessed supported her in interpreting the I-AIM in ways that were similar to the meanings intended for the I-AIM stages. There were some differences, such as Nicole's understanding of application as providing real world experiences rather than focusing on providing students with practice using new ideas or her focus on discovery rather than providing scientific information. However, more often than not, the connections that Nicole made allowed her to make interpretations of the I-AIM stages that were similar, or at least not at cross- purposes, to most of the intended meanings. Furthermore, unlike both Leslie and Dana, Nicole had a mentor teacher whose guidance was similar to the guidance Nicole received from her science methods course instructor. Nicole did not feel the pressure to balance many expectations for her work. She, her mentor teacher, and her instructor all expected her to teach a unit that supported students in achieving the learning goals, engaged them in scientific practices, and matched their resources for learning. In Nicole's case, her interpretation of the I-AIM stages mediated her successful use of the I-AIM and CA&P tools to meet these expectations.

Chapter Summary

Nicole had a successful experience planning and teaching a unit on sound to her second-grade students. She and Dominique, the first grade intern, worked together to develop a unit organized around helping students recognize and use two important patterns: 1) An object that makes a sound vibrates, and 2) one object vibrating can make another object vibrate. By the end of Nicole's enacted activity sequence, students were able to explain how various objects made sound and how people could hear those sounds.

Nicole came to teaching the unit on sound with a prior experience teaching a unit on sound to fifth-grade students. She had a solid grasp of the molecular model that explains sound, but at first struggled to figure out how to translate that understanding into a unit appropriate for second-grade students. However, when Dr. Adams helped them identify the key patterns for their unit, Nicole and Dominique were able to pull together their ideas to select activities and plan an instructional approach that engaged students in many experiences and helped them see the key patterns.

Nicole's planned instructional approach and enacted activity sequence fit all of the analysis features of the I-AIM and CA&P tool. Although she did not establish the question she and Dominique identified in their learning goals, Nicole did repeatedly ask questions about how objects make sounds and how we hear sounds in the context of the phenomena the students were exploring. Nicole provided students with many experiences of objects making sounds, objects vibrating, and vibrating objects making other objects vibrate. After each experience with a new example, Nicole brought the students together to identify the patterns in their experiences. Nicole carefully and subtly helped students label their ideas with scientific words (i.e. vibrations), recognize the patterns in their experiences, and learn to use the patterns to answer the questions about how sounds are made and how we hear sounds. At the end of the unit, the students had many opportunities to practice using what they had learned about sounds when they went to the music store to look at many different instruments, invented their own instruments, and guided their parents through their sound museum. Throughout the unit, Nicole paid close attention to students' ideas, either challenging their naïve ideas or incorporating their congruent ideas as necessary. In addition, she incorporated students experiences both inside and outside of class when the opportunities arose, thus taking full advantage of the intellectual and cultural resources the students brought to learning.

Nicole's successful use of the I-AIM and CA&P tools was mediated by her interpretations of the I-AIM stages. Many of the meanings that Nicole made of the I-AIM stages were similar to the intended meanings of the I-AIM stages. Nicole had converging support from her science methods instructor and her mentor teacher that helped her interpret the I-AIM in ways that were similar to the intended I-AIM meanings. Even when Nicole's interpretations did not match the intended meanings of the I-AIM stages, such as her focus on students discovering explanations rather than providing scientific information, her interpretations were close enough to enable her to enact a unit that fit the I-AIM functions.

At the beginning of the semester, Nicole wanted to learn how to plan and teach science lessons that were different from the types of science lessons she remembered from her elementary school years. However, she felt that she did not have the models to help her do what she wanted to do. By the end of the semester, she found what she was looking for in the EPE framework and I-AIM and CA&P tools. When I asked her if she would use the I-AIM again, she said, Yeah. All of it. I think just because it just worked so well...It just flowed. Yeah. I mean I would totally like totally do it the same...I am not even, not just, not spitting it back out because it is a nicely published. I mean, you know, it works. It works. So I have evidence... I for sure will do the same things. Definitely. I'm sold. (Nicole Interview, 4/13/2007)

CHAPTER 7

Discussion and Conclusions

Chapter Overview

In the previous three chapters I described in detail each interns' planned instructional approach and enacted activity sequence. I then described how each intern used the I-AIM and CA&P tools in her planning and teaching. Finally, I identified mediators that influenced each intern's use of the tools.

In this chapter I look across the three cases to look for cross-cutting themes and commonalities. First, I look at whether or not the I-AIM and CA&P tools are useful scaffolds of preservice teachers' planning and teaching practices. Then, I look at the various mediators that influenced the intern's uses of the tools. As I will describe in this chapter, the process of identifying these mediators helped me identify some limitations of Remillard's framework. In this chapter I introduce an explanatory framework based on Wenger's (1998) construct of communities of practice and Gee's construct of Discourses (1989, 1997, 1999) that addresses these limitations and situates the mediators that influenced how the interns used the tools in the larger sociocultural context. Although I realize that frameworks are usually introduced in the frameworks chapter of a dissertation, this explanatory framework grew from my analysis rather than framed it, and thus, fits better here in the discussion chapter. I use the results of my analysis to discuss the implications of this new framework for thinking about the goals for preparing elementary teacher to teach science. In the last section of this chapter I summarize the conclusions of this dissertation.

The I-AIM and CA&P Tools as Useful Scaffolds

This research has demonstrated that the I-AIM and CA&P tools can be useful scaffolds of preservice teachers' developing relationship with curriculum materials and practices for planning and teaching science. Dana, Leslie, and Nicole had successes using the tools to analyze curriculum materials, plan activity sequences that supported students in learning key science learning goals and engaged students in inquiry and application practices, and account for students intellectual and cultural resources for learning.

The three interns in this study had different types of curriculum materials available to use in their planning. All three were able to use the I-AIM and CA&P to analyze their curriculum materials, recognize some of the strengths and weaknesses of their materials, and make some appropriate modifications. Dana had the most traditional textbook materials available. In her curriculum materials analysis, she identified that the curriculum materials did not engage students in many hands-on activities involving phenomena and the hands-on activities that were provided did not provide students with opportunities to collect or analyze data. She was also particularly critical that the curriculum materials did not elicit student ideas or provide students with opportunities to revise their initial ideas. Leslie had available two different curriculum materials. In her curriculum materials analysis, she identified that the *Planet Guide* did not support students in making connections between their ideas and new science ideas. Leslie also recognized and was able to leverage some of the conceptual change aspects of the *Food for Plants* materials. Furthermore, she identified ways that the materials related to her own students' interests and experiences and was able to predict and then account for how her students would respond to the central question asked in the *Food for Plants* materials. Nicole had only a collection of activities to use to plan her unit. She and Dominique were able to recognize which activities addressed their learning goals and which activities supported their students in learning the key patterns necessary to achieve their learning goals.

All three interns also used their available curriculum materials to plan and enact activity sequences that fit parts of the I-AIM. Dana was able to identify an appropriate central question and plan a unit that addressed the question about how we see color. Although she did not establish the question explicitly at the beginning of her unit, she did focus most of her activities around that question and by the end of the unit had asked students to explain how we see the color of objects. She also provided experiences with phenomena and gave students several opportunities to use the scientific explanations in new contexts. Leslie was also able to establish a central question. She successfully leveraged the conceptual change aspects of the I-AIM by asking a question, eliciting student ideas, presenting scientific information, and providing students with opportunities to revise their ideas. She also provided students with opportunities to apply what they had learned to new situations. Nicole was most successful using the I-AIM. She established the central question, provided students with experiences with phenomena before providing scientific information. She made the patterns explicit and provided students with many opportunities to practice using their new understandings in new contexts.

Furthermore, all three interns accounted for and leveraged students' intellectual and/or cultural resources for learning. Dana considered her students' intellectual resources by identifying common student naïve conceptions and planning a sequence that systematically addressed those naïve conceptions. Leslie also considered students' intellectual resources by identifying common student naïve conceptions and presenting students with information and opportunities to revise their ideas. In addition, Leslie planned activities that matched and took advantage of her students' ways of being by including activities that provided them with opportunities to write songs and skits, role play, make posters, and go outside. Like the other two interns, Nicole also confronted students' naïve conceptions by presenting them with discrepant events that challenged their ideas. At the same time, she leveraged students' congruent conceptions by incorporating their ideas into her instructional sequence. In addition, Nicole leveraged students' funds of knowledge, including their family relationships and their knowledge of popular culture by planning and enacting activities that leveraged those student strengths. Furthermore, she incorporated students' invented experiences, such as the popcorn buzzing in a cup, into her instructional sequences.

One additional point about the I-AIM is important here. These interns' success demonstrates that the I-AIM and CA&P tools can serve as scaffolds to help preservice teachers critically use curriculum materials to plan and enact science lessons that support students in learning specified learning goals, engage students in the practices of inquiry and application, and leverage students intellectual and cultural resources for learning. However, the power of the I-AIM as a scaffold is that as an instructional model it helps preservice teachers see and understand pedagogical patterns (Schwarz & Gwekwere, 2007). Using an instructional model to apply general principles to organize a sequence of activities for a particular topic for a particular group of students amounts to pedagogical model-based reasoning. Nicole's use of the I-AIM to develop a unit on sound for her second-grade students illustrates pedagogical model-based reasoning from the general to the particular. Dana's use of the example electricity sequence as a template, however, failed to provide her with access to the general framework of the model. She was able to access and use some of the features of the I-AIM that were represented by the example electricity sequence. However, when the example did not quite fit her situation, she was unable to tap the general principles represented by the instructional model to modify the example to fit her situation. Unlike other scaffolds, such as the example electricity sequence, the I-AIM scaffolds pedagogical model-based reasoning in planning and teaching science.

Interns' Mediated Use of the I-AIM and CA&P Tools

While in the cases of these interns the I-AIM and CA&P tools served as useful tools, each of the interns also used the I-AIM and CA&P tools differently and achieved different results. Furthermore, some of the interns' uses of the I-AIM and CA&P tools differed in important ways from the intended use of the tools. Dana used the example electricity sequence as a template for her unit. Although Dana met some of the intentions of the I-AIM and CA&P, Dana's enactment undermined the inquiry aspects of her planned instructional approach by front-loading her enacted sequence with presentations of scientific information. Moreover, although she identified the patterns she wanted her students to recognize and planned activities that would make those patterns explicit, she did not make the patterns explicit to her students during instruction. Dana also did not leverage the cultural resources that her students brought to learning about science. Leslie also missed key features of the I-AIM. Although Leslie successfully leveraged the conceptual change aspects of the I-AIM, she did not succeed in engaging her students in inquiry practices because she did not engage students in experiences with phenomena. As a result she was unable to make patterns in experiences visible to her students. In contrast to Dana and Leslie, Nicole's planned instructional approach and enacted activity sequence closely fit the I-AIM and CA&P. She focused on providing students with many experiences with phenomena that illustrated the patterns in the experiences that were necessary to explain how we hear sounds.

These differing ways of using the tools and differing results from using these tools can be explained by identifying the various factors that mediated the interns' use of the tools. As described in Chapter 2, all action is situated within a social/cultural/historical context. Elements of this context shape, or mediate, human actions (Wertsch, 1991). Researches have identified multiple types of mediators. Putnam & Borko (1997, 2000) and Cobb (1994) consider how social interactions among members of a group, or classroom, mediate the actions, and thus learning of students in the classroom. Wertsch (1991), after Vygotsky and Cole, focuses on tools, signs, and other semiotic systems as mediators of human actions. Similarly, Lemke looks at how language mediates human meaning-making behaviors. Remillard (2005) identifies mediators as characteristics of either tools or teachers. Table 7.1 summarizes some of the mediators that shaped the interns' use of the tools.

Table 7.1

Summary of mediators

Intern	Use of the tools	Mediators
Dana	Managing Expectations	• Oppositional relationship with and goal to teach differently from mentor teacher • Vision for teaching science • Goal to meet requirements of the science methods course • Belief that all students will succeed if held to high expectations. • Textbook & resources from former science content instructor • Experiences as a science learner
Leslie	Conceptual Change Teaching	• Conceptual change orientation to teaching • Goal to use the EPE framework • Interpretations of experiences, patterns, and explanations • *Food for Plants* & *Planet Guide* • Experiences as a science learner
Nicole	Finding Patterns	• Guidance from science methods course instructor • Guidance from mentor teacher • Partnership with Dominique • Discovery orientation

Dana used the I-AIM and CA&P tools to negotiate the many expectations that she and others had for her teaching. Dana's relationship with her mentor teacher, her vision of science teaching, and her need to meet the requirements of the science methods course as efficiently as possible mediated her use of the example electricity sequence as a template for her unit. Furthermore, her belief that all students will succeed if held to high expectations mediated her awareness and consideration of her students' cultural resources for learning. In addition, the textbook that Dana used and the materials that her former science content course instructor provided mediated the activities she included in her planned instructional approach and enacted activity sequence.

Leslie used the conceptual change aspects of the I-AIM and CA&P tools, but did not engage her students in inquiry practices. In Leslie's case, her conceptual change orientation mediated her use of the conceptual change features of I-AIM. However, the thematic patterns to which she connected mediated the interpretations Leslie made of the EPE framework and resulted in the lack of inquiry in her science teaching. The *Food for Plants* and the *Guide to Planet Earth* curriculum materials also mediated Leslie's teaching pattern and the activities that she chose to use and in her plans and enactment.

Nicole used the I-AIM and CA&P tools to help her students see patterns in experiences. For Nicole, the convergence of her mentor teacher's and science methods course instructor's guidance and her own vision for science teaching helped her use the tools in ways that more closely matched the intentions of the tools. The collection of possible activities and former interns' plans also mediated some of her choices for activities.

The mediators listed in Table 7.1 include social relationships, beliefs, goals, visions, and features of curriculum materials. In Remillard's framework for teacher-curriculum materials participation, introduced in Chapter 2, the mediators of teachers' use of curriculum materials are identified as characteristics of teachers or features of curriculum materials and are listed inside the teacher and curriculum materials circles. However, not all of the mediators listed in Table 7.1 fit inside Remillard's teacher or curriculum materials circles. By identifying mediators as characteristics of teachers and listing them inside the circle representing the teacher, Remillard essentializes the mediators as innate traits of individuals located inside the head of individuals (Cobb, 1994; Lemke, 1990; Sfard, 1998). Mediators such as the interns' relationship with their mentor teachers or guidance from a course instructor are not innate characteristics of an individual. Remillard's model isolates teachers from their sociocultural context and overlooks social interactions as possible mediators of teachers' actions. It also leaves unanswered questions. For example, where did these mediators come from? Why these mediators and not others? From a teacher education perspective, answers to these questions could inform our understanding of how preservice teachers learn to teach. Situating mediators in the sociocultural context might help us better meet the needs of and account for the resources preservice teachers bring to learning to plan and teach science.

Discourses and Communities

To situate the mediators of Dana, Leslie, and Nicole's uses of the I-AIM and CA&P tools, Cobb & Hodges' (Cobb & Hodge, 2002, 2003) relational perspective that connects Wenger's (1998) communities of practice to Gee's (1989, 1997, 1999) broader Discourses is helpful.

Gee (1989, 1997, 1999) defines a Discourse as the combination of ways of talking, doing, being, valuing and believing that identify a socially meaningful group. As such, Discourses serve as identity toolkits. The ways of talking, being, doing (practices) in which one engages aligns one with a social identity. Gee makes a distinction between discourse with a lowercase "d" and Discourse with a capital "D" (little "d" and big "D" Discourse). He limits little "d" discourse to "connected stretches of language that make sense" (1989, p. 6). Big "D" Discourses tie individuals to larger contexts or communities. Big "D" Discourses are also different from discourse communities (Putnam & Borko, 1997; Resnick, 1991) because little "d" discourse communities are defined just by the ways of speaking or writing shared by a group of people.

Discourses are also different from communities of practice. Wenger defines a community of practice as "groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly" (Wenger, undated). Integral to this construct is the idea that participants in the community are mutually engaged in a common endeavor (Cobb & Hodge, 2002, 2003; Wenger, 1998). Discourses are not confined to local groups. Discourses extend beyond the scope of mutual engagement and tie local communities into larger configurations (Cobb & Hodge, 2003; Wenger, 1998). Thus, a Discourse of college student could be defined as the ways of talking, dressing, and acting that identify one as a college student, even though all college students do not live in one place and do not all interact directly with one another. Furthermore, because Discourses play out differently in different communities, there is diversity within Discourses (Cobb & Hodge, 2002). The college students at College A and College B are tied together by the Discourse of college student even though there may be important differences between the two communities.

While Discourses tie communities together, it is only through participation in the practices of communities that individuals connect to Discourses (Cobb & Hodge, 2003; Wenger, 1998). Individuals draw on Discourses when learning the practices of new communities in which they have not previously participated or when constructing new social structures (Cobb & Hodge, 2003; Wenger, 1998). As a result, Discourses serve as the resources for the construction of new communities. However, because Discourses are defined by the practices of the communities, Discourses also evolve or go extinct (Cobb & Hodge, 2002, 2003; Gee, 1997, 1999). This relationship between local communities and Discourses also means that because individuals participate in many different communities at one time, they draw on many Discourses. When drawing on several Discourses, resources of the various Discourses being drawn upon may interfere with each other (Gee, 1989, 1999) in any given community.

This framework of Discourses tying together local communities helps situate and explain the mediators that influenced Dana, Leslie, and Nicole's use of the I-AIM and CA&P tools. Dana, Leslie, and Nicole's mediators were situated in three communities (the science methods course, the field placement classroom, and the science content courses) and in the curriculum materials that they had available. Each of these local communities and the curriculum materials were tied to larger Discourses. In participating in these communities, Dana, Leslie, and Nicole encountered and drew on a variety of Discourses as they learned to use the I-AIM and CA&P tools. Some of the resources of these Discourses interfered with and some supported the interns in using the I-AIM and CA&P tools. By locating the individual mediators in these other communities and related Discourses, it is possible to connect the interns' use of the I-AIM and CA&P to larger social relationships and thus, hopefully, better understand the influences on how these interns used the I-AIM and CA&P tools.

Below, I will describe five principal Discourses that these interns encountered and drew upon in their planning and teaching of science. I will then describe three community settings (plus the curriculum materials) in which the preservice teachers encountered and drew on these Discourses as they engaged in planning and teaching their science units. For each community setting, I will provide examples of how the various Discourses from which the interns were drawing interfered with or supported their use of the I-AIM and CA&P tools. The example communities and Discourses that I describe are the communities and Discourses that rose to the fore in this analysis. There are certainly other communities and other Discourses that could have been important for each intern. Furthermore, while I have identified and labeled several different communities and Discourses and talk about them as separate entities, in fact, there is considerable overlap across the communities and Discourses as well. That is, while I may talk about planning in the context of the science methods course, the mediators that influenced the interns' planning practices were also situated in other communities and Discourses as well.

It is important to note that this communities and Discourses framework posits an explanation for the interns' use of the I-AIM and CA&P tools. I did not conduct empirical work to document the interns' Discourse practice outside of the university and school. However, as Cobb & Hodge (2002) note, the relational perspective is an interpretative stance towards students' activities in classrooms. Relevant aspects of Discourses on which students draw can be inferred from students' solutions to tasks they are asked to complete. Cobb & Hodge describe the work of Ladson-Billings (Ladson-Billings, 1995) who identified the Discourse practices of a particular African American community that influenced how certain students in a classroom interpreted and solved a particular math problem. Ladson-Billings did not investigate the students' Discourse practices outside the classroom, but was able to infer them from the students' ways of solving the math problems. Similarly, I am inferring the Discourse practices that were influencing the interns' use of the I-AIM and CA&P from their planning of their science units in their science methods course and their enactment of their units in their field placement classrooms.

Discourses

The mediators that influenced how the interns used the I-AIM and CA&P tools were situated in at least five possible Discourses inferred from the interns' actions while they were planning and teaching science. While there could be additional Discourses at play, the Discourse that I interred were the Discourse of the university student, the Discourse of traditional science teaching, the Discourse of reform science teaching, the

Discourse of elementary teacher, and the Discourse of new teacher of science. These Discourses are not necessarily mutually exclusive, and at any one time, an intern or teacher could be drawing on multiple Discourses. Gee (1999) notes that Discourses provide a standpoint or perspective from which to view the world. Therefore, at any given moment, a teacher in a classroom could draw on and identify with the Discourse of elementary teacher in general, or might more align with the practices of the Discourse of reform science teacher specifically. The purpose of describing these Discourses separately is to characterize the important practices (ways of talking, thinking, acting), that align with the perspectives or standpoints of each Discourse. In the following descriptions I will identify the central standpoint of each Discourse and some of the practices that align with that perspective.

Discourse of University Student. Similar to elementary and secondary classrooms, academic work in university courses is embedded in an evaluation structure in which student performance is exchanged for a grade (Becker *et al.*, 1968; Doyle, 1983; Feiman-Nemser & Buchmann, 1985). Success in a university course depends on a favorable evaluation from the course instructor. The course instructor and the university or college establish the requirements for the course, the assignments or tasks that must be completed, and the criteria for evaluation. From the perspective of the university student, the central goal of university work is to exchange a performance for the desired rewards. Some students may desire high academic rewards while other students may decide that other rewards of extra-curricular college life are also valuable. Students balance the requirements for the course with the rewards they desire.

University students engage, both individually and collectively, in many ways of talking, thinking, and acting to get the grades they want (Becker et al., 1968). These practices may include

> seeking information, working hard, attempting to manipulate faculty in order to get a better grade, organizing for collective action to improve the chances of getting good grade, allocating effort in such a way as to maximize the overall GPA, and so on. (Becker et al., 1968, p. 133)

Students who either do not have access to or do not engage in these practices do not succeed in the structure imposed by this academic system (Gee, 1989, 1999).

The Discourse of university student is accessed and practiced in a variety of ways, depending on the communities in which students are participating. For example, what it means to be successful in a history course may look different from what it means to be successful in a science lab course or a teacher preparation course (Cobb & Hodge, 2002). Nevertheless, in all university courses, successful university students know and engage in the ways of talking, thinking, and acting that will get them the evaluation they hope to receive.

The interns in this study had already had at least four years of university course work. As such, they had become proficient in many of the practices of being successful university students. For example, they could talk and interact in class discussions, read course texts, and submit completed assignments. They all recognized that in order to pass the science methods course and obtain their recommendation for licensure, they needed to fulfill the requirements established by Dr. Adams. They recognized that important among these requirements was planning a science unit using the frameworks that Dr. Adams established, including using the I-AIM and CA&P tools. Furthermore, because the science methods course was part of a selective professional education program, most interns in the science methods course valued and expected to receive a high evaluation of their work. When deciding in which Discourses the mediators of interns' actions were situated, I inferred the Discourse of university student whenever the interns' actions/practices suggested that the interns were at least partially motivated by the goal of fulfilling the course requirements in order to receive a favorable evaluation.

Discourse of Traditional Science Teaching. This Discourse describes the traditional, didactic ways of teaching science in the classroom. The perspective of this Discourse is that teaching science is about presenting students with content information, facts, and concepts that they must learn and repeat back on tests or worksheets(Anderson & Smith, 1987; Roth *et al.*, 1987). Example practices characteristic of this Discourse include lecturing or assigning students to read from a textbook and answer questions on a worksheet. Teachers may also present demonstrations or involve students in hands-on activities, but these activities are usually offered as examples of ideas already established. Traditional teaching focuses on explanations and does not make explicit patterns or experiences that support the explanations (Anderson, 2003). I inferred the Discourse of traditional science teaching whenever the interns or mentor teachers engaged in didactic teaching practices or otherwise indicated that they viewed science teaching as presenting science content for students to memorize and repeat.

Discourse of Reform Science Teaching. As Gee noted, Discourses often exist in relationship to other Discourses (Gee, 1999). The Discourse of reform science teaching is defined in relationship to traditional science teaching. In contrast to traditional science teaching, reform science teaching focuses on supporting all students in achieving science literacy (National Research Council, 1996; Rutherford & Ahlgren, 1989). There are many practices that would fall under this Discourse, including, but not limited to, focusing on student ideas and thinking, rather than just the content that students repeat (Anderson & Smith, 1987; Roth et al., 1987), and engaging students in the practices of science, including inquiry and application (Anderson, 2003; National Research Council, 2000). The I-AIM and CA&P tools are representations of the Discourse of reform science teaching and the practices associated with their intended use, as described earlier in this dissertation, fall under this Discourse. I inferred the Discourse of reform science teaching whenever the interns or mentor teachers engaged in reform practices or expressed reform perspectives, especially when those practices and perspectives aligned with the intentions of the I-AIM and CA&P tools.

Discourse of Elementary Teacher. This is a broad and general Discourse that encompasses the practices and perspectives focused on teaching young children in the formal education setting. It includes all of the ways of talking, thinking, and acting that mark one as an elementary teacher, such as managing student behavior; establishing and running classroom routines; managing the administrative tasks of teaching; planning and teaching many content areas to diverse students; interacting with other teachers, administrators, and parents, etc. I mention this Discourse because all of the interns encountered it as they participated in the field placement classrooms and worked with their mentor teachers. However, what it means to be an elementary teacher takes different forms to different teachers in different communities. The Discourses of both traditional and reform science teaching overlap significantly with the Discourse of elementary teacher. However, the Discourse of elementary teacher extends beyond just a focus on teaching science and encompasses all of the other practices and perspectives that elementary teachers engage in and recognize. In general, I inferred the Discourse of elementary teacher when I encountered intern or mentor teacher actions or perspectives that attended to pedagogical or management tasks but that were broader than just the practices and perspectives of teaching science.

Discourse of New Teacher of Science. Some of the mediators that influenced how the interns used the I-AIM and CA&P tools reflect what I call a Discourse of new teacher of science. This Discourse reflects what some might call naïve notions of teaching and teaching science. This Discourses reflects the practices, perspectives, beliefs, and visions that the interns accessed through their participation in other teacher education courses, their previous field placements, their science content courses, their own apprenticeship of observation in their own elementary student classrooms (Lortie, 1975), and various other contexts and communities in which they participated in their personal histories. With regards to teaching science, some features of the new teacher Discourse include the view that students should discover science explanations for themselves, that learning science should be fun and hands-on, and that the purpose of teaching science is to extinguish or fix students' misconceptions (Anderson & Smith, 1987; Davis et al., 2006; Gunckel & Smith, 2007; Schwarz et al., 2008). Furthermore, new teachers often hold naïve ideas about the nature of science, characteristically lack in-depth understanding of science content, and often assess their own understanding of science as weak (Abd-El-Khalick, 2000; Chochran & Jones, 1998; Davis et al., 2006; Lederman, 1992).

Communities

Individuals encounter and interact with Discourses in communities of practice (Cobb & Hodge, 2002, 2003; Wenger, 1998). During the last semester of their internship year, the interns participated in two communities plus they participated with their curriculum materials while learning to plan and teach science. A third community, the community of their science content courses, was also important, even though they did not participate in that community during the same semester in which this study took place. I will describe each community and the ways that the mediators that were influencing their use of the I-AIM and CA&P tools were situated in the various Discourses which they encountered and drew upon in each community. For each community I will identify the primary activities, planning and/or teaching, that were central to that community, recognizing that in many instances, the boundary between what constitutes planning as opposed to teaching is fuzzy, with each activity reflexively influencing the other.

Science Methods Course. One community in which the interns were participating was the science methods course. Participants in this community included the interns and Dr. Adams. Both the interns and Dr. Adams were drawing on larger Discourses as they shaped the practices of the science methods course (Figure 7.1) The interns were drawing on the Discourse of university student. Dr. Adams drew on the Discourse of reform-based science teaching and the Discourse of university course instructor in the design and enactment of the science methods course. Dr. Adams' goal was to help the interns to develop reform-based practices that would serve them well as they began their teaching careers. The planning and teaching practices that Dr. Adams asked the interns to participate in reflected the practices of the Discourse of reform science teaching. The EPE framework and the I-AIM and CA&P tools were prominent representations of this Discourse in the science methods course. Dr. Adams drew from the Discourse of university course instructor when he developed the course syllabus with assignments for the interns to complete, formats for the assignments, and a timeline for completing the assignments. He also developed the criteria for evaluating the interns' work.

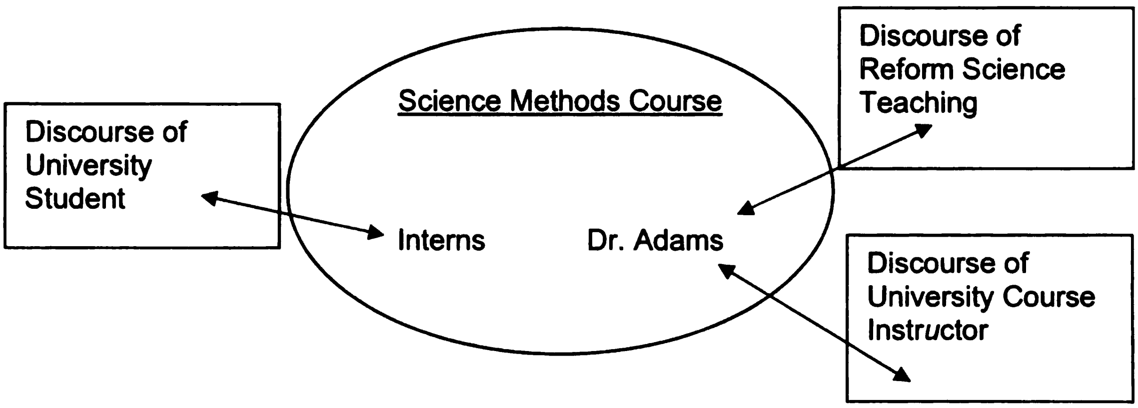

Figure 7.1. Discourses on which participants in the science methods course drew

The interns' planning of the science unit was situated primarily in the science methods course. Dr. Adams established the evaluation criteria for the plans. As a result, an important concern for the interns was to figure out how they were going to meet these criteria. The interns were also planning their units to be enacted in their field placement course. As a result, the context of their field placement also influenced how they planned their lessons. For example, Nicole's mentor teacher, Annette, wanted Nicole to plan a field trip, which was a requirement additional to the instructor's expectations. Nevertheless, the instructor was the evaluator of the plans and it was expected that the interns' would figure out how to meet the expectations of the field placement from within the framework of the requirements for the science methods course.

For each of the interns, the practices of the Discourse of university student mediated their use of the I-AIM and CA&P tools as they planned their science unit. Each intern engaged in strategies that would ensure that they met the requirements for the course in order to get a positive evaluation on their work. Dana, for example, was trying to balance the many expectations that she, her mentor teacher, and Dr. Adams had for her science unit. Comments that Dana made in her interviews and her enactment of the pre-unit activities not included in the planned instructional approach suggest that Dana saw using the I-AIM and CA&P tools to plan the science unit as an academic task that was necessary for her to complete for the science methods course and was not part of her professional practice in the classroom. She recognized that Dr. Adams valued and used certain science instructional strategies. She also recognized that the example electricity sequence that Dr. Adams used in class was a reification of the EPE framework and I-AIM model that Dr. Adams wanted interns to use to plan their science units. Dana realized that using the example electricity sequence as a template would ensure that her planned instructional sequence included the reform-based science instructional strategies that Dr. Adams valued, thus increasing her chances of receiving a favorable evaluation of her plans. In addition, there were elements of the I-AIM that matched Dana's own vision for teaching science, including opportunities for hands-on activities and opportunities for students to talk about their ideas. By using the example electricity sequence as a template, Dana could efficiently plan a unit that would meet Dr. Adams' expectations and at the same time, meet her own visions for teaching science in a way that was different from the way her mentor teacher taught science.

Leslie also drew on the Discourse of university student as she planned her unit. Leslie's talk about her unit plans shows that she was thinking about experiences, patterns, and explanations as she put together her plans. As a successful student, Leslie had learned that in order to meet the requirements of a university course, one needed to recognize and pay attention to the central framework of the course. Leslie recognized the EPE framework as a central organizing framework. She saw the EPE framework as the model that she needed to follow in order to plan her instructional approach. Her attention to the EPE framework because it was a part of the science methods course constrained her approach to planning her science unit. That is, her talk about planning shows that she was trying to plan according to Dr. Adams' course requirements as opposed to planning a science unit following a different framework or approach. Leslie focused her energy on making sense of the EPE framework, even though the meanings that she constructed were different from the intended meanings. In contrast to Dana, Leslie's did not view the use of the EPE framework as a primarily academic task. Her comments in interviews that she found the EPE framework helpful in planning science units indicate that she was also taking a professional stance towards using the course frameworks. Nevertheless, one mediator of her use of the EPE framework was the intention to meet the course requirements in order to receive a favorable grade for her work.

Like Leslie, Nicole also paid close attention to the course frameworks. Nicole was the top preservice teacher in her graduating class, receiving in her senior year one of only nineteen special recognition awards from the University Board of Trustees for the entire university undergraduate graduating class ("Student honors", 2006). As a highly successful student, Nicole had learned how to ask for and follow guidance from her course instructors. She often emailed or called Dr. Adams with specific questions related to the course assignments. Nicole leveraged this guidance in identifying the key patterns that she used to organize her unit on sound. Nicole's comments about how useful she found the I-AIM and CA&P tools indicates that like Leslie, Nicole also took a professional stance towards using the I-AIM and CA&P tools and did not see her use of the tools as a primarily academic task. Nevertheless, Nicole used the tools and paid attention to Dr. Adams' guidance because she recognized that in order to be the successful student she expected herself to be, she needed to meet the requirements of the course. Table 7.2 summarizes how the mediators of the interns' actions in the science methods course were situated in the Discourse of university student in which the interns recognized that there was an expectation to meet the course requirements in return for a favorable evaluation.

Table 7.2
Mediators situated in the Discourse of university student

Intern	Mediated action	Mediator
Dana	Use of the example electricity sequence as a template	Recognition of the example electricity sequence as a reification of course requirements
Leslie	Interpreting EPE as a model for planning	Recognition of EPE framework as central organizing framework of course
Nicole	Identification of key patterns	Attention to guidance from course instructor

Field Placement Schools: Relationships with Mentor Teachers. Each intern also participated in the community of her field placement school and classroom. These communities were complex, with many participants including teachers, students, principals, and staff, all of whom drew on a variety of Discourses as they engaged in the formal education of elementary-age children. For example, the principals drew on the Discourse of principals and the teachers drew on the Discourse of elementary teacher, among others. The ways in which the participants in each school drew on the various Discourses to co-construct the practices of each school community resulted in three different field placement communities. At Turner Elementary School where Nicole was placed, the school valued science instruction. The school district had issued a directive that language arts and mathematics were district priorities. The principal explained that some district teachers had interpreted the directive to mean that they could not teach science and social studies. However, at Turner, while language arts and mathematics took priority, the principal emphasized that all teachers should also teach science and social studies. At Peace Middle School where Leslie worked, the team-teaching approach to organization reflected a school community where collaboration was valued. Teachers shared ideas and worked together to address problems. Students were also expected to positively contribute to the school community. In contrast, Libby Elementary, where Dana taught, reflected a community where individual teachers were isolated in their self-contained classrooms. According to the Libby teachers, the principal did not emphasize science instruction and thus teaching science was a low priority.

It was within the community of the field placement classroom that the interns enacted their planned instructional approach. However, the field placement also influenced and constrained the interns planning as well. There were two relationships that were important in influencing the interns' learning to use the I-AIM and CA&P tools. One was the interns' relationship with their mentor teachers and the other was the interns' participation with their curriculum materials. I will first talk about the Discourses that the interns' had access to through their mentor teachers and how the mediators that influenced their plans and their enactments were situated in these Discourses. In the next section, I will talk about the interns' participation with their curriculum materials.

In the field placement communities, the interns and their mentor teachers interacted closely. The mentor teachers brought to this relationship their identities as elementary teachers. They drew from several Discourses to construct their practices and identities as elementary teachers, including the Discourse of reform and/or traditional science teacher. For each mentor teacher, what it meant to be an elementary teacher planning and teaching science differed greatly (Cobb & Hodge, 2002, 2003). The interns were also beginning to develop their own identities as elementary teachers and as elementary teachers of science. The interns' relationships with their mentor teachers strongly influenced how the interns participated in the community of their field placement school. Furthermore, the ways that the interns participated in the field placement classrooms mediated the interns' use of the I-AIM and CA&P to plan and teach their science units.

In Nicole's field placement classroom, many of the planning and teaching practices in which Nicole's mentor teacher, Annette, and Annette's partner teacher, Cindy, engaged aligned with the practices of the Discourse of reform-based teaching and the intents of the I-AIM and CA&P tools. For example, in their own science teaching, Annette and Cindy focused on aligning all activities with curriculum benchmarks, identified and made explicit a central question, engaged students in experiences with phenomena, and provided students with opportunities to express and revise their ideas. Annette and Cindy modeled these practices for Nicole and Dominique. At the beginning of the school year, Annette and Cindy involved Nicole and Dominique in the planning and teaching of the first science unit on plants. Annette and Cindy showed Nicole and

Dominique all of the school district science curriculum documents and modeled how they used a variety of curriculum materials to plan their science lessons. When Nicole and Dominique were planning their science unit on sound, Annette and Cindy established the expectation that every activity would align with the district benchmarks. They also expected the interns to include hands-on explorations and a field trip in the unit. Both Annette and Cindy provided feedback on the overall unit plan and individual science lessons, and participated as another adult in the classroom during many of the science lessons. Annette and Cindy modeled their teaching practices, then gradually faded their support as the interns took on the responsibility for planning and teaching all science lessons (J. S. Brown *et al.*, 1989; Collins *et al.*, 1989). In addition, Nicole worked closely with Dominique. Their partnership provided both of them additional opportunities for sense making and support while planning and teaching their units. By participating in the field placement classroom, which included two mentor teachers and another intern Nicole had access to and was able to draw from the Discourse of reform science teaching. The practices of this community mediated Nicole's development of her sophisticated understanding of the nature and role of the central question in planning and organizing an instructional sequence and use of many experiences to establish a pattern during the Explore & Investigate stage of her unit. These mediators influence both Nicole's planning and her enactment of her unit. Thus, the practices of the Discourse of reform science teaching influenced some of the interpretations that Nicole made of the I-AIM and CA&P tools and mediated her use of these tools in ways that matched the intent of the tools.

In contrast, Dana's mentor teacher, Melinda, did not engage in many science planning and teaching practices that aligned with the I-AIM and CA&P tools. Her practices, including having students read about science and answer the question directly from the textbook, reflected a Discourse of traditional school science teaching. Melinda's traditional teaching practices could have influenced Dana to reject the I-AIM and CA&P tools. However, Dana's oppositional relationship with Melinda mediated Dana's use of the tools in a different manner. In this case, Melinda's practices of teaching science represented a strong contrast to Dana's own vision for teaching science. I will discuss later the other Discourses on which Dana may have been drawing in developing her vision for science teaching. Rather than become enculturated into Melinda's practices, Dana rejected Melinda's practices. For example, in the pre-unit and post-unit lessons that she taught, Dana engaged students in hands-on activities and peer conversations, activities that Dana claimed were relatively rare in her mentor teacher's science instruction. As such, this case illustrates that the practices of the mentor teachers can mediate interns' practices in ways that are either more or less congruent with the Discourses from which the mentor teacher draws.

In addition, Dana's oppositional relationship with her mentor teacher may also have had an influence on Dana's planned instructional approach. As I discussed in the previous section, Dana used the example electricity sequence as a template. In doing so, Dana was primarily participating in the community of the science methods course and drawing on the Discourse of university student. However, as Dana was also participating in the field placement classroom at the same time that she was participating in the science methods course, some of the events and situations in the field placement classroom influenced how she engaged in the tasks in the science methods course. In this case, Dana recognized that the example electricity sequence more closely matched her vision for science teaching and stood in opposition to the practices that her mentor teacher modeled. I think that the nature of Dana's oppositional relationship with Melinda meant that the example electricity sequence offered Dana the opportunity to explicitly and overtly reject Melinda's approach to teaching. In this way, in addition to drawing on the Discourse of university student when planning her unit, Dana's participation in the community of her field placement and her rejection of her mentor teachers' Discourse of traditional science teaching may have also influenced Dana's use of the example electricity sequence as a template for her own planned instructional approach.

Leslie's participation with her mentor teacher illustrates another aspect of how the mediators that influenced the interns' use of the I-AIM and CA&P tools were situated in the Discourses at play in the field placement community. Important characteristics of Discourses are the ways that Discourse participants employ the semiotic resources at their disposal in habitual and characteristic ways (Lemke, 1990). These characteristic uses of language and other semiotic resources, such as facial expressions and gestures, constitute the thematic patterns of the Discourse that allow participants to make similar meanings and thus communicate with one another (Cobb & Hodge, 2003; Gee, 1989, 1999; Lemke, 1990). Within communities, meanings are negotiated (Wenger, 1998). That is, participants negotiate which Discourses and thematic patterns have currency within the community. In Leslie's case, the thematic patterns that held currency in the classroom mediated the meanings that Leslie made of the EPE framework. In the Discourse of elementary teacher on which Leslie's mentor teacher, Rebecca, was drawing to create her own teaching practice, teachers employ a variety of strategies to help students put together the pieces of science stories in a coherent manner. Leslie made sense of EPE by connecting the words "experiences," "patterns," and "explanations" to the ways her mentor teacher was talking about planning lessons in general. These meanings differed in important ways from the intentions of the EPE framework, and as a result, Leslie's use of the EPE framework differed significantly from the intended use. In contrast, the thematic patterns that Nicole's mentor teacher accessed were more closely aligned with the intentions of the EPE framework and I-AIM/CA&P tools and thus helped Nicole make sense of the EPE framework and I-AIM tools in ways that more closely matched the intents for the tools.

Proportionally, interns spent more time in their field placement classrooms than they did in their science methods course. Therefore, it is no surprise that elements of the field placement communities and the Discourses of teaching that were drawn upon in these communities would strongly mediate the interns' uses of the EPE framework and I-AIM/CA&P tools. Just spending time in a place does not necessarily result in learning the practices of a new community (Lave & Wenger, 1991; Putnam & Borko, 2000). However, in these cases, the interns were becoming legitimate peripheral participants in these new communities. Thus, the Discourse values, thematic patterns, and practices that were part of each community served as a ready source of influence on the interns' developing identities as elementary teachers and science planning and teaching practices and mediated their use of available tools.

Field Placement Schools: Curriculum Materials. Another important aspect of the field placement community was the curriculum materials available. Curriculum materials, as products of social, historical, and institutional settings, also represent and carry the values, perspectives, and practices of the Discourses in which they were constructed (M. W. Brown & Edelson, 2003; Remillard, 2005; Wertsch, 1991). As such, they too can provide access to the Discourse resources that mediated how the interns used the I-AIM and CA&P tools to plan and teach science. The interns engaged with the curriculum materials primarily during their planning of their instructional approaches, although for Dana, as I describe below, the curriculum materials may have also mediated the teaching she engaged in outside of her planned instructional approach.

Of the three interns, only Leslie had curriculum materials that represented the reform-oriented science teaching Discourse. *Food for Plants* reflected a conceptual change model of science teaching. It engaged students with a question about phenomena, elicited and explored their ideas, introduced new scientific ideas, and helped students reconcile their ideas with the scientific ideas (Roth, 1997; E. L. Smith, 1991). Leslie's orientation to teaching and her teaching pattern reflected a similar approach and may have been influenced, or at least supported, by the conceptual change aspects of the *Food for Plants* materials.

On the other hand, Dana had curriculum materials that reflected more traditional science teaching Discourses. The *Holt Science and Technology: Physical Science* textbook emphasized coverage of content and thus supported both the school district's focus and Dana's tendency to cover the topics assigned to the sixth-grade curriculum. At the same time, the textbook, by Dana's assessment, did not include many hands-on experiences for students. The textbook portrayed the assumption that teachers should follow the text verbatim and that students would learn science by reading the textbook. In this way, the textbook supported the traditional Discourse of science teaching that Dana's mentor teacher modeled. While the textbook may have mediated Dana's tendency to cover topics assigned in the curriculum, it also represented the Discourse of traditional science teaching that Dana resisted. Dana turned to the curriculum resources offered by her former science content course instructor to develop hands-on activities that more closely matched her vision for engaging students in hands-on activities.

Another aspect of the curriculum and curriculum materials that may have been a factor in the interns' use of the EPE framework and I-AIM and CA&P tools was the content of the topic of instruction. Dana and Nicole had topics for which the key patterns and experiences are relatively concrete and accessible. Both Dana and Nicole were able, with some guidance, to recognize and use the patterns to plan their science units. Leslie, however, had a more difficult topic. The patterns involved in understanding photosynthesis and the carbon cycle are much less concrete than the patterns involved in understanding how we hear sound or see color. Furthermore, none of the curriculum materials that the interns had available supported them in identifying the patterns that they needed to make explicit or provided activities that were explicitly identified as supporting students in recognizing those patterns. What remains unclear, in all three cases, is what would have happened if each intern had been assigned a different topic. Would Nicole have been as successful if she had been assigned to teach about photosynthesis? Would Leslie have struggled less if she had been assigned to teach about sound? The role that the topic of instruction plays in mediating interns' use of the EPE framework and I-AIM/CA&P tools needs further study.

Science Content Courses. As part of their teacher preparation program, all three interns took one or more science content courses for elementary teachers. These courses were taught in the College of Natural Sciences rather than the College of Education. As in the science methods course, participants in the science content courses drew on the Discourses of university student and university course instructor. In addition, the science content course instructors probably drew on other Discourses related to science and science teaching. I am not suggesting that the science content courses or course instructors purposely drew on the Discourse of new teacher or intentionally promoted naïve notions of science teaching. As with the science methods course, the meanings that preservice teachers made of course content often differed from the intended meanings of the content. In the cases of Dana, Leslie, and Nicole, however, I do think that there were elements of the science content courses that reinforced naïve notions of what it means to be an elementary teacher teaching science and mediated how the interns used the I-AIM and CA&P tools. The interns drew on these meanings as they engaged in planning and teaching in the communities of their field placement and science methods courses.

As described in the on-line course descriptions, the science content courses for elementary teachers were intended to "promote confidence in and mastery of scientific concepts." The course descriptions emphasized that these courses modeled appropriate elementary science teaching methods, including the "integration of discovery-based science (hands-on component) with reflection and theory (minds-on component)" and connection to "everyday experiences" ("Division of science and mathematics education undergraduate courses", 2005). What is important in the descriptions of these courses is not whether or not the courses actually enacted a discovery-based approach to science teaching as much as it is that what they called hands-on teaching was also labeled and possibly portrayed as discovery teaching. Furthermore, the courses included instruction in common science misconceptions that elementary teachers should address.

Of the three interns, Leslie most closely matched the general description of a preservice elementary teacher with weak science content understanding and low confidence in teaching science. However, Leslie did not shy away from teaching science and elements of the science unit that she planned and taught in her field placement classroom reflect aspects of the practices and ways of thinking about science teaching that were at play in her science content courses. For example, it is possible that her experiences in the science content course for elementary teachers, which emphasized developing in-depth knowledge of the topics in the state science curriculum framework ("Division of science and mathematics education undergraduate courses", 2005) rather than engaging students in inquiry practices, shaped her vision of teaching science as putting together the pieces of the story. Furthermore, the emphasis in the science content course on common misconceptions may have also influenced Leslie's conceptual change orientation to teaching.

Dana, on the other hand, demonstrated the most confidence in her science teaching. As an integrated science major, she had also taken more science content courses than the other two interns. Aspects of Dana's science unit that she planned and taught in her field placement classroom reflect elements of Discourse of new teacher of science that she probably accessed through her participation in her science content courses. For example, preservice teachers confident in science often emphasize the learning of science facts and correct answers (Davis et al., 2006; D. C. Smith & Anderson, 1999). By focusing her pre-unit lessons on science vocabulary as opposed to offering students opportunities to try out new ideas for themselves, Dana was displaying elements of a traditional Discourse of science teaching characteristics of preservice teachers knowledgeable of and confident in science. Furthermore, Dana's experiences as a successful science learner may have also partially influenced (along with the textbook) her emphasis on covering many topics about light. The wave nature of light is a standard physics topic. As a student, she probably learned about the wave nature of light and therefore, as a teacher, engaged in the same practices of covering the topics that her own teachers had covered. In addition, Dana's emphasis on hands-on activities and student conversations match the "hands-on, minds-on" approach of the science content courses for elementary teachers that she had taken in her teacher preparation program. Finally, Dana's insistence on holding students to the same high expectations without making accommodations reflects a new teacher Discourse naïve belief that teaching for equity requires teachers to treat all students the same (Chochran-Smith, 1995; Settlage & Southerland, 2007).

Aspects of Nicole's interpretation of the I-AIM stages also reflect some of the characteristics of the science content courses for teaching that she took as part of her teacher preparation program. In particular, her emphasis on facilitating student discovery may have been influenced by the self-proclaimed emphasis on "discovery-based science" in the science content course for elementary teachers. Furthermore, her emphasis on connecting to the "real world" may have also been influenced by the science content course emphasis on connections to everyday experiences. All three interns were drawing on elements of a Discourse of new teacher of science that they may have accessed through their participation in their science content courses and that influenced the ways in which they used the I-AIM and CA&P tools to plan and teach science in their field placement classrooms.

Swirling Discourses

Dana, Leslie, and Nicole were all members of the same science methods course and were assigned to use the I-AIM and CA&P tools to plan and teach science units in their field placement classrooms. Yet, each intern used the tools differently and produced different results. Each intern's use of the tools was mediated by a variety of resources that each intern brought to using the tools, including their visions for science teaching, the thematic patterns to which they connected to make sense of the frameworks and tools, their goals for themselves and others, and their beliefs about teaching, students, and science. In the previous chapters, I identified and described some of these mediators. There were probably many other mediators that were present, including additional intern beliefs and goals that I did not talk about. These mediators were not just characteristics of the interns themselves, but were situated in the many Discourses that the interns accessed through their participation with many communities and curriculum materials during their internship and teacher preparation program. This work suggests that important Discourses for these interns included the Discourse of the university student from their science methods and science content courses, the various Discourses in their field placement schools and classrooms, the Discourses of new teachers teaching about science that they accessed through their science content courses (among others), and the Discourses represented by the curriculum materials they had available.

In addition, although I did not detail them here, the interns were also participating in the communities of their other methods courses, such as the mathematics, literacy, and social studies courses. Each of these courses included additional Discourses that the interns were negotiating and drawing upon, such as the Discourse of reform mathematics teaching or the Discourse of social studies teaching. There could have been mediators of the interns' use of the I-AIM and CA&P tools that were situated in the Discourses of these other methods course communities. For example, Cartier et al. (Cartier et al., 2008) document how perspectives from a mathematics methods course interfered with preservice teachers' attempts to learn how to plan science units. Thus, the swirl of Discourses that the interns encounter is broader than just the Discourses encountered as they learned to plan and teach science.

Tables 7.3, 7.4, and 7.5 list some of the mediators and the Discourses in which these mediators were situated for each intern as they planned and taught their science units. While I have identified mediators of actions and assigned them to a Discourse, it is important to recognize that in a network of sociocultural relationships as complex as those related to learning to teach, there are many overlaps among the boxes. For example, planning did not just take place in the science methods course, but was also influenced by what happened in the field placement, previous science content courses, and other communities for which I had little access and so was not able to include. Nevertheless, these tables do summarize the major mediators and Discourses at play. Figure 7.2 then illustrates how these Discourses fit into the theoretical framework for how each intern used the I-AIM and CA&P tools.

Table 7.3

Summary of mediators and Discourses for Dana

Community	Tasks	Mediated action	Mediators	Situating Discourses
Science methods course	Planning	Use of the example electricity sequence as a template	Recognition of the example electricity sequence as a reification of course requirements	University student
Field placement: relationship with mentor teacher	Planning	Use of example electricity sequence as a template	Oppositional relationship with mentor teacher	Traditional science teaching vs. New teacher of science
	Teaching	Use of hands-on experiences and peer conversations	Vision for teaching science	New teacher of science
Field placement: curriculum materials	Planning	Use of hands-on experiences and peer conversations	Resources from former science instructor	New teacher of science
	Teaching	Covering topics (i.e. wave nature of light)	School district textbook	Traditional science teaching
Science content courses & other courses	Teaching	Use of hands-on experiences and peer conversations	Vision for teaching science	New teacher of science
		No attention to cultural resources	Beliefs about students (i.e. Holding all students to same expectation)	
		Attending to student intellectual resources (i.e. following student ideas)	Vision for science teaching	
		Covering topics (i.e. wave nature of light)	Experiences as a science learner	Traditional science teaching

Table 7.4

Summary of mediators and Discourses for Leslie

<table>
<tr><th>Community</th><th>Tasks</th><th>Mediated action</th><th>Mediators</th><th>Situating Discourses</th></tr>
<tr><td>Science methods course</td><td>Planning</td><td>Interpreting EPE as a model for planning</td><td>Recognition of EPE framework as central organizing framework of course</td><td>University student</td></tr>
<tr><td rowspan="2">Field placement: relationship with mentor teacher</td><td>Planning</td><td rowspan="2">Interpretations of EPE (i.e. experiences as activity types)</td><td rowspan="2">Thematic pattern of field placement classroom</td><td rowspan="2">Elementary teacher (?)</td></tr>
<tr><td>Teaching</td></tr>
<tr><td>Field placement: curriculum materials</td><td>Planning</td><td rowspan="2">Conceptual change teaching pattern</td><td rowspan="2">Conceptual change orientation</td><td rowspan="2">Reform science teaching</td></tr>
<tr><td rowspan="2">Science content courses & other courses</td><td rowspan="2">Teaching</td></tr>
<tr><td>Interpretations of EPE – (i.e. teaching science as putting together pieces of a story)</td><td>Experiences as a science learner</td><td>Traditional science teaching</td></tr>
</table>

Table 7.5

Summary of mediators and Discourses for Nicole

Community	Tasks	Mediated action	Mediators	Situating Discourses
Science methods course	Planning	Identification of key patterns	Guidance from course instructor	University student
Field placement: relationship with mentor teacher	Teaching	Interpretations of I-AIM stages	Guidance from mentor teacher Partnership with Dominique	Reform science teaching
Field placement: curriculum materials	Planning	Choosing activities to meet learning goals	Guidance from mentor teacher Partnership with Dominique	Reform science teaching
Science content courses & other courses	Planning	Interpretations of I-AIM stages	Discovery orientation	New teacher of science

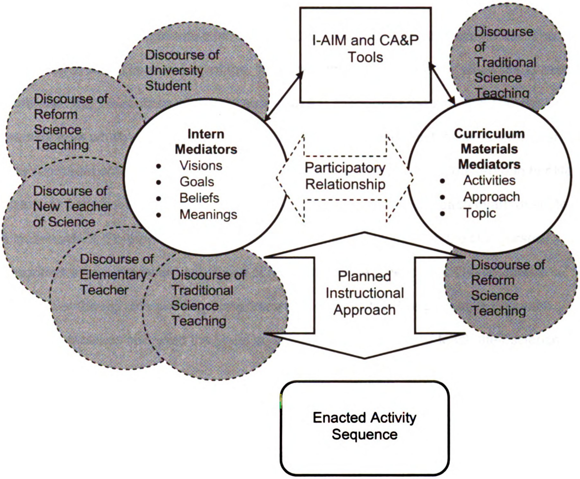

Figure 7.2. Discourse connections to interns' use of the I-AIM and CA&P tools

Gee emphasizes that individuals are the meeting point of the many Discourses in which they participate(Gee, 1999). Each individual takes a unique trajectory through the many Discourses they encounter (Cobb & Hodge, 2002, 2003; Gee, 2000). Each person draws on different resources from these Discourses. These resources, in turn, act as mediators that influence how each person interacts with subsequent Discourses that they meet. Considering the interns learning to make sense of the EPE framework and use the I-AIM and CA&P tools, it is no wonder that each intern, with her unique personal history and set of resources drawn from the various Discourses she had encountered in her life, and particularly in her life as a student and a preservice teacher, would use the tools in different ways and produce different results from the other interns. One might imagine an intern trying to make her way through Discourses swirling around her. The resources of each Discourse combine, interfere with, and influence the other Discourses in her life. The Discourses described above rose to the fore as the principal sources of practice from which these interns drew in learning to plan and teach science. However, they represent only a fraction of the many Discourses each intern encountered in her life history and there were probably many other Discourses from which each intern drew, to a lesser extent. Furthermore, the pathways each intern took through the Discourses described above, represent only three of myriad possible trajectories. The countless trajectories through the swirling Discourses accounts for the diverse results that each intern produced as she used the I-AIM and CA&P tools to plan and teach their science units.

Conclusions

In this section I summarize the three important conclusions of this dissertation.

Conclusion #1: The I-AIM and CA&P Tools can Scaffold Preservice Teacher Planning and Teaching Practices

The I-AIM and CA&P tools can be useful scaffolds for helping preservice teachers learn to use curriculum materials and plan and teach science units that support students in learning key science learning goals, engage students in inquiry and application practices, and account for students intellectual and cultural resources for learning. All three interns had some successes using the I-AIM and CA&P to analyze their curriculum materials, and plan and teach science lessons that fit the intentions of the I-AIM and CA&P tools. Furthermore, the I-AIM and CA&P tools provide the power of generality that enables preservice teachers to recognize pedagogical patterns and scaffold their pedagogical model-based reasoning.

Conclusion #2: Interns' use of the I-AIM and CA&P Tools is Mediated

Although the I-AIM and CA&P tools can be effective scaffolds of preservice teachers planning and teaching practices, preservice teachers use the tools differently from each other, producing differing results. All three interns in this study used the tools in different ways, and some of their ways of using the tools were different from how the tools were intended to be used. These differences can be accounted for by the variety of mediators that influenced the interns' use of the I-AIM and CA&P tools. Some of the mediators that were important for these interns were their relationships with their mentor teachers; their own beliefs, goals, and visions for teaching science; and features of the curriculum materials they had available.

Conclusion #3: Mediators are Connected to Larger Sociocultural Discourses that both Interfere with and Support Participation in New Discourses

The mediators of preservice teachers' use of the I-AIM and CA&P tools are not characteristics of individuals, but are situated in the larger sociocultural context in which preservice teachers participate. Preservice teachers participate in many communities, the practices of which are constructed from the Discourses that participants in those communities bring. In this research, some of the communities in which the interns participated that were important for their use of the I-AIM and CA&P tools were their science methods course, their field placement schools and classrooms, and their science content courses. As preservice teachers participate in these communities, they encounter the many Discourses that are in play in each community. The mediators that influence how the preservice teachers use the I-AIM and CA&P tools are rooted in the Discourses from which participants in communities draw as they construct and negotiate their practices within these communities. For the interns in this study, the Discourses that rose to the fore were the Discourse of university student in the science methods course, the various teaching Discourses of the field placement, and the Discourses of new teacher of science in the science content and other courses. Other communities and Discourses could have also been influential for any one of these interns. As preservice teachers move through their teacher preparation program, they encounter many Discourses swirling about them. Some of these Discourses interfere with or support preservice teachers' use of such tools as the I-AIM and CA&P. Dana, Nicole, and Leslie each traveled through these different Discourses, but encountered different practices, goals, beliefs, perspectives, and ways of making sense that mediated how they used the I-AIM and CA&P tools. These different mediators thus account for the different results that each intern achieved as she used the tools to plan and teach science.

CHAPTER 8

Implications

Chapter Overview

In this final chapter, I discuss some of the implications for the conclusions of this dissertation. In the first part of this chapter I pick up where Chapter 7 left off. I discuss the big picture implications that the challenges associated with learning the practices of a new Discourse might have on the goals for preparing preservice teachers to use tools such as the I-AIM and CA&P tools. In the second part of this chapter I describe some of the more direct implications of this research on elementary teacher preparation and research.

Powerfully Learning the Practices of New Discourses: Implications for the Goals of Learning to Use I-AIM and CA&P

The EPE framework and the I-AIM and CA&P tools are products of a Discourse of reform science teaching. The I-AIM and CA&P tools were designed to scaffold preservice teachers' participation in some of the practices of this Discourse, including analyzing curriculum materials, considering students' intellectual and cultural resources, and planning and teaching science units that engage students in the practices of inquiry and application. Dana, Leslie, and Nicole's cases, however, illustrate some of the challenges associated with learning the practices of a new Discourse. Individuals bring with them elements from other Discourses that mediate how they interact with the tools and practices of the new Discourse. In this section I will discuss the implications of this situation for preparing preservice teachers to use tools such as the I-AIM and CA&P to engage in the practices of the Discourses of reform science educators.

Learning to Participate in New Discourses

To begin this discussion, I need to introduce Gee's (1999) framework for how people learn new Discourses. Gee makes a distinction between acquiring a Discourse and learning a Discourse. Gee defines acquisition as the "process of acquiring something subconsciously by exposure to models and a process of trial and error, without a process of formal teaching" (p. 5). Learning, on the other hand, is "a process that involves conscious knowledge gained through teaching" (Gee, 1999, p.5). I will unpack these ideas, and then discuss the results of this research in light of these constructs.

Acquisition / Enculturation. Gee's choice of the word "acquisition" is somewhat confusing. In his earlier work, Gee used the word "enculturation" to describe the process of apprenticeship into "social practices through scaffolded and supported interaction with people who have already mastered the Discourse" (Gee, 1989, p. 7). Ten years later, Gee labeled the same process "acquisition" (Gee, 1999). Sfard (1998) points out that the word "acquisition" elicits the metaphor of having or owning something, of getting by taking or receiving. However, Gee's construct of Discourses is about participation in practices, not having or owning a practice. I suspect Gee was not aware of the way the word "acquisition" elicits this metaphor of having or owning something. However, since Gee made the distinction between acquisition and learning in his 1999 paper, researchers have become more aware of this metaphorical reference, and thus it is difficult to use the word "acquisition" without connoting Sfard's acquisition metaphor. In contrast, "enculturation" better elicits a metaphor of participation (Sfard, 1998), a metaphor that more closely fits with Gee's construct of Discourse. Gee's original use of "enculturation" also fits with Brown, Collins, and Duguid (1989) use the word "enculturation" to define the process of adopting the behaviors and belief systems of a social group, either consciously or subconsciously, through participation and interaction with others. Furthermore, enculturation also fits with Lave & Wenger's (1991) construct of apprenticeship through legitimate peripheral participation with the practices of a community. I will refer to Gee's process of "acquisition" as "enculturation" because I think that it better elicits the metaphor of participation that is inherent in the construct of Discourses.

In Gee's (1989) framework, successful enculturation results in mastery. Mastery is defined as "full and effortless control" of a Discourse (Gee, 1999, p. 8). The easiest Discourse to master is a person's primary Discourse, the Discourse into which one is apprenticed when one is born. Other Discourses, called secondary Discourses, are harder to master, depending on how similar a person's primary Discourse is to the secondary Discourse. Once the apprenticeship is over, one either has mastered the new Discourse or one has not (Gee, 1989). There is no in between.

The goal of the university science methods course was to scaffold interns into the practices of reform-based science teaching. Dr. Adams engaged the interns in a cognitive apprenticeship of planning and teaching science lessons (J. S. Brown et al., 1989; Collins et al., 1989). He used the example electricity sequence to model the use of the I-AIM and CA&P tools in planning and teaching. He then provided careful coaching as he guided the development of the interns' planned instructional approaches, finally fading his support as the interns enacted their activity sequences in the classroom. All three interns made some progress towards the goal practices. Nicole, for example, made big strides in moving from the periphery to legitimate participation with many of the practices. Dana moved far beyond the practices of her own mentor teacher. Even Leslie demonstrated proficiency in some of the practices, including identifying a central question and accounting for students' intellectual and cultural resources. While the interns made progress towards proficiency in some of these practices, when the apprenticeship ended, none of the interns had mastered the new Discourse.

Enculturation in the practices of a Discourse is often espoused as a goal for education. Researchers as diverse as Lave & Wenger (1991), Cobb, et al. (1994, 2003), Driver, et al (1994), Brown, et al. (1989), Collins (1989), Putnam & Borko (2000), Duschl (1990), and Sharma & Anderson (2003), among others, argue that engaging students in the practices of a Discourse (or culture or community) are important for helping students understand and make sense of the disciplines they are studying. Yet researchers such as Calabrese Barton (2003, 2000), Moje, et al (2001), Lee & Fradd (1996), and Jegede & Aikenhead (1999), among others, describe the challenges posed when students' own Discourses interfere with enculturation. The cases of Dana, Leslie, and Nicole illustrate, in the context of elementary science teacher education, how the Discourses from which preservice teachers may draw sometimes interfere with the Discourse of the apprenticeship. Leslie's access of thematic patterns from different Discourses, Dana's insistence on treating all students the same, and Nicole's focus on facilitating student discovery all interfered, to a greater or lesser extent, with each interns' participation in the reform science Discourse practices that the I-AIM and CA&P tools were meant to scaffold.

Furthermore, Dana, Leslie, and Nicole were not just apprenticing in the new Discourses of reform science teaching. They were, at the same time, also apprenticing in many other new Discourses, including the Discourses of the field placement school and classroom, as well as the new Discourses of social studies, mathematics, and literacy education. Gee, and many of the researchers mentioned in the previous paragraph, consider education in the context of participation in one Discourse (or culture or community) at a time. Cobb (1994; Cobb & Hodge, 2003), for example, considers students' engagement in the practices of mathematics, and Calabrese Barton (2003, 2000) and Lee & Fradd (1996, 1998) consider students' practices in the context of learning science. In considering how students draw from other Discourses when learning new practices, the necessary focus on the new practices of one Discourse sometimes renders the other Discourses as static. That is, these other Discourses are just pools of practices already mastered from which to borrow. Yet, in the cases of these interns, the practices of reform science teaching were likely also influencing the interns' participation in the other Discourses as well. The interns' participation with other new Discourses were each influencing, sometimes interfering, sometimes supporting, interns' participation in all of the Discourses. In an experience as concentrated and intense as an internship year in a teacher education program, the swirl of Discourses becomes almost tornadic, with many Discourses thrown together in the storm of education. In such a situation, enculturation into several Discourses, or even one Discourse, would be nearly impossible.

Learning. In Gee's framework, learning is different from enculturation. Gee explains that Discourses cannot be mastered through overt instruction. However, overt instruction can provide the metaknowledge of a Discourse necessary to analyze and critique other Discourses. While mastery of a Discourse through enculturation provides access to the social goods and status of the dominant social Discourses, learning the metaknowledge necessary to critique these Discourses provides power of a different type. Gee (1989) states, "Metaknowledge is liberation and power, because it leads to the ability to manipulate, to analyze, to resist while advancing" (p. 13).

Again, Gee's label is somewhat misleading, because the term "learning" has many meanings in many different Discourses. To some, the term "learning" has a principally cognitive connotation that does not necessarily acknowledge the ways that participation in social practices can and should be considered learning (Cobb, 1994; Sfard, 1998). It is difficult to talk about education and not talk about learning, as if learning could be reserved for only one type of education or the result of only one practice. The important distinction is the role that overt instruction plays in learning a new Discourse. Overt instruction can provide students with access to the liberation of metaknowledge about Discourses and the powerful practices of analysis and critique of Discourses.

In this era of accountability, the Discourse of reform science education is not part of the dominant social Discourse. Reform science education is not the Discourse of power and status. Science is not a valued core subject of instruction for elementary schools. When science is taught, more traditional approaches that emphasize didactic science teaching practices and the use of mass-market curriculum materials that rarely support students in learning important science concepts predominate (Anderson, 2003; Anderson & Smith, 1987; Kesidou & Roseman, 2002). Yet developing the metaknowledge to critique the dominant teaching Discourses could provide new teachers with the liberation of choice that Gee's notion of learning offers.

Dana's critique of her mentor teachers' science teaching practices most closely illustrates this possibility. Dana's critique of her mentor teacher focused mostly on the fact that her mentor teacher did not engage students in hands-on experiences or allow them to participate in conversations with each other. Dana's critique was only possible because she had access to another Discourse from which to analyze the strengths and weaknesses of her mentor teacher's science teaching. Dana was drawing from the Discourses of her science content courses and the Discourses of her own science learning as a standpoint from which to critique her mentor teacher. The goal of learning to use I-AIM and CA&P tools, then would be that Dana would eventually have access to the reform science education Discourse and therefore to be able to further critique her mentor teacher's lack of inquiry in her science instruction. Dana would then be able to move toward engaging in more inquiry practices in her own teaching, even if she had not achieved mastery of the reform science teaching Discourse.

Goals for Providing Access to New Discourses

This discussion has implications for the goals of using the I-AIM and CA&P to provide preservice teachers with access to the Discourse of reform science teaching. Given the swirl of Discourses that preservice teachers navigate in their teacher preparation program, mastery of the Discourse of reform science teaching, as defined by Gee, is not a feasible goal. Furthermore, mastery of the Discourse of reform science teaching through enculturation might not even be a desirable goal for elementary preservice teachers. Enculturation, as defined by Gee and Brown, et al. often involves developing new practices subconsciously by interacting with others. As such, students or apprentices may not be aware of the practices in which they are engaging, why they engage in them, or the consequences of their engagement with those practices. Thus, mastery of the Discourse of reform science education does not position new teachers to recognize the affordances and constraints of their own teaching situations. At the same time, in Gee's framework, learning focuses on metaknowledge about a Discourse and not on learning the practices of a Discourse. He states, "acquisition (enculturation) is good for performance, learning is good for meta-level knowledge" (Gee, 1999, p. 6). Therefore, simply providing instruction about the Discourse of reform science teaching does not prepare a new teacher to engage in reform planning and teaching. This is the point that advocates of enculturation have stated for a long time (J. S. Brown et al., 1989; Driver et al., 1994; Lave & Wenger, 1991; Wenger, 1998). Yet, I think in the focus on apprenticing new teachers into the practices of new Discourses, some of the difficulties and challenges of enculturation are overlooked. There needs to be a goal that allows for participation in the practices of the Discourse of reform science teaching, that acknowledges and accounts for the challenges that the swirl of Discourses presents in engaging in the practices, and at the same time, provides preservice teachers with the powerful literacy necessary to engage critically in the many Discourses of teaching that they will encounter. This goal includes participation in the practices of the new Discourse, but it also highlights the importance of preparing preservice teachers to be powerfully literate about the Discourse.

The I-AIM and CA&P tools were designed to scaffold preservice teachers' participation in the science planning and teaching practices of the Discourse of reform science teaching. They are part of the science methods course community, but intended to help make the Discourse of reform science teaching accessible to interns who are negotiating the swirl of Discourses in the many communities in which they participate (Figure 8.1). The idea was that if the preservice teachers could use these tools as intended, they would be able to participate in the practices of the Discourse of reform science teaching. As tools, the I-AIM and CA&P are abstractions; they do not exist separately from their mediated use. They point to a Discourse, but they do not capture, define, or guide the full range of possible teaching outcomes that exist in the swirl of teacher, student, school Discourses. The goal of learning to use the I-AIM and CA&P tools should be to introduce preservice teachers to the practices of the Discourse of reform science teaching, provide them with opportunities to use the practices and help them develop the metaknowledge about the practices necessary to recognize and critically analyze different approaches to teaching science. By the end of their teacher preparation program, elementary preservice teachers should be proficient enough in the practices of the Discourse of reform science teaching to be able to draw on them as resources and recognize the affordances and constraints of these practices as they learn to participate in their new teaching situations (Figure 8.2). In this way, new teachers would be able to draw on and incorporate elements of the Discourse of reform science teaching as they develop their new teacher identity. In this way too, new elementary teachers drawing on the practices of the Discourse of reform science teaching would shift what it means to be an elementary teacher to include more reform-based science teaching perspectives, goals, and practices.

All three interns made some progress towards these goals. All three interns drew on some of the practices scaffolded by the I-AIM and CA&P tools. Furthermore, all three interns recognized how their planning and teaching differed from the traditional didactic approaches with which they had had the most prior experience. Finally, all three interns recognized that there were strengths and weaknesses of their own performances, and set goals for their future planning and teaching that matched some aspects of the EPE framework and I-AIM tools. Dana thought that the I-AIM tools might not work for teaching all topics to all students, because not all topics afford easy access to direct experiences available in a classroom. However, for her own teaching, she desired to continue to find and use experiences that would make patterns visible to her students. Leslie recognized that there were many shortcomings in her plans and her enactment, but she was confident that she would continue to learn from her own experiences. Nicole walked away from her teaching experience excited about the possibilities that reform science teaching practices could offer. Sold on the affordances of I-AIM and confident that she could now teach science well, Nicole had the vision, practices, and metaknowledge necessary to powerfully employ I-AIM in the future.

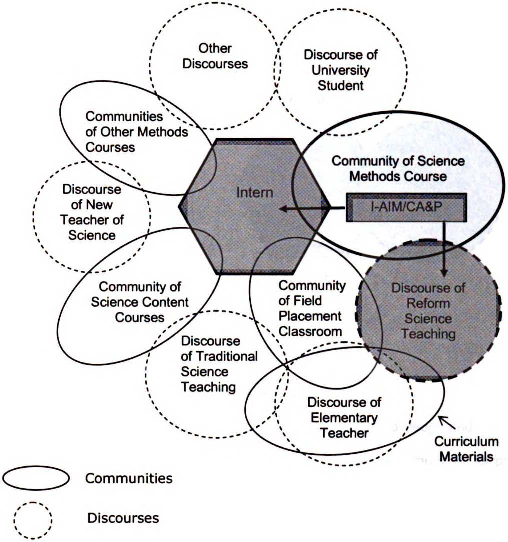

Figure 8.1. Role of I-AIM/CA&P tools in the swirl of Discourses and communities

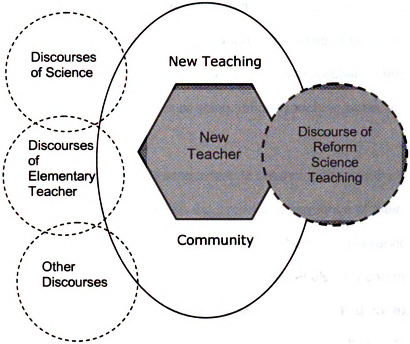

Figure 8.2. Goal of elementary science teacher preparation

An important aspect of this goal is identifying what knowledge and metaknowledge about practices of reform science teaching are important for preservice teachers to learn in order to be powerfully literate. There is some knowledge that preservice teachers need in order to use the I-AIM in the first place. For example, preservice teachers need to understand what counts as an experience with phenomena and how these experiences are different from other types of learning experiences. Preservice teachers also need to be able to articulate what a pattern in experiences is and how explanations are different from patterns in experiences. Knowledge about I-AIM becomes metaknowledge when preservice teachers can talk about the practices of reform teaching from within the framework of the I-AIM. For example, preservice teachers use metaknowledge when they can explain how certain practices meet the intentions of the I-AIM. This important metaknowledge includes recognizing that there are patterns in teaching and that different teaching patterns have different purposes and lead to different types of results. For example, preservice teachers need to be able to recognize inquiry and application-based teaching patterns and distinguish these teaching patterns from other common teaching patterns, including didactic teaching and conceptual change teaching patterns. Furthermore, preservice teachers need to recognize the affordances and constraints of using various teaching patterns, including the I-AIM patterns.

One of the big challenges that teachers face is balancing the requirements for teaching that meets the intents of I-AIM with the scope and sequence of their curriculum and the time available for planning and teaching science. Therefore, preservice teachers need to be able to determine which curriculum units and materials they can most efficiently modify to meet the intents of I-AIM and CA&P. They may find, for example, that some available materials already include activities that fit the I-AIM functions and CA&P intentions and therefore require little modification where as other units may require more substantial modification. Preservice teachers need the metaknowledge necessary to understand the potential trade-offs between student learning and meeting the expectations of the established curriculum that decisions making modifications entail. Preservice teachers need to learn how to determine which modifications will best help them meet their teaching goals and engage students in the practices of inquiry and application within the constraints of their teaching context.

Implications for Elementary Science Teacher Preparation & Research

In this section, I present some of the implications of this research for supporting preservice teachers in learning the practices of the Discourse of reform science teaching and the metaknowlege about necessary to become powerfully literate in the Discourse of reform science teaching. I look at implications for instruction of the science methods course, field placements, science content courses, organization of elementary teacher education programs, and the redesign of the I-AIM and CA&P tools, and future research.

Implications for Science Methods Courses

Instruction in science methods courses needs to span the boundaries between the Discourse of reform science teaching and the Discourses that the preservice teachers are drawing on when learning to use the I-AIM and CA&P tools. Boundary spanners can be people, objects, or experiences that help make a new Discourse more accessible to new participants (Buxton *et al.*, 2005; Covitt *et al.*, In review). In learning to use I-AIM, boundary spanners would help preservice teachers recognize the Discourse of reform science teaching, support them in learning the new practices of the Discourse, and help them understanding how the Discourse of reform science teaching is similar to and different from other Discourses of science teaching. These cases highlight some important points in the science methods course where people, curriculum materials, and scaffolds could serve as boundary spanners to help preservice teachers learn to use the I-AIM and CA&P tools.

First, the course instructor needs to be a boundary spanner or a cultural broker who can participate in the reform-based Discourses but also knows the practices and common meanings in other Discourses from which the preservice teachers may be drawing (Aikenhead, 1996; Banks *et al.*, 2005; Jegede & Aikenhead, 1999; Wenger, 1998). The course instructor needs to be able to highlight and contrast the practices of the Discourse of reform science teaching with the practices of the Discourses from which the preservice teachers draw. In this way, the course instructor both makes the practices more accessible and builds metaknowledge about the Discourse. Leslie's case highlights this point. Leslie accessed the thematic patterns of the Discourses of her field placement to make sense of the words "experiences," "patterns," and "explanations." In her field placement, these words had different meanings than they have in the Discourse of reform-based science planning and teaching. While Dr. Adams modeled experiences in the example electricity sequence, he did not specifically define what constitutes an experience with phenomena or contrast the intended meaning with other possible meanings. Similarly, he modeled finding patterns and demonstrated how the explanations accounted for the patterns, but he did not define "patterns" or "explanations" in terms of the Discourse of reform science or contrast the meanings of these words with other common meanings. Thus, in Leslie's case in particular, having her use the I-AIM and CA&P to plan and teach her science unit did not provide her with access to the thematic patterns she needed to use the tools as intended. By helping preservice teachers recognize the thematic patterns that give the intended meanings of the terms "experiences," "patterns," and "explanations," the course instructor would serve as a boundary spanner to provide support in learning to use the I-AIM and CA&P tools and develop the metaknowledge about the tools and EPE framework to understand how they differ from other ways of planning and teaching science.

Second, curriculum materials that make patterns in experiences explicit could serve as boundary spanners by supporting preservice teachers in identifying the patterns in experiences that are necessary for students to understand key science concepts. Even when preservice teachers understand the science-reform meaning of the words "experiences," "patterns," and "explanations," they do not always have the resources necessary to help them identify the key patterns and recognize the key experiences that would help their students learn the scientific explanations. All three interns would have benefited from curriculum materials that helped them identify patterns in experiences. While Nicole was able to identify the necessary patterns for her unit, it was only because she was able to leverage Dr. Adams' guidance. She did not come to the patterns on her own and received no assistance from her folder of collected activities in either identifying or using patterns in experiences. Leslie had a topic for which the patterns in experiences were difficult to identify and for which she had few curriculum materials to help her either recognize those patterns or identify experiences that she could use in the classroom to help her students learn the patterns. Similarly, although Dana recognized the patterns that students needed to learn, she had a difficult time making those patterns explicit to students. Curriculum materials that help make patterns explicit would serve as boundary spanners by helping preservice teachers recognize and use patterns in experiences to plan their instructional approaches. Furthermore, because learning to recognize patterns in experiences is a big shift in perspective about the nature of science or science teaching, such materials would also help preservice teachers develop the metaknowledge about how making these patterns in experiences explicit to students differentiates teaching using the I-AIM from the teaching patterns of other teaching approaches (i.e. conceptual change, discovery, or didactic teaching).

Third, boundary spanners are needed to help preservice teachers recognize and take advantage of students' cultural resources for learning. All three interns recognized and made use of students' intellectual resources for learning. All three interns identified common student naïve conceptions and addressed those conceptions in their planned instructional approaches and enacted activity sequences. Nicole was even able to take advantage of students' congruent conceptions. These interns' success with this aspect of the CA&P tool suggests that the field of science education has made important strides in supporting preservice teachers in recognizing and addressing students' naïve conceptions in planning and teaching. However, preservice teachers still struggle with identifying and taking advantage of students' funds of knowledge, youth genres, and other cultural resources for learning. Nicole was able to take advantage of both funds of knowledge and student youth genres in her planning and teaching. Similarly, Leslie was aware of and incorporated student youth genres in her work. Dana, however, did not make any cultural connections in her planning and teaching. Boundary spanners such as curriculum materials that prompt teachers' consideration of their own students' resources would be helpful, as would new strategies and tools for recognizing and leveraging student cultural resources in learning. In addition, boundary spanners such as new tasks and teaching activities in science methods courses, are needed to provide preservice teachers with opportunities to view cultural diversity in students from a strength-based, rather than a deficit-based, perspective (Banks et al., 2005; Calabrese Barton *et al.*, 2007; Gay, 2001). For example, preservice teachers might read a case description or transcript of a classroom of students engaged in an activity and then work in groups to think about what the students were bringing to the activity and how they as teachers might modify the activity to better leverage the students' resources. Such materials and supports would help preservice teachers become powerfully literate about reform science teaching by helping them develop the metaknowledge necessary to recognize their own perspectives on student diversity and to recognize the impact of potential curriculum materials modifications for various students' science learning.

Helping preservice teachers learn to use tools such as the I-AIM and CA&P tools requires providing preservice teachers with opportunities to use the tools. However, preservice teachers also need instruction about the tools. This instruction must span the Discourses that the preservice teachers bring to learning to plan and teach science and the target Discourse of reform-based science planning and teaching. The instruction must support preservice teachers in developing the metaknowledge about the tools necessary to use the tools critically in their own teaching situations. Boundary spanning people (course instructors), objects (curriculum materials), and activities are needed to accomplish this goal.

Implications for Field Placements

This research again confirms the impact of the field placement classroom in preparing preservice teachers (Brouwer & Korthagen, 2005; Darling-Hammond *et al.*, 2005; Feiman-Nemser & Buchmann, 1985, 1987). When the Discourses of the field placement align with the Discourses of the science methods course, as in Nicole's situation, preservice teachers experience converging support. However, when the Discourses of the field placement are different from the Discourses of the science methods course, as in Dana's and Leslie's situations, then the potential for interfering Discourses increases. Dr. Adams attempted to cross the borders between the field placement classroom and the science methods course by holding workshops in each field placement for the mentor teachers and interns to spend time co-planning the science unit. However, the one-time, two-hour workshop provided only minimal opportunities for the mentor teacher unfamiliar with the Discourse of reform science teaching to grasp the theoretical underpinnings of the I-AIM and CA&P tools, recognize the implications of the use of the tools on teaching science, and support their interns in using the tools. The mentor teachers' reactions to the workshop reflected the interns' use of the tools. Melinda thought that the frameworks were unrealistic for the classroom, which paralleled Dana's consideration of planning using the I-AIM and CA&P tools as an academic task; Rebecca thought she understood inquiry and was enthusiastic about the workshop, but like Leslie, did not recognize how her meanings of inquiry differed from the meanings intended by the tools and frameworks; and Annette, through all of her past experience working with the university teacher preparation program, was able to grasp the underlying framework and help Nicole make sense of and use the tools in ways that matched the intentions of the tools.

In order for the field placement classroom to be a community that supports preservice teachers in making sense of and using the I-AIM and CA&P tools in ways that match the intended uses of the tools, teacher preparation programs need to do more to help mentor teachers' access the Discourse of reform science teaching from the field placement community. Building a community in which the course instructor, preservice teachers, and mentor teachers work together to build understanding of the frameworks could go a long way toward supporting preservice teachers in accessing the Discourse practices of reform teaching. For example, if mentor teachers also engaged in planning and teaching at least one unit using the I-AIM and CA&P tools, they might be better prepared to support preservice teachers in also using the tools in ways match the intentions for the tools. Course instructors would again act as boundary spanners, helping both preservice teachers and mentor teachers consider the course framework within the constraints of the field placement setting. In this way, preservice teachers and mentor teachers would engage in sense-making together and thus begin to create another community in which preservice teachers can access the Discourse of reform science teaching.

Implications for Science Content Courses

One challenge that preservice teachers often have is coordinating what they learn about science and science teaching from their science content courses with what they learn about science and science teaching from their science methods courses. The goals of these two courses are different, and sometimes they provide access to different Discourses that come into conflict when preservice teachers are learning to plan and teach science. While I did not observe these interns in their science methods courses, informal conversations with former instructors and with preservice teachers suggest that these courses modeled science teaching as a presentation of science ideas followed by hands-on activities designed to demonstrate, explicate, and confirm the science ideas. Although the science content course does engage preservice teachers in hands-on experiences and sometimes with experiences with phenomena, this type of teaching matches more traditional "school science" by providing explanations before experiences (Anderson, 2003; Sharma & Anderson, 2003). Preservice teachers do not often recognize how the pattern of teaching that they experienced learning science in their science content courses differed from the teaching pattern intended by the I-AIM. Content courses that make their own teaching patterns explicit, even if it is just illustrating that they are providing explanations followed by experiences, could help preservice teachers build metaknowledge about patterns of science teaching and more easily understand the intent of I-AIM when they take their science methods courses. A more effective alternative would be for science content course instructors to teach all or some of the science content using an experiences-before-explanations teaching pattern.

Implications for Elementary Teacher Education

The results of this dissertation also have implications for elementary teacher education in general. In teacher education programs, preservice teachers take methods courses in the core subject areas of the curriculum, sometimes taking all of those methods courses together in one year or one semester. Teacher educators of those different subject areas often focus on helping preservice teachers learn the practices of each Discourse as if each subject-related Discourse existed separately and the preservice teachers were only making one transition from their own preservice teacher Discourses to a new Discourse of reform-based teaching. However, this research shows that preservice teachers are traversing many Discourses at one time, including the field placement Discourses and the Discourses of all of the other methods classes in which they are participating. The Discourses of university content courses in all of these subject areas, as well as the Discourses of other teacher education courses are present as well. All of these Discourses can interfere with each other (or in some cases, support each other). Teacher educators and program coordinators need to recognize the swirl of Discourses through which preservice teachers traverse as they learn to become new teachers. Coherent programs that recognize potential interference points and work to build points of convergence among Discourses might better serve preservice teachers trying to make sense of multiple Discourses at the same time. For example, course instructors could compare lesson plan formats and lesson planning strategies across various methods courses. They could also examine and compare and contrast their own teaching patterns and the teaching patterns that they advocate. Are there instructional models in other disciplines? How do their teaching patterns compare to I-AIM? How can instructors help preservice teachers negotiate the differences among teaching patterns? By making differences and similarities in approaches to teaching in each discipline and methods course explicit, elementary teacher education programs could potentially better help preservice teachers become powerfully literate in not only each subject area separately, but also in all of the Discourses of reform-based elementary teaching together.

Implications for the Redesign of I-AIM and CA&P

Design-based research is an iterative process, with each cycle of design, enactment, and analysis informing the next cycle of design. As tools for scaffolding preservice teachers' reform-based planning and teaching practices, including the use of curriculum materials, the I-AIM and CA&P show promise. The experiences of the using these tools in the science methods course in this design cycle spurred some immediate changes in the lay-out and presentation of the I-AIM and CA&P tools. For example, the color coding technique that was helpful in analyzing the interns' use of the tools has now become part of the tools themselves. That is, when presented to preservice teachers, the stages and functions are color-coded. This color coding helps preservice teachers see right away the teaching patterns that fit I-AIM (i.e. greens before blues mean experiences before explanations). Course instructors can now ask preservice teachers to color-code their own sequences to see how well their planned instructional approaches are matching the intended teaching patterns. In the future, course instructors might be able to also help preservice teachers recognize other teaching patterns such as a didactic teaching pattern or a discovery teaching pattern (Anderson & Smith, 1987) as well. This approach will hopefully help preservice teachers understand what an instructional model is and recognize the pedagogical power of instructional models.

Another important redesign has been the re-naming of the Engage stage to the Question stage. This re-naming distinguishes the I-AIM and CA&P from the 5E (Bybee, 1997) and other similar instructional models that also begin with an Engage stage. In I-AIM, the function of the first stage is to establish a problem, which is a more specific purpose than to just motivate students to be interested in learning about the topic (Reiser et al., 2003; Rivet & Krajcik, 2004; E. L. Smith, 2001). Renaming the Engage stage highlights the emphasis on establishing a question. Leslie was the only intern to explicitly establish a question at the beginning of her enacted sequence. Dana eventually implicitly established a central question during her enactment; although she elicited student ideas about reflection at the beginning of her unit, she never asked students the question about how we see color until much later in the unit. Similarly, Nicole recognized the importance of the central question in her planning, but focused more in the beginning of her enactment on establishing a context and purpose for studying the topic. Establishing a context by providing experiences at the beginning of the unit does fit the intents of the I-AIM, but if a question is not also established explicitly at the beginning, then the Engage stage is not complete. Nicole was able to eventually establish a question. It is hypothesized that placing more of an emphasis on the question aspect of the Engage stage by renaming it the Question stage might make that intention more visible to preservice teachers.

Implications for Future Research

This research also has implications for future research. As a design-experiment, this research has implications for future cycles of design and analysis of supports for helping preservice teachers learn to use curriculum materials to plan and teach science. Covitt et al. (In review) are already pushing forward on developing curriculum materials analysis boundary spanning tasks. As mentioned above, more work needs to be done to develop similar boundary spanners for helping preservice teachers understand the EPE framework, recognize teaching patterns, and learn to identify and leverage students' cultural resources.

This dissertation developed a new analysis technique for analyzing teachers planned and enacted activity sequences. Identifying and color-coding the functions of activities in a sequence and then analyzing the patterns in those functions can reveal preservice teachers' teaching patterns. These teaching patterns can be used to identify how preservice teachers use tools such as I-AIM or other instructional models. They can also help identify preservice teachers' orientations to teaching (Magnusson *et al.*, 1999). Future research could focus on identifying and characterizing other teaching patterns as a tool for both supporting new teachers in teaching reform-based science and for examining the affordances and constraints of different teaching patterns in different situations. Recognizing and understanding preservice teachers' teaching patterns and the teaching patterns suggested in curriculum materials could be powerful in pushing forward research on science teaching and learning.

In addition, this research demonstrated the usefulness of analyzing preservice teachers' planned instructional approaches and enacted activity sequences together.

Teacher educators often only have access to preservice teachers' lesson plans and planned instructional approaches. As Leslie's case shows, preservice teachers can sometimes use the language of the course in ways that might suggest they understand the frameworks. However, examination of their enacted activity sequences shows what they are actually able to do in the classroom. As Discourses are about what people do as well as what they say, examination of preservice teachers plans and enactments together is important for understanding preservice teachers' progress in learning to use the practices of a new Discourse.

This dissertation research focused on preservice teachers' development of science planning and teaching practices. Understanding the development of preservice teachers' pedagogical practices, especially with regard to using curriculum materials to plan and teach science, is an area that has received little attention (Davis *et al.*, 2006; Simon, 2000). This dissertation has provided some insight into how preservice teachers learn to use tools that are designed to scaffold their learning of science planning and teaching practices and the sociocultural factors that influence how they use these tools. This research has also provided some insight into the challenges that preservice teachers face in learning the practices of new teaching Discourses. Important future research should follow preservice teachers into their years as beginning teachers to examine how these teachers draw on the I-AIM and CA&P tools in their new teaching situations. Are they able to use the I-AIM and CA&P tools to help them plan and teach new science units without the direct support of a course instructor? Are they able to use the tools critically to analyze the resources they have available and develop units that match their students' resources for learning? If so, how do they use the tools? What aspects do they draw on the most? What new challenges do the teachers face using the tools? The color-coded function analysis of beginning teachers' plans and enactments could be helpful in identifying new teachers' teaching patterns to answer these questions too.

In addition, this dissertation suggests that there needs to be considerably more research on the interactions of multiple Discourses at play in learning to teach. I have hypothesized some Discourse interactions in learning to use the I-AIM and CA&P tools. For example, the Discourse of elementary teacher can interfere with understanding how experiences with phenomena are important aspects of the Discourse of reform science teaching. Yet, this research looks at only some of the communities of practice in which preservice teachers engage as they learn to teach. I speculate that there could be other interesting interactions among Discourses related to teaching science and the Discourses of other methods courses. For example, the Discourse practice in reform mathematics may have interesting interactions with the Discourse practices of reform science teaching. Furthermore, for each intern, there were probably interactions with the Discourse of their own major that interacted with their learning to teach science. For example, some of the mediators that influenced how Leslie used the tools may have been situated in the Discourse of social studies or social studies teacher. There may be other common Discourses that were overlooked in this research, too. Dana might have been drawing on the Discourse of showing rabbits, or Nicole might have been drawing on the Discourse of summer camp counselor when engaging in new practices of planning and teaching science.

Future research needs to continue to consider how preservice teachers negotiate the swirl of Discourses that they traverse in learning to teach. This dissertation pushes sociocultural researchers to look not just at the personal resources that preservice teachers bring to learning how to teach science, but to examine how those resources are embedded in the larger sociocultural contexts, and how these contexts vary and interact. This line of research would have important theoretical implications as well. While the swirl of Discourses in teacher education may be particularly strong, all people participate in multiple Discourses or communities of practice at any particular time, and understanding the interplay of multiple Discourses will help us better understand how people learn to participate in new Discourses.

APPENDIX A: INQUIRY APPLICATION INSTRUCTIONAL MODEL (I-AIM)

EPE	Stage	Function	Description
Experiences	Engage	Establish A Question	Pose a question that will drive the overall inquiry and provide a sense of purpose. The question should be comprehensible, relevant, & motivating.
		Elicit Students' Initial Ideas	Invite students to share initial ideas about possible answers to question. Probe students' ideas to find out how they understand the question.
Patterns	Explore & Investigate	Explore Phenomena For Patterns	Provide opportunities for students to explore scientific phenomena related to the question to find & understand patterns. This includes: • Conducting investigations to try out & test ideas • Making & recording observations of first hand observations • Looking for patterns in observations
		Explore Ideas About Patterns	Provide opportunities for students to share their ideas about patterns. This includes: • Sharing ideas about patterns & evidence for them • Comparing/coming to agreement about observed patterns
Explanations	Explain	Students Explain Patterns	Provide opportunities for students to express their ideas. They can: • Share their own explanations (reasons) for the patterns • Share ideas of how their explanations answer the question.
		Introduce Scientific Ideas	Provide accurate & comprehensible representations of the scientific idea(s). This is a grade level appropriate scientific explanation for the patterns students observed.
Application		Compare Student & Scientific Ideas	Help students compare their own explanations with the scientific explanation provided by the teacher. Students can compare, test & revise their own explanations. Students use the scientific explanation to answer the question.
	Apply	Apply To Near & Distant Contexts With Support	Provide opportunities for students to apply the scientific explanation in new contexts. Initially, provide support though modeling & coaching. Students can answer questions about new experiences involving the same patterns & explanation. New questions can be more similar to or different from the original question.
		Apply With Fading Support	Provide opportunities for students to apply the scientific explanation in new contexts with diminishing support from the teacher.

Developed by Kristin L. Gunckel, Christina V. Schwarz, Edward L. Smith, and Beth A. Covitt

APPENDIX B: CRITICAL ANALYSIS AND PLANNING GUIDE (CA&P)

Model Stage	Activity Function	Curriculum Materials Analysis Questions	Knowing My Students Questions	Planning Questions
Engage	Establish a Question	Is there a relevant, interesting, understandable problem that is set in a real world context that addresses the learning goal?	What problems are relevant and interesting to my students? How can I connect to my students' lived experiences?	What relevant, interesting, motivating, understandable problem will I use? How is this problem related to my students' lived experiences?
	Elicit Students' Initial Ideas	Does the material elicit student ideas and help the teacher understand student ideas about the learning goal?	What ideas do my students have related to this learning goal? How do my students make sense of their world?	How will I elicit student ideas? How will I have students share their ideas with other students?
Explore & Investigate	Explore Phenomena for Patterns	Do the students explore (have experiences with) a variety of phenomena? Do the students collect data, record observations, look for patterns related to the learning goal?	What are the types of everyday experiences that my students engage in? How can I engage my students in scientific practices?	What problems or phenomena will students explore? How will the students collect data, record observations, look for patterns?
	Explore Student Ideas About Patterns	Do the students explore, share & justify their ideas? Does the material build on student ideas, challenge student ideas when necessary, and give students opportunities to revise their ideas based on evidence?	What resources (funds of knowledge, personal experiences) do my students bring to learning science? What ways of knowledge-sharing are my students familiar/comfortable with?	How will the students explore & share their ideas? How will I build on student ideas, challenge student ideas, and give students opportunities to revise their ideas?

Appendix B Continued

Model Stage	Activity Function	Curriculum Materials Analysis Questions	Knowing My Students Questions	Planning Questions
Explain	Students Explain Patterns	Does the material provide opportunities for my students to explain the patterns they find?	What are possible explanations my students might come up with? Why do those explanations make sense to my students?	How will I provide students with opportunities to develop their explanations?
	Introduce Scientific Ideas	Does the material present scientific ideas related to the learning goal? Are the ideas represented effectively? Does the material introduce new terms in the context where they are useful?	What representations are understandable to my students (familiar, accessible, etc.)?	How will I present scientific ideas? How will I effectively represent scientific ideas?
	Compare Student Ideas and Scientific Ideas	Does the material provide opportunities for the students to compare new science ideas to their own previous ideas and note similarities and differences? Does the material include effective assessments related to the learning goal throughout and give the teacher opportunity to modify instruction based on assessments?	What ways of knowledge-sharing are my students familiar/comfortable with?	How will I build on student ideas, challenge student ideas, and give students opportunities to revise their ideas? How will I allow students to share their ideas with each other and begin building group consensus? How will I assess student progress and modify my instruction to meet my students' needs?
Apply	Apply To Near & Distant Contexts With Support	Does the material allow students to apply their new ideas to new situations related to the learning goal?	What applications are relevant to my students' lived experiences?	What situations will I use?
	Apply with Fading	Is support for student performance provided and gradually reduced?	What support will my students need?	What situations will I use?

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REFERENCES

Abd-El-Khalick, F. (2000). Improving science teachers' conceptions of nature of science: A critical review of the literature. *International Journal of Science Education, 22*(7), 665-701.

Abd-El-Khalick, F., & Akerson, V. (2004). Learning as conceptual change: Factors mediating the development of preservice elementary teachers' views of nature of science. *Science Education, 88*, 785-810.

Abd-El-Khalick, F., Bell, R., & Lederman, N. G. (1998). The nature of science and instructional practice: Making the unnatural natural. *Science Education, 82*, 417-436.

Abell, S. K., Bryan, L. A., & Anderson, M. A. (1998). Investigating preservice elementary science teacher reflective thinking using integrated media case-based instruction in elementary science teacher preparation. *Science Education, 82*(4), 491-509.

Abell, S. K., & Smith, D. C. (1994). What is science? Preservice elementary teachers' conceptions of the nature of science. *International Journal of Science Education, 16*(4), 475-487.

Abraham, M. R. (1998). The learning cycle approach as a strategy for instruction in science. In B. J. Fraser & K. G. Tobin (Eds.), *International handbook of science education*. Boston: Kluwer.

Aikenhead, G. (1996). Science education: Border crossing into the subculture of science. *Studies in Science Education, 27*, 1-52.

American Film Institute. (2005). Top 100 movie quotes. Retrieved February 20, 2008, from http://connect.afi.com/site/DocServer/quotes100.pdf?docID=242

Anderson, C. W. (2003). *Teaching science for motivation and understanding.* Unpublished manuscript, East Lansing, MI: Michigan State University.

Anderson, C. W., & Smith, E. L. (1987). Teaching science. In V. Richardson-Koehler (Ed.), *The educators' handbook: A research perspective* (pp. 84-111). New York: Longman.

Bae, M. (2007). *Pre-service teachers' interpretations and use of an instructional model in analyzing and adapting curriculum materials.* Paper presented at the Knowledge Sharing Institute, Washington, D.C.

Ball, D. L., & Cohen, D. (1996). Reform by the book: What is - or might be- the role of curriculum materials in teacher learning and instructional reform? *Educational Researcher, 25*(9), 6-8, 14.

Ball, D. L., & Feiman-Nemser, S. (1988). Using textbooks and teachers' guides: A dilemma for beginning teachers and teacher educators. *Curriculum Inquiry, 18*(4), 401-423.

Banks, J., Cochran-Smith, M., Moll, L. C., Richert, A., Zeichner, K. M., LePage, P., et al. (2005). Teaching diverse learners. In L. Darling-Hammond & J. Bransford (Eds.), *Preparing teachers for a changing world: What teachers should learn and be able to do* (pp. 232-274). San Francisco, CA: John Wiley & Sons.

Barab, S., & Luehmann, A. L. (2003). Building sustainable science curriculum: Acknowledging and accommodating local adaptation. *Science Education, 87*(4), 454-467.

Barab, S., & Squire, K. D. (2004). Design-based research: Putting a stake in the ground. *Journal of the Learning Sciences, 13*(1), 1-14.

Becker, H. S., Geer, B., & Hughes, E. (1968). *Making the grade: The academic side of college life*. New York: John Wiley & Sons, Inc.

Ben-Peretz, M. (1990). *The teacher-curriculum encounter: Freeing teachers from the tyranny of texts*. Albany, New York: State University of New York.

Bogdan, R. C., & Biklin, S. K. (2003). *Qualitative research for education: An introduction to theory and methods*. New York: Allyn and Bacon.

Borko, H., & Shavelson, R. J. (1990). Teacher decision making. In B. F. Jones & L. Idol (Eds.), *Dimensions of thinking and cognitive instruction* (pp. 331-346). Hillsdale, NJ: Lawrence Erlbaum Associates.

Brouwer, N., & Korthagen, F. (2005). Can teacher education make a difference? *American Educational Research Journal, 42*(1), 153-224.

Brown, A. L., & Campione, J. C. (1996). Psychological theory and the design of innovative learning environments: On procedures, principles, and systems. In L. Schauble & R. Glaser (Eds.), *Innovations in learning: New environments for education* (pp. 289-325). Mahwah, New Jersey: Erlbaum.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher, 18*(1), 32-42.

Brown, M. W., & Edelson, D. (2003). *Teaching as design: Can we better understand the ways in which teachers use materials so we can better design materials to support their changes in practice?* Evanston, IL: Center for Learning & Technology in Urban Schools, Northwestern University.

Bullough, R. V. J. (1992). Beginning teacher curriculum decision making, personal teaching metaphors, and teacher education. *Teaching & Teacher Education, 8*(3), 239-252.

Buxton, C., Carlone, H. B., & Carlone, D. (2005). Boundary spanners as bridges of student and school discourses in an urban science and mathematics high school. *School Science and Mathematics, 105*(6), 302-312.

Bybee, R. W. (1997). *Achieving scientific literacy*. Portsmouth, NH: Heinemann.

Calabrese Barton, A., Ermer, J. L., Burkett, T., & Osborne, M. D. (2003). *Teaching science for social justice*. New York: Teachers College Press.

Calabrese Barton, A., Gunckel, K. L., & McLaughlin, D. (2007). *Considering students' strengths: Helping elementary preservice teachers take account of students' resources in planning and teaching science lessons.* Paper presented at the Knowledge Sharing Institute, Washington D.C.

Calabrese Barton, A., & O'Neill, T. (2008). Counter-storytelling in science: Authoring a place in the worlds of science and community. In R. Levinson (Ed.), *Creative encounters: Science and art*. London: Wellcome Trust.

Calabrese Barton, A., Tan, E., & Rivet, A. (2008). Creating hybrid spaces for engaging school science among urban middle school girls. *American Educational Research Journal, 45*(1), 63-103.

Calabrese Barton, A., & Yang, K. (2000). The culture of power and science education: Learning from Miguel. *Journal of Research in Science Teaching, 37*(8), 871-889.

Carlsen, W. S. (1991). Subject-matter knowledge and science teaching: A pragmatic perspective. *Advances in Research on Teaching, 2*, 115-143.

Cartier, J., Gunckel, K. L., Schwarz, C. V., Smith, E. L., Sink, W., Kannan, P., et al. (2008). *Examining elementary science curriculum materials through the lens of instructional frameworks: Supporting pre-service teacher learning.* Paper presented at the American Educational Research Association, New York.

Chochran-Smith, M. (1995). Confronting the dilemmas of race, culture, and language diversity in teacher education. *American Educational Research Journal, 32*(3), 493-522.

Chochran, K. F., & Jones, L. L. (1998). The subject matter knowledge of preservice science teachers. In B. J. Fraser & K. G. Tobin (Eds.), *International handbook of science education* (Vol. 2, pp. 707-718). Boston: Kluwer.

Cobb, P. (1994). Where is the mind? Constructivist and sociocultural perspectives on mathematical development. *Educational Researcher, 23*(7), 13-20.

Cobb, P., Confrey, J., DiSessa, A. A., Lehrer, R., & Schauble, L. (2003). Design experiments in educational research. *Educational Researcher, 32*(1), 9-13.

Cobb, P., & Hodge, L. L. (2002). A relational perspective on issues of cultural diversity and equity as they play out in the mathematics classroom. *Mathematical Thinking and Learning, 4*(2), 249-284.

Cobb, P., & Hodge, L. L. (2003). Culture, identity and equity in the mathematics classroom. In N. S. Nasir & P. Cobb (Eds.), *Improving access to mathematics: Diversity and equity in the classroom*. New York: Teachers College Press.

Cohen, E. G. (1994). *Designing groupwork: Strategies for the heterogeneous classroom* (2nd ed.). New York: Teachers College Press.

Collins, A., Brown, J. S., & Newman, S. E. (1989). Cognitive apprenticeship: Teaching the crafts of reading, writing, and mathematics. In L. B. Resnick (Ed.), *Knowing, learning, and instruction: Essays in honor of Robert Glaser* (pp. 453-494). Erlbaum: Hillsdale, NJ.

Collopy, R. (2003). Curriculum materials as a professional development tool: How a mathematics textbook affected two teachers' learning. *The Elementary School Journal, 103*(3), 287-311.

Covitt, B., Schwarz, C. V., Mikeska, J., & Bae, M. (In review). Facilitating the development of preservice teachers' professional practices through curriculum materials analysis boundary spanning activities.

Darling-Hammond, L., Hammerness, K., Grossman, P., Rust, F., & Shulman, L. (2005). The design of teacher education programs. In L. Darling-Hammond & J. Bransford (Eds.), *Preparing teachers for a changing world: What teachers should learn and be able to do*. San Francisco, CA: Jossey-Bass.

Davis, E. A. (2006). Preservice elementary teachers' critique of instructional materials for science. *Science Education, 90*(2), 348-375.

Davis, E. A., & Krajcik, J. (2004a). Designing educative curriculum materials to support teacher learning. *Educational Researcher, 34*(3), 3-14.

Davis, E. A., & Krajcik, J. (2004b). *Supporting inquiry-oriented science teaching with curriculum: Design heuristics for educative curriculum materials.* Paper presented at the American Educational Research Association, San Diego.

Davis, E. A., Petish, D., & Smithey, J. (2006). Challenges new science teachers face. *Review of Educational Research, 76*(4), 607-651.

DeBoer, G., Morris, K., Roseman, J. E., Wilson, L., Capraro, M. M., Capraro, R., et al. (2004). *Research issues in the improvement of mathematics teaching and learning through professional development.* Paper presented at the American Educational Research Association, San Diego, CA.

Design-Based Research Collective. (2003). Design-based research: An emerging paradigm for educational inquiry. *Educational Researcher, 32*(1), 5-8.

Division of science and mathematics education undergraduate courses. (2005). Retrieved May 8, 2008, from http://www.dsme.msu.edu/undergrad_intro.htm

Doyle, W. (1983). Academic work. *Review of Educational Research, 53*(2), 159-199.

Driver, R., Asoko, H., Leach, J., Mortimer, E., & Scott, P. (1994). Constructing scientific knowledge in the classroom. *Educational Researcher, 23*(7), 5-12.

Duschl, R. A. (1990). *Restructuring science education: The importance of theories and their development.* New York: Teachers College Press.

Erickson, F. (1986). Qualitative methods in teaching. In M. C. Wittrock (Ed.), *Handbook on research in teaching* (pp. 119 - 161). New York: Macmillian.

Erickson, F. (1998). Qualitative research methods for science education. In B. J. Fraser & K. G. Tobin (Eds.), *International handbook of science education* (pp. 115-1173). Great Britain: Kluwer.

Feiman-Nemser, S. (2001). From preparation to practice: Designing a continuum to strengthen and sustain teaching. *Teachers College Record, 103*(6), 1013-1055.

Feiman-Nemser, S., & Buchmann, M. (1985). Pitfalls of experience in teacher preparation. *Teachers College Record, 87*(1), 53-65.

Feiman-Nemser, S., & Buchmann, M. (1987). When is student teaching teacher education? *Teacher & Teacher Education, 3*(4), 255-273.

Gay, G. (2001). Preparing for culturally responsive teaching. *Journal of Teacher Education, 53*(2), 106-116.

Gee, J. (1989). Literacy, discourse, and linguistics: Introduction. *Journal of Education, 171*(1), 5-17.

Gee, J. (1997). Thinking, learning, and reading: The situated sociocultural mind. In D. Kirschner & J. A. Whitson (Eds.), *Situated cognition: Social, semiotic, and psychological perspectives* (pp. 235-260). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Gee, J. (1999). What is literacy? In C. Mitchell & K. Weiler (Eds.), *Rewriting literacy: Culture and the discourse of the other* (pp. 3-11). Westport, CM: Bergin & Gavin.

Gee, J. (2000). Identity as an analytic lens for research in education. *Review of research in education, 25*, 99-125.

Gilbert, A., & Yerrick, R. (2001). Same school, separate worlds: A sociocultural study of identify, resistance, and negotiation in a rural, lower track science classroom. *Journal of Research in Science Teaching, 38*(5), 574-598.

Gonzalez, N., Moll, L. C., & Amanti, C. (Eds.). (2005). *Funds of knowledge: Theorizing practices in households, communities, and classrooms.* Mahwah, New Jersey: Erlbaum.

Grossman, P., & Thompson, C. (2004). *Curriculum materials: Scaffolds for new teacher learning?* Seattle, WA: Center for the Study of Teaching and Policy and Center on English Learning & Achievement (CELA).

Gunckel, K. L., Bae, M., & Smith, E. L. (2007). *Using instructional models to promote effective use of curriculum materials among preservice elementary teachers.* Paper presented at the National Association of Research in Science Teaching, New Orleans, LA.

Gunckel, K. L., & Smith, E. L. (2007). *Challenges to teaching about analyzing and modifying curriculum materials to elementary preservice teachers.* Paper presented at the Association for Science Teacher Educators, Clearwater, FL.

Hogan, K., & Corey, C. (2001). Viewing classrooms as cultural contexts for fostering scientific literacy. *Anthropology and Education Quarterly, 32*(2), 214-243.

Hoover, E., & Mercier, S. (1994). *Primarily physics: Investigations in sound, light, and heat energy for k-3.* Fresno, CA: AIMS Educational Foundation.

Jegede, O., & Aikenhead, G. (1999). Transcending cultural borders: Implications for science teaching. *Journal of Science and Technology Education, 17*, 45-66.

Kauffman, D., Johnson, S. M., Kardos, S. M., Lui, E., & Peske, H. G. (2002). "Lost at sea": New teachers' experiences with curriculum and assessment. *Teachers College Record, 104*(2), 273-300.

Kesidou, S., & Roseman, J. E. (2002). How well do middle school science programs measure up? Findings from project 2061's curriculum review. *Journal of Research in Science Teaching, 39*(6), 522-549.

Ladson-Billings, G. (1995). Making mathematics meaningful in a multicultural context. In W. G. Secada, E. Fennema & L. B. Adajian (Eds.), *New directions for equity in mathematics education* (pp. 126-145). New York: Cambridge University Press.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation.* Cambridge: Cambridge University Press.

Lederman, N. G. (1992). Students' and teachers' conceptions of the nature of science: A review of the literature. *Journal of Research in Science Teaching, 36*, 916-929.

Lederman, N. G., Abd-El-Khalick, F., Bell, R., & Schwartz, R. S. (2002). Views of nature of science questionnaire: Toward valid and meaningful assessment of learner's conceptions of nature of science. *Journal of Research in Science Teaching, 39*(6), 497-521.

Lee, O. (1997). Scientific literacy for all: What is it, and how can we achieve it? *Journal of Research in Science Teaching, 34*(3), 219-222.

Lee, O. (2003). Equity for linguistically and culturally diverse students in science education: A research agenda. *Teachers College Record, 105*(3), 465-489.

Lee, O., Deaktor, R., Hart, J., Cuevas, P., & Enders, C. (2005). An instructional intervention's impact on the science and literacy achievement of culturally and linguistically diverse elementary students. *Journal of Research in Science Teaching, 42*(8), 857-887.

Lee, O., & Fradd, S. H. (1996). Literacy skills in science learning among linguistically diverse students. *Science Education, 80*(6), 651-671.

Lee, O., & Fradd, S. H. (1998). Science for all, including students from non-English-language backgrounds. *Educational Researcher, 27*(4), 12-21.

Lemke, J. (1990). *Talking science: Language, learning, and values*. Norwood, NJ: Ablex.

Lortie, D. C. (1975). *Schoolteacher*. Chicago: University of Chicago Press.

Luykx, A., Cuevas, P., Lambert, J., & Lee, O. (2005). Unpacking teachers' "resistance" to integrating students' language and culture into elementary science instruction. In A. J. Rodriguez & R. S. Kitchen (Eds.), *Preparing mathematics and science teachers for diverse classrooms* (pp. 119-142). Mahwah, NJ: Lawrence Erlbaum.

Luykx, A., & Lee, O. (2007). Measuring instructional congruence in elementary science classrooms: Pedagogical and methodological components of a theoretical framework. *Journal of Research in Science Teaching, 44*(3), 424-447.

Magnusson, S., Krajcik, J., Borko, H., &. (1999). Nature, sources, and development of pedagogical content knowledge for science teaching. In J. Gess-Newsome & N. G. Lederman (Eds.), *PCK and science education*. Netherlands: Kluwer Academic Publishers.

Michigan Department of Education. (2000). Michigan curriculum framework.

Mohan, L., Chen, J., & Anderson, C. W. (2008). *Developing a multi-year learning progression for carbon cycling in socio-ecological systems.* Paper presented at the National Association for Research in Science Teaching, Baltimore, MD.

Moje, E. B., Ciechanowski, K. M., Kramer, K., Ellis, L., Carrillo, R., & Collazo, T. (2004). Working toward third space in content area literacy: An examination of everyday funds of knowledge and discourse. *Reading Research Quarterly, 39*(1), 38-70.

Moje, E. B., Collazo, T., Carrillo, R., & Marx, R. W. (2001). ``maestro, what is `quality'?": Language, literacy, and discourse in project-based science. *Journal of Research in Science Teaching, 38*(4), 469-498.

Moll, L. C., Amanti, C., Neff, D., & Gonzalez, N. (1992). Funds of knowledge for teaching: Using a qualitative approach to connect homes and classrooms. *Theory into Practice, 31*(2), 132-141.

National Research Council. (1996). *National science education standards*. Washington, D.C.: National Academy Press.

National Research Council. (2000). *Inquiry and the national science education standards: A guide for teaching and learning*. Washington, D.C.: National Academy Press.

National Research Council. (2007). *Taking science to school: Learning and teaching science in grades k-8*. Washington, D.C.: National Academies Press.

Page, R. (1999). The uncertain value of school knowledge: Biology at Westridge high. *Teachers College Record, 100*(3), 554-601.

Pinar, W. F., Reynolds, W. M., Slattery, P., & Taubman, P. M. (2000). *Understanding curriculum: An introduction to the study of historical and contemporary curriculum discourses*. New York: Peter Lang.

Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education, 66*(2), 211-227.

Putnam, R., & Borko, H. (1997). Teacher learning: Implications of new views of cognition. In B. J. Biddle, T. L. Good & I. F. Goodson (Eds.), *International handbook of teachers and teaching* (Vol. II, pp. 1223 - 1296). Boston: Kluwer Academic Publishers.

Putnam, R., & Borko, H. (2000). What do new views of knowledge and thinking have to say about research on teacher learning? *Educational Researcher, 29*(1), 4-15.

Reiser, B. J., Krajcik, J., Moje, E. B., & Marx, R. W. (2003). *Design strategies for developing science instructional materials.* Paper presented at the 2003 Annual Meeting of the National Association of Research in Science Teaching, Philadelphia, PA.

Remillard, J. T. (1999). Curriculum materials in mathematics education reform: A framework for examining teachers' curriculum development. *Curriculum Inquiry, 29*(3), 315-342.

Remillard, J. T. (2005). Examining key concepts in research on teachers' use of mathematics curricula. *Review of Educational Research, 75*(2), 211-246.

Resnick, L. B. (1991). Shared cognition: Thinking as social practice. In L. B. Resnick, J. M. Levine & S. D. Teasley (Eds.), *Perspectives on socially shared cognition* (pp. 1-20). Washington, D.C.: American Psychological Association.

Rivet, A., & Krajcik, J. (2004). Project-based science curricula: Achieving standards in urban systemic reform. *Journal of Research in Science Teaching, 41*(7), 669-692.

Rosebery, A. (2005). What are we going to do next? Lesson planning as a resource for teaching. In R. Nemirovsky, A. Rosebery, J. Solomon & B. Warren (Eds.), *Everyday matters in science and mathematics: Studies of complex classroom events* (pp. 299-327). New Jersey: Lawrence Erlbaum Associates.

Rosebery, A., Warren, B., & Conant, F. (1992). Appropriating scientific discourse: Findings from language minority classrooms. *Journal of the Learning Sciences, 2*(1), 61-94.

Roth, K. J. (1997). *Food for plants: Student text and teacher's guide.* East Lansing, MI: Michigan State University.

Roth, K. J., Anderson, C. W., & Smith, E. L. (1987). Curriculum materials, teacher talk and student learning: Case studies in fifth grade science teaching. *Journal of Curriculum Studies, 19*(6), 527-548.

Rutherford, F. J., & Ahlgren, A. (1989). *Science for all Americans*. Washington, D.C.: American Association for the Advancement of Science.

Schneider, R. M., Krajcik, J., & Blumenfeld, P. (2005). Enacting reform-based science materials: The range of teacher enactments in reform classrooms. *Journal of Research in Science Teaching, 42*(3), 283-312.

Schwarz, C. V. (2007). Personal communication.

Schwarz, C. V., Gunckel, K. L., Smith, E. L., Covitt, B. A., Bae, M.-J., Enfield, M., et al. (2008). Helping elementary preservice teachers learn to use curriculum materials for effective science teaching. *Science Education, 92*(2), 345-377.

Schwarz, C. V., & Gwekwere, Y. N. (2007). Using a guided inquiry and modeling instructional framework (EIMA) to support pre-service k-8 science teaching. *Science Education, 91*(1), 158-186.

Settlage, J., & Southerland, S. (2007). *Teaching science to every child: Using culture as a starting point*. New York: Routledge.

Sfard, A. (1998). On two metaphors for learning and the dangers of choosing just one. *Educational Researcher, 27*(2), 4-13.

Sharma, A., & Anderson, C. W. (2003). *Transforming scientists' science into school science.* Paper presented at the National Association of Research in Science Teaching, Philadelphia, PA.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4-14.

Shulman, L. S. (1990). Forward. In M. Ben-Peretz (Ed.), *The teacher-curriculum encounter: Freeing teachers from the tyranny of texts* (pp. vii-xi). Albany, New York: State University of New York.

Simon, M. A. (2000). Research on the development of mathematics teachers: The teacher development experiment. In A. E. Kelly & R. A. Lesh (Eds.), *Handbook of research design in mathematics and science education* (pp. 335-359). Mahwah, NJ: Erlbaum.

Simon, M. A., & Tzur, R. (1999). Explicating the teacher's perspective from the researchers' perspectives: Generating accounts of mathematics teachers' practice. *Journal for Research in Mathematics Education, 30*(3), 252-264.

Sloane, F. C., & Gorard, S. (2003). Exploring modeling aspects of design experiments. *Educational Researcher, 32*(1), 29-31.

Smith, D. C., & Anderson, C. W. (1999). Appropriating scientific practices and discourses with future elementary teachers. *Journal of Research in Science Teaching, 36*(7), 755-776.

Smith, E. L. (1991). A conceptual change model of learning science. In S. M. Glynn, R. H. Yeany & B. K. Britton (Eds.), *The psychology of learning science*. Hillsdale, NJ: Erlbaum.

Smith, E. L. (2001). *Strategic approaches to achieving science learning goals.* Paper presented at the Improving Science Curriculum Materials Through Research-Based Evaluation, Washington, DC.

Smith, E. L., & Anderson, C. W. (1984). Plants as producers: A case study of elementary science teaching. *Journal of Research in Science Teaching, 21*(7), 685-698.

Smith, E. L., & Anderson, C. W. (1986). Alternative student conceptions of matter cycling in ecosystems, *National Association of Research in Science Teaching*. San Francisco.

Stern, L., & Roseman, J. E. (2004). Can middle-school science textbooks help students learn important ideas? Findings from project 2061's curriculum evaluation study: Life science. *Journal of Research in Science Teaching, 41*(6), 538-568.

Student honors. (2006). *New Educator* 12 (1). Retrieved May, 11, 2008, 2008, from http://www.educ.msu.edu/neweducator/Fall06/students.htm

Sussman, A. (2000). *Dr. Art's guide to planet earth: For earthlings ages 12 to 120*. White River Jct, VT: Chelsea Green Publishing.

Varelas, M., Becker, J., Luster, B., & Wenzel, S. (2002). When genres meet: Inquiry into a sixth-grade urban science class. *Journal of Research in Science Teaching, 39*(7), 579-605.

Warren, B., Ballenger, C., Ogonowski, M., Rosebery, A., & Hardicourt-Barnes, J. (2001). Rethinking diversity in learning science: The logic of everyday sense-making. *Journal of Research in Science Teaching, 38*(5), 592-552.

Warren, B., Ogonowski, M., & Pothier, S. (2005). "Everyday" and "scientific": Rethinking dichotomies in modes of thinking in science learning. In R. Nemirovsky, A. Rosebery, J. Solomon & B. Warren (Eds.), *Everyday matters in science and mathematics: Studies of complex classroom events* (pp. 119-148). New Jersey: Lawrence Erlbaum Associates.

Watson-Gegeo, K. A. (1988). Ethnography in ESL: Defining the essentials. *TESOL Quarterly, 22*(4), 575 - 592.

Wenger, E. (1998). *Communities of practice: Learning, meaning, and identity*. New York: Cambridge University Press.

Wenger, E. (undated). Communities of practice. Retrieved June, 2008, from http://www.ewenger.com/theory/

Wertsch, J. W. (1991). *Voices in the mind: A sociocultural approach to mediated action.* Cambridge, MA: Harvard University Press.

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