

**PRESERVICE ELEMENTARY TEACHERS' DEVELOPMENT OF
PEDAGOGICAL DESIGN CAPACITY FOR INQUIRY – AN
ACTIVITY-THEORETICAL PERSPECTIVE**

by

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DEDICATION

To Susanne and Owen

Ad Astra per Aspera

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TABLE OF CONTENTS

DEDICATION	ii
ACKNOWLEDGEMENTS	iii
LIST OF TABLES	viii
LIST OF FIGURES	ix
LIST OF APPENDICES	xi
ABSTRACT	xii
CHAPTER 1 INTRODUCTION	1
CHAPTER 2 THEORETICAL FRAMEWORK	10
Teachers' Knowledge, Beliefs, and Orientations Regarding Scientific Inquiry and Inquiry-Oriented Science Teaching	10
Teachers and Curriculum Materials	12
A Situated Framework for the Teacher-Curriculum Relationship	18
Cultural-historical Activity Theory (CHAT)	25
Summary	42
CHAPTER 3 RESEARCH METHODS	43
Research Questions	43
Instructional Context	44
Participants	47
Data Collection	56
Data Analysis	66
Methods Summary	83
CHAPTER 4 PRESERVICE ELEMENTARY TEACHERS' MOBILIZATION AND ADAPTATION OF SCIENCE CURRICULUM MATERIALS DURING THE SCIENCE METHODS COURSE	85

Preservice Teachers' Curriculum-Design Decisions	85
Inquiry Orientations of Pre- and Post-Adaptation Curriculum Materials	96
Effect of Curriculum Materials and Preservice Teachers' Curriculum Design Decisions on Inquiry Scores and Change in Inquiry Scores	99
Summary of Quantitative Results	104
CHAPTER 5	106
CURRICULUM PLANNING FOR INQUIRY: FOUR PRESERVICE ELEMENTARY TEACHERS' INSTANTIATION OF INQUIRY IN PLANNED SCIENCE LESSONS	
Preservice Teachers' Goals for Curriculum Design	108
Curriculum Planning for Inquiry	110
Planning for First Science Lessons	112
Curriculum Planning – Planning for Subsequent Science Lessons	123
Inquiry Practices Targeted through Post-RT1 Curriculum Planning	125
Summary of Curriculum Planning	136
Cultural Mediation of Curriculum Planning	136
Summary	140
CHAPTER 6	142
CURRICULUM ENACTMENT AND THE EVOLUTION OF PRESERVICE TEACHERS' INQUIRY MODELS AND CURRICULUM PLANNING PRACTICES	
Overview of Findings	142
Teacher Cases	148
Lauren	148
Mike	156
Kelly	165
Aliza	175
Summary of Preservice Teachers' Curriculum Enactments	184
Summary of Case Study Findings	185
CHAPTER 7 DISCUSSION AND IMPLICATIONS	188
Curriculum Planning Sub-Process	190
Curriculum Planning Sub-Processes: Preservice Teachers' Curriculum Design Actions and Outcomes	190
Curriculum Planning Sub-Processes: The Influence of Preservice Teachers' Espoused Inquiry Frameworks on Curriculum Design Actions and Outcomes	194

Summary of Curriculum Planning Sub-Processes	195
Cultural-Mediation of Curriculum Design Decisions and Outcomes	195
Implications for Enhancing Teachers' Pedagogical Design Capacity for Inquiry	200
Implications for Theory and CHAT-Based Research	210
Limitations	218
Conclusion	220
APPENDICES	221
BIBLIOGRAPHY	238

LIST OF TABLES

Table 2.1: Summary of Dimensions of Curriculum Design and Enactment Activity Systems	39
Table 3.1: Overview of Data Sources	57
Table 3.2: Data Collection Schedule	66
Table 3.3: Coding Key for Types of Curriculum Materials	68
Table 3.4: Coding Key for Types of Adaptations to Curriculum Materials	69
Table 3.5: Inquiry Scoring Rubric for Lesson Plans	69
Table 3.6: Coding Key for All Research Questions	73
Table 3.7: Contradictions and Preservice Teachers' Curriculum Design Decision-Making for a Given Cycle of Curriculum Design for Inquiry	77
Table 3.8: Contributions of a Contradiction to Preservice Teachers' Curriculum Design Decision-Making over Time	78
Table 3.9: Data Sources by Research Question and Participant Sample	81
Table 4.1: Frequencies and Percentages of Curriculum Materials Used by Preservice Teachers in Reflective Teaching Assignments ($n_{RT1} = 46$, $n_{RT2}=45$)	87
Table 4.2: Frequencies and Percentages of Adaptations Made by Preservice Teachers in Reflective Teaching Assignments ($n_{RT1}=46$, $n_{RT2}=45$)	92
Table 4.3: Effect of Teachers' Curriculum Materials' Use on Post-Adaptation Inquiry Scores of Lessons ($n_{RT1}=45$, $n_{RT2}=44$)	102
Table 6.1: Emergent Contradictions in Preservice Teachers' Curriculum Enactment for Inquiry	147

LIST OF FIGURES

Figure 2.1: Cultural-Historical Activity Theory Model of Activity (Engeström, 1987; 2008)	27
Figure 2.2: Four Levels of Contradictions in a Network of Human Activity Systems (Engeström, 1987)	29
Figure 2.3: Activity-Theoretical Framework for Preservice Elementary Teachers' Curriculum Design for Inquiry	33
Figure 2.4: 3-Dimensional Model of Teachers' Curriculum Planning for Inquiry	35
Figure 4.1: Mean Number of Curriculum Materials Used by Preservice Teachers in Reflective Teaching Assignments 1 and 2	86
Figure 4.2: Frequencies of Curriculum Materials Used by Preservice Teachers in Reflective Teaching Assignments 1 and 2	88
Figure 4.3: Number of Types of Curriculum Materials Used by Preservice Teachers in Reflective Teaching Assignments 1 and 2	89
Figure 4.4: Mean Number of Adaptations Made by Preservice Teachers in Reflective Teaching Assignments 1 and 2	91
Figure 4.5: Frequencies of Adaptations Made by Preservice Teachers in Reflective Teaching Assignments 1 and 2	94
Figure 4.6: Number of Types of Adaptations Made by Preservice Teachers in Reflective Teaching Assignments 1 and 2	95
Figure 4.7: Pre- and Post-Adaptation Inquiry Scores of Preservice Teachers' Lesson Plans in Reflective Teaching Assignments 1 and 2	97
Figure 5.1: Preservice Elementary Teachers' Curriculum Planning for Inquiry	107
Figure 5.2. CHAT-based Model of Curriculum Planning for Inquiry	111
Figure 5.3. Influence of Elementary Science Methods Course as an Instrument-Producing Activity Supporting the Development of Preservice Elementary	120

Teachers' Espoused Inquiry Frameworks

Figure 6.1. CHAT-based Model of Traditional, Didactic Science Teaching	143
Figure 6.2. CHAT-based Model of Constructivist Science Teaching	144
Figure 6.3. Emergent Contradictions in Preservice Elementary Teachers' Constructivist Science Teaching	145
Figure 6.4. Tertiary Contradiction Between Traditional, Didactic and Constructivist Science Teaching	146
Figure 6.5. Lauren's End-of-the-Year Professed Model of Inquiry	153
Figure 6.6. Secondary Contradictions in Mike's First Three Enacted Lessons	158
Figure 6.7. Mike's End-of-the-Year Professed Model of Inquiry	162
Figure 6.8. Emergent Contradictions in Kelly's Fourth Enacted Lesson	170
Figure 6.9. Resolution of Contradictions in Kelly's Fourth Enacted Lesson	171
Figure 6.10. Kelly's End-of-the-Year Professed Model of Inquiry	172
Figure 6.11. Secondary Contradictions in Aliza's First Three Lessons	177
Figure 6.12. Resolution of Contradictions in Aliza's Third Enacted Lesson	180
Figure 6.13. Aliza's End-of-the-Year Professed Model of Inquiry	181
Figure 7.1. Production Sub-Process of Curriculum Planning for Inquiry	190
Figure 7.2. 3-Dimensional Model of Preservice Elementary Teachers' Curriculum Design for Inquiry	193
Figure 7.3. CHAT-based Model of Constructivist Science Teaching	197
Figure 7.5. Tertiary Contradiction Between Traditional, Didactic and Constructivist Science Teaching	200

LIST OF APPENDICES

Appendix A: Lesson Plan Format	222
Appendix B: Lesson Plan Rationale	225
Appendix C: Reflective Teaching Assignment Post-Enactment Reflective Journal	227
Appendix D: Journal Entry (Inquiry and Science Curriculum Materials)	228
Appendix E: Formal Interview Protocol	229
Appendix F: Pre- and Post-Enactment Lesson Planning Interviews	234
Appendix G: Lesson Enactment Observation Protocol	236
Appendix H: In-Class RT Co-Planning and Debriefing	237

ABSTRACT

Preservice elementary teachers need to begin developing their pedagogical design capacities for inquiry by learning how to translate their conceptions of inquiry into classroom practice through the adaptation and enactment of curriculum materials. Using both qualitative and quantitative research methods, I draw upon cultural-historical activity theory (CHAT) to investigate preservice elementary teachers' curriculum design and development of pedagogical design capacity for inquiry during the final year of their teacher education program. This study involved analysis of curricular artifacts and survey data from 46 prospective elementary teachers in two sections of an undergraduate elementary science teaching methods course, as well as interviews, observational fieldnotes, reflective journals, and other artifacts from four preservice teachers from this larger group studied during the methods and student teaching semesters.

Results show that preservice teachers were able to translate their espoused inquiry frameworks into planned and enacted science lessons. This involved adapting existing curriculum materials to better promote specific inquiry practices, but also to fundamentally shift the nature of classroom science. The preservice teachers' curriculum design efforts were constrained, however, by features of their institutional contexts and subject to emergent tensions. In attempting to resolve these tensions through curriculum design for inquiry, the preservice teachers ultimately articulated a fundamental contradiction between two distinct and competing visions for classroom inquiry: traditional classroom science, which promotes students' reproduction of scientific explanations by objectifying students, and a novel form of classroom inquiry that repositions students as contributing community members involved in the co-construction of knowledge through lesson-specific shared problem-spaces. For each of the preservice teachers, this contradiction had important implications for the design of science learning environments and remained unresolved at the end of the study.

These findings have implications for practice and theory. While they illustrate the important role both formal teacher education and science curriculum materials play in supporting teachers to engage in inquiry-oriented science teaching, they also highlight the need for schools to foster inquiry practices in the classroom. Findings also provide novel insights into the teacher-curriculum relationship, teacher learning, the nature and goals of inquiry-oriented science teaching and learning, and CHAT-based research on teachers.

CHAPTER 1

INTRODUCTION

As never before, students need to learn to engage in increasingly scientifically- and technologically-based social, economic, and political dimensions of public life. As such, science is one of the most critical subjects in the American public school curriculum. At the elementary level, experiences with science leverage young students' natural curiosities and form a foundation for future science learning (National Research Council [NRC], 2007). Though some evidence points to a relative deprioritization of science at the elementary level in recent years (e.g., Marx & Harris, 2006), science will undoubtedly remain a core academic subject that is necessary to prepare students for life outside of school.

Teachers play a crucial role in supporting students' learning in science by designing and facilitating, in conjunction with curriculum standards and resource, effective science learning environments. Elementary teachers, however, particularly beginning teachers, face many challenges in engaging their students in reform-minded, standards-based, inquiry-oriented science (Abell, 2007; Davis, Petish, & Smithey, 2006;). In order to confront these challenges, elementary teachers require effective and consistent support across the teacher professional continuum. Formal teacher education is a primary context in which teacher learning can be supported at the preservice stage of the teacher professional continuum. However, to learn how to best support preservice elementary teachers, more research is needed to understand how they learn to plan for, engage in, and reflect upon their science teaching. The study presented here focuses specifically on how preservice elementary teachers learn to use science curriculum materials to engage in curriculum design for inquiry.

In the sections that follow, I outline the recent history of science curriculum reform and development, as well as current perspectives on the relationship between

teachers and curriculum materials. Finally, I provide an overview of this study and its goals and objectives.

Science Education Reform and Curriculum Development

Over the past fifty years, science education reform has often been at the forefront of broader efforts to reform public education in the United States. A consistent theme in these science education reform efforts has been the preeminence of curriculum and associated curriculum materials as a vector for change. Here, I refer to *curriculum* as standards and goals for student learning and use the term *curriculum materials* to reference the textbooks, lesson plans, and other instructional artifacts meant to support classroom teaching and learning. It is commonly perceived that of all the different methods for communicating and instantiating educational policy, curriculum materials possibly exert the most direct influence on day-to-day classroom activity (Brown & Edelson, 2003; Cohen & Ball, 1999). As a result, the history of science education reform is fundamentally intertwined with that of science curriculum development (Rudolph, 2002).

However, science education reform and associated curriculum development projects have been marked by shifting orientations and emphases within, and rationales for, science education (DeBoer, 1991). The arguments for the prominence of science education in the public school curriculum are many and varied. For example, one perennially-heard and admittedly strong argument for science education originates largely from corporate, governmental, and quasi-scientific institutions and their interests. It is largely based on a need for a strong and self-sustaining cadre of scientists who can advance the economic interests of the United States, as well as maintain its national security (Committee on Prospering in the Global Economy in the 21st Century, 2007). This particular perspective, originally given urgency by the launch of the Sputnik satellite by the Soviet Union in 1957, provided the impetus for the largest science curriculum development effort in the history of United States (Rudolph, 2002). These science curriculum development efforts during the 1950s and 1960s largely took form as large-scale, National Science Foundation-funded, national science curriculum development projects. The scientific community took a leading role in this work and the resulting physics, chemistry, and biology curricula reflected a purist, disciplinary structure

(DeBoer, 1991; Rudolph, 2002). The primary objective of these curriculum development efforts was to effectively prepare the next generation of scientists.

By the late 1960s and early 1970s, however, the nature of science education reform shifted away from the disciplinary structure of science to an emphasis on making science accessible and relevant to all students. Whereas the argument for science education grounded in economic and national security primarily emphasized science learning for a small subset of the population, the evolving view of ‘science for all’ focused largely on essential science learning for living. This perspective is evidenced today (American Association for the Advancement of Science [AAAS], 1993; NRC, 1996, 2007; Rutherford & Ahlgren, 1990) in the recognition that science education must help students develop the capacity to successfully engage and participate in an increasingly complex, globalized, technology- and science-based world. This reform agenda has yielded notions of scientific literacy, which allude to a minimum proficiency with science that every individual must possess in order to meet the demands of contemporary life. It was the shift towards science education for all that laid the groundwork for the current science education reform environment which, informed by advancements in fields such as cognitive science (Bransford, Brown, & Cocking, 2000), is specifically marked by an emphasis on conceptual understanding and the development of scientific literacy through standards-based inquiry teaching and learning (AAAS, 1993; NRC, 1996, 2000).

Current science education reform efforts emphasize science as inquiry as the most effective model of science teaching and learning (AAAS, 1993; NRC, 1996, 2000). What, then, is inquiry? In a broad sense, inquiry-based school science is designed to engage students in practices that mirror those of scientists. These practices include asking and answering scientifically-oriented questions; collecting, organizing, and analyzing data and evidence; constructing evidence-based explanations; comparing explanations to alternative explanations; and communicating and justifying methods and explanations (NRC, 2000). The fundamental assumption of inquiry-oriented science teaching and learning is that engaging in these inquiry practices not only effectively promotes students’ learning of scientific concepts, but also the epistemological and ontological foundations of how scientific knowledge is constructed. By engaging in

these practices together, teachers and students establish and reinforce a ‘culture of inquiry’ in the classroom (Llewellyn, 2007).

In conjunction with shifting emphases of science education reform toward teaching and learning of science as inquiry, science curriculum development has been characterized by the design of standards-based, inquiry-oriented science curricula (e.g., Davis, Smithey, & Petish, 2004; Edelson, Gordin, & Pea, 1999; Linn, Davis, & Eylon, 2004; Sandoval & Reiser, 2004; Singer, Marx, Krajcik, & Chambers, 2000; Songer, Lee, & Kam, 2002; The Cognition and Technology Group at Vanderbilt, 1990; White & Frederiksen, 1998). In contrast to the massive, mid-century, national science curriculum development projects discussed previously, more recent efforts have been smaller-scale, based on constructivist theories of learning, often utilized emerging educational technology, and focused on supporting and promoting all students’ learning rather than just a relatively small subset of high-achieving students.

Despite these efforts, achieving sought-after reforms in science education has proven difficult (Brown & Edelson, 2003; Cohen & Ball, 1999; Duschl, 1994; Grandy & Duschl, 2007). Even with the vast amounts of funding devoted to science curriculum development projects, and the scientific and educational expertise they have mobilized, science classrooms remain much as they have looked over the past fifty years. As science education moves forward in a new millennium, as well as within an evolving federal education policy environment, the field continues to face many of the same challenges it has confronted for the past 25 years.

Teachers and Curriculum Materials

While there are many challenges associated with achieving systemic reform in science education (Marx & Harris, 2006), one reason for the consistent failure of curriculum-based reform, including that in science education, is that teachers have historically been viewed by curriculum developers as a delivery mechanism for curriculum content. Teachers are central to any educational reform effort, including those anchored by curricular reform. Yet, many curricula developed over the years were designed to speak *through* teachers rather than directly *to* them (Remillard, 2000). This fundamentally top-down approach to curriculum reform, consistent with what Shulman (1983) calls the “remote control of teaching”, represents a perspective on curricular

reform in which a primary objective is to minimize the mediating influence of the teacher, sometimes referred to as ‘teacher effects’ (Nye, Hedges, & Konstantopoulos, 2004), on curriculum enactment.

However curriculum materials are developed and disseminated, teachers ultimately determine how they are used in classrooms. Teachers are not passive targets of reform but rather active agents in curriculum design and enactment. More recently, an alternative perspective on the teacher-curriculum relationship has begun to emerge that not only recognizes this practical reality, but acknowledges it as a potential affordance (Brown, 2002, 2009; Connelly & Clandinin, 1988; Remillard, 2005). From this perspective, the teacher-curriculum relationship is one fundamentally characterized by design, in which teachers interact with the curriculum materials they use, interpreting, critiquing, selecting, adapting, and categorizing them. As local agents with in-depth knowledge of both their students and unique school contexts, teachers are invaluable curriculum co-designers whose context-specific curricular adaptations can make curriculum materials more effective. To afford them the opportunity to do so, however, educational policy, including that which guides curriculum development, “must be designed as a shell within which the kernel of professional judgment and decision-making can function comfortably” (Shulman, 1983, pg. 501).

Previous research has shown, however, that the quality and productiveness of teachers’ curricular adaptations can vary (Pintó, 2004; Remillard & Bryans, 2004; Roehrig & Kruse, 2005; Roehrig, Kruse, & Kern, 2007; Schneider, Krajcik, & Blumenfeld, 2005). While teachers should, in theory, be able to successfully employ their expertise to make instructional decisions, evidence suggests that they are not always able to do so. In order to make optimally-effective instructional decisions, including the adaptation of existing curriculum materials, teachers need to develop robust *pedagogical design capacity* (Brown, 2002, 2009), or the ability to accomplish instructional goals through the mobilization and use of their own personal resources (knowledge, beliefs, identities, etc.) and curriculum materials in light of affordances and constraints of their professional contexts. Each of these three elements (teacher characteristics, curriculum materials, and context) plays a crucial role in determining the overall quality of science teaching and learning practice in the classroom.

Overview and Purpose of the Study

The focus of this study is preservice elementary teachers' development of pedagogical design capacity for inquiry-based elementary science teaching. The notion of pedagogical design capacity can be applied to science teachers across grade levels and stages on the teacher professional continuum. It is especially important for preservice elementary teachers to develop robust pedagogical design capacity for science teaching since, as beginning elementary teachers, they confront many challenges to engaging elementary students in inquiry-based science (Davis, Petish, & Smithey, 2006), including limited subject-matter knowledge (Abell, 2007; Anderson & Mitchener, 1994), insufficient curricular resources (Appleton, 2003; Appleton & Kindt, 2002), and a deemphasis of science in the elementary curriculum (Marx & Harris, 2006; Spillane, Diamond, Walker, Halverson, & Jita, 2001).

To prepare elementary teachers to confront these challenges and engage students in science as inquiry, science teacher educators need to provide preservice elementary teachers ample opportunities to develop their pedagogical design capacity for science. Yet, we know little about how teachers, particularly preservice elementary teachers, interact with and use curriculum materials and how they can best be supported to learn to do so (Remillard, 1999, 2005). A fundamental question remains to be adequately addressed: *how do preservice elementary teachers learn to engage in curriculum design for inquiry?*

The study presented here is designed to begin to address this question. I employ multiple methods and an activity-theoretical framework (Engeström, 1987) to investigate how, over the final year of their teacher education program, preservice elementary teachers engage in curriculum design for inquiry across planning and enactment domains and how this process facilitates the development of their espoused inquiry frameworks. To address this question, I ask the following specific research questions:

1. Are preservice elementary teachers able to mobilize and adapt science curriculum materials to make them more inquiry-based?
 - a. What curriculum design decisions do preservice elementary teachers make?

- b. Do their curriculum design decisions lead to more inquiry-oriented instructional artifacts?
2. Why do preservice elementary teachers mobilize and adapt science curriculum materials in ways that they do, particularly in light of their espoused inquiry frameworks?
 - a. What are their espoused inquiry frameworks?
 - b. What goals do they articulate for curriculum design for inquiry?
 - c. What contradictions (i.e., tensions) do they identify, both within and across curriculum design settings, in relation to their goals?
 - d. How do they attempt to resolve these contradictions through their curriculum design decision-making in an effort to meet their goals?
3. How do preservice elementary teachers' espoused inquiry frameworks and curriculum design practices for inquiry change over time?

This research is a response to calls for curriculum research as related to teachers' knowledge, beliefs, and orientations (Remillard, 2005), science teachers' practice and learning in response to policy-driven curricular reform (Simmons et al., 2005), and the use of activity-theoretical frameworks in education research (Grossman, Smagorinsky, & Valencia, 1999; Roth, 2004; Roth & Lee, 2007).

This study addresses a number of important issues under the broader umbrella of research on teachers and curriculum materials. First, little existing research has explored patterns of preservice teachers' curriculum materials use. Here, using quantitative methods and drawing from data from 46 preservice teachers in an elementary science teaching methods course, I characterize how they use existing science curriculum materials to plan for inquiry-based instruction. Specifically, I focus on the types and number of both curriculum materials they use and the adaptations they make to them. These findings provide important descriptive evidence for patterns of preservice elementary teachers' curriculum design decision-making for inquiry.

Second, evidence from previous research suggests that preservice teachers often struggle to, first, articulate frameworks for inquiry-based teaching and learning that are consistent with those advocated in science education reform and, second, to translate those frameworks into practice (Abell, 2007; Bryan & Abell, 1999; Crawford, 1999;

Davis, Petish, & Smithey, 2006; Southerland & Gess-Newsome, 1999; Zembal-Saul, Blumenfeld, & Krajcik, 2000). This study is designed to assess whether preservice elementary teachers actually are able to adapt curriculum materials to make them more inquiry-oriented, both quantitatively based on data from the 46 preservice teachers, as well as qualitatively based on case studies of four preservice teachers followed over the entire year. Findings from this study inform the existing research base on preservice elementary teachers' abilities to engage in inquiry-oriented professional practice by assessing the degree to which they are able to engage in more inquiry-based curriculum adaptation.

It is also critical to understand *why* preservice teachers adapt curriculum materials in the ways that they do. In addition to descriptively mapping their curriculum design decisions, I pursue explanatory questions that help illuminate reasons for the preservice teachers' curriculum design decision-making and inquiry-orientation of their lessons. First, using data from the whole group of 46 preservice teachers, I present a regression model that illustrates how the preservice teachers' curriculum design decisions and the inquiry orientations of the curriculum materials help explain the overall inquiry orientations of the lessons they develop through curriculum design. These findings provide strong empirical evidence for the impact of the preservice teachers' curriculum design decisions and features of the curriculum materials they used on their revised lessons, as well as changes in the preservice teachers' curriculum design during the methods semester.

Second, I explore the preservice teachers' rationales for making such decisions, particularly how they employ their espoused inquiry frameworks to do so, and how inquiry-based their planned science lessons actually are. Using case studies of four preservice teachers, I draw explicitly upon cultural-historical activity theory (CHAT - Engeström, 1987) to characterize their espoused inquiry frameworks, curriculum design practices, and how both evolve over time. Consistent with tenets of activity-theoretical research, I focus my analyses on the preservice teachers' goals for curriculum design, the tensions or contradictions they articulate in both planning and enacting their lessons, and how they attempt to resolve these contradictions through their curriculum design decision-making. Findings from this component of the study not only illustrate how

preservice elementary teachers' espoused inquiry frameworks change over time, but also how they employ them to make instructional decisions and how this process is socially- and culturally-mediated. This is a direct contribution to furthering the field's understanding of preservice elementary teachers' development of pedagogical design capacity for science.

In the chapters that follow, I present the justification for and design of the study, as well as its findings and implications. First, in Chapter 2, I provide a thorough discussion of existing research that informs this study, as well as the theoretical and analytical framework in which it is based. In Chapter 3, I describe the context and design of the study itself. In Chapter 4, I present results from the quantitative component of the study focused on data collected from the whole group of preservice teachers during the methods semester. In Chapters 5 and 6, I present results from cases of four preservice teachers studied over the entire year. Finally, in Chapter 7, I discuss these findings and their implications for both theory and practice.

CHAPTER 2

THEORETICAL FRAMEWORK

In laying the groundwork for this study, I first explore research on preservice teachers' knowledge and beliefs about, as well as orientations toward, inquiry-oriented science teaching and learning. Second, I discuss research on teachers and curriculum materials. Third, I outline a perspective on teachers' use of curriculum materials that draws upon sociocultural theories of learning and practice and that builds upon developing perspectives of the teacher-curriculum relationship within the field. Finally, I provide an overview of cultural-historical activity theory, the theoretical framework upon which this study is based.

Teachers' Knowledge, Beliefs, and Orientations Regarding Scientific Inquiry and Inquiry-Oriented Science Teaching

In order to engage students in standards-based, inquiry-oriented science, teachers must develop a thorough understanding of scientific inquiry and inquiry-oriented teaching practices, as well as orientations towards science teaching that are congruent with inquiry teaching and learning. As noted in *Inquiry and the National Science Education Standards* (NRC, 2000), "for students to understand inquiry and use it to learn science, their teachers need to be well-versed in inquiry and inquiry-based methods" (pg. 87). However, supporting teachers in developing requisite knowledge and abilities to engage in inquiry-oriented science teaching practice remains a challenge. As the National Research Council (2000) also acknowledges,

...most teachers have not had opportunities to learn science through inquiry or to conduct scientific inquiries themselves. Nor do many teachers have the understanding and skills they need to use inquiry thoughtfully and appropriately in their classrooms. (pg. 87)

These sentiments are reinforced by a recent review of education research that focused on challenges preservice and beginning teachers face in science teaching (Davis, Petish, & Smithey, 2006). A major section of this review focused on teachers' knowledge and

beliefs about scientific inquiry, the nature of science, and inquiry-oriented science teaching. There is some evidence that teachers, particularly preservice teachers, hold views of scientific inquiry and inquiry-oriented science teaching that are often inconsistent with those advocated in current science education reform.

Preservice teachers possess existing conceptions about and orientations toward scientific inquiry and inquiry-oriented teaching practice (Howes, 2002). They often view the nature of science as a body of facts rather than negotiated and constructed through scientific practices (Gess-Newsome, 2002). Preservice teachers also often view these scientific practices, embodied by the field's conceptions of scientific inquiry, as linear and lockstep rather than dynamic and iterative (Windschitl, 2003). However, they can come to appropriate views of scientific inquiry that are more consistent with those articulated by science education scholars and scientists (Bryan, 2003; Gess-Newsome, 2002). Not surprisingly, a particularly powerful influence on preservice teachers' developing understanding of inquiry and inquiry-oriented practice is their involvement in authentic scientific investigations as part of teacher education (Haefner & Zembal-Saul, 2004; Windschitl, 2003). While preservice teachers can develop inquiry-specific knowledge, translating that knowledge into science teaching practice presents a more difficult task (Bryan & Abell, 1999; Crawford, 1999; Southerland & Gess-Newsome, 1999; Zembal-Saul, Blumenfeld, & Krajcik, 2000). They often struggle to develop more coherent views of inquiry-oriented science teaching (Smithey & Davis, 2002; Windschitl, 2004). However, there is encouraging evidence that preservice teachers can learn to engage in effective, inquiry-oriented science teaching over time (Crawford, 1999, 2007).

This body of research provides some insight into preservice teachers' ideas about and orientations toward scientific inquiry and inquiry-oriented science teaching. Nonetheless, Davis and colleagues (2006) suggest that science education scholars have much yet to learn about preservice teachers' ideas about and orientations toward scientific inquiry and inquiry-oriented science teaching. In particular, they note that much of the existing research on preservice teachers' knowledge, beliefs, and orientations regarding scientific inquiry and inquiry-oriented practice focuses on specific process skills that are indirectly related to inquiry practices as defined in current science education reform (AAAS, 1993; NRC, 1996, 2000). Most studies have not

operationalized elements of scientific inquiry and inquiry-oriented science teaching as defined in current reform, including asking and answering scientific questions, prioritizing evidence and evidence-based explanation, and communicating and justifying findings and explanations (NRC, 1996, 2000). As Davis and colleagues (2006) argue, “Without understanding these aspects of scientific inquiry, new teachers are unlikely to be successful at teaching through inquiry” (pg. 618). It is important that further research be undertaken to investigate novice teachers’ ideas about and orientations toward scientific inquiry and inquiry-oriented science teaching in light of those dimensions specifically explicated in *The National Science Education Standards and Benchmarks for Science Literacy*. This is one goal of this study.

Teachers and Curriculum Materials

A crucial component of teachers’ professional practice involves the use of curriculum materials. A growing body of educational research, particularly from the fields of science and mathematics education, has begun to illuminate the ways in which teachers use curriculum materials to engage in teaching practice (Barab & Luehmann, 2003; Brown & Edelson, 2003; Collopy, 2003; Davis, 2006; Drake & Sherin, 2006; Enyedy & Goldberg, 2004; Forbes & Davis, 2008; Grossman & Thompson, 2004; Pintó, 2004; Remillard, 2005; Roehrig & Kruse, 2005; Schneider, Krajcik, & Blumenfeld, 2005; Valencia, Place, Martin, & Grossman, 2006). A consistent theme in these studies is that teachers’ beliefs, knowledge, identity, and general orientations influence how they mobilize, evaluate, and adapt science curriculum materials to engage in teaching practice.

In the sections that follow I discuss this research and outline perspectives on the teacher-curriculum relationship. First, I define and operationalize the term ‘curriculum materials’. I next discuss relevant research on teachers’ use of curriculum materials, specifically research focused on preservice teachers, and ways to support teachers’ use of curriculum materials. Next I outline and describe general models for teachers’ use of curriculum materials, as well as articulate the model I use in this study.

Defining Curriculum Materials

The term ‘curriculum materials’ is used to refer to the various curricular resources teachers use to engage students in classroom practices in light of goals specified by the

curriculum. As Shulman (1986) noted over two decades ago, the curriculum and curriculum materials are a primary structuring influence on classroom teaching:

The curriculum and its associated materials are the material medica of pedagogy, the pharmacopia from which the teacher draws those tools of teaching that present or exemplify particular content and remediate or evaluate the adequacy of student accomplishments. (pg. 10)

The most common use of the term curriculum materials is to reference those resources explicitly designed to support and guide the work that teachers and students undertake in classrooms. These resources include, among others, lesson plans, textbooks, student and teacher workbooks, laboratory manuals, and relevant scientific representations, such as graphs, tables, models, charts, and images. While all of these are important resources in classrooms, lesson plans are particularly crucial since they are representations of classroom practice and are used by teachers. Curriculum materials usually entail the mobilization and use of additional physical resources, such as investigation materials, and apparatus. While not as often considered 'curriculum materials' in the same way as the usually text-based resources mentioned previously, they too serve a fundamental role in supporting teachers and students in collaborative work towards curricular goals. While the term curriculum materials can be interpreted broadly to include all resources employed in classroom activity, I use it here to refer explicitly to the representational curricular resources (lesson plans, worksheets, textbooks, etc.) designed to be used by teachers and students in pursuit of particular instructional goals.

Research on Teachers' Use of Curriculum Materials

The relationship between teachers and curriculum materials is an active one in which teachers evaluate, critique, adapt, and enact curriculum materials in light of their own unique needs, those of their students, and the contexts in which they work. Through iterative cycles of curriculum design, teachers can learn to engage with curriculum materials and in teaching practice more productively. Teachers' knowledge and beliefs regarding students, the nature of teaching and learning, subject matter, and instructional repertoires, as well as their own identities and orientations towards the role of curriculum materials, directly influence the ways in which they mobilize and use curriculum materials within their unique classroom contexts. Collectively, these individual

conceptions inherent to a given teacher can be called *teacher resources* (Brown, 2002, 2009; Brown & Edelson, 2003).

Thus far, curriculum research has been focused largely on, for example, elementary teachers' use of mathematics curriculum materials (Collopy, 2003; Lloyd, 1999; Remillard, 1999; Remillard & Bryans, 2004) and middle and secondary science teachers' use of science curriculum materials (Enyedy & Goldberg, 2004; Fishman, Marx, Best, & Tal, 2003; Pintó, 2004; Roehrig & Kruse, 2005; Roehrig, Kruse, & Kern, 2007; Schneider, Krajcik, & Blumenfeld, 2005). Additionally, theoretical contributions to the research base have proposed frameworks for the teacher-curriculum relationship (Remillard, 2005) and explored the role of educative curriculum materials, or curriculum materials designed to explicitly support teacher learning (Ball & Cohen, 1996; Davis & Krajcik, 2005). While a substantial amount of research has been focused on inservice teachers' use of science and mathematics curriculum materials, a more limited body has only begun to emerge focused on preservice elementary teachers' use of and learning from science curriculum materials (Davis, 2006; Dietz & Davis, in press; Forbes & Davis, 2008; Schwarz, Gunckel, Smith, Covitt, Enfield, Bae, & Tsurusaki, 2008). While our understanding of preservice teachers' use of and learning from science curriculum materials is limited, these studies provide important insight into how they mobilize teacher resources in their interactions with curriculum materials.

Just as preservice teachers articulate existing ideas about science teaching, including inquiry, they also draw upon these ideas as criteria by which they critique and adapt science curriculum materials. Many of the criteria they employ are consistent with those intended by the curriculum developers (Dietz & Davis, in press) and advocated in current science education reform (AAAS, 1993; NRC, 1996, 2000). They also mirror those dimensions of science teaching practice that preservice elementary teachers prioritize elsewhere. For example, many studies have illustrated preservice elementary teachers' child-centered perspectives on teaching (Abell, 2007; Abell, Bryan, & Anderson, 1998; Howes, 2002; Levitt, 2002). Preservice teachers similarly draw upon these orientations in their critique and adaptation of science curriculum materials, specifically in their prioritization of student engagement and connections to students' lives outside of school (Davis, 2006; Forbes & Davis, 2008).

Similarly, elementary teachers emphasize active, hands-on science experiences for students in science (Abell, 2007; Abell, Bryan, & Anderson, 1998; Howes, 2002). Preservice elementary teachers also prioritize the investigative dimensions of inquiry and inquiry-oriented teaching in their use of science curriculum materials. Unfortunately, they often do so at the expense of explanation-construction, a crucial component of scientific inquiry (Davis, 2006). In fact, while novice teachers can learn to teach science as inquiry (Crawford, 1999), they often prioritize other relevant criteria over inquiry and inquiry-oriented science teaching (Dietz & Davis, in press). This is consistent with findings from other studies which found that preservice teachers generally possess less well-developed understandings of inquiry-oriented teaching practice (Smithey & Davis, 2002; Windschitl, 2004). However, preservice elementary teachers' generally positive orientations toward active, hands-on, investigation-based science can serve as a productive foundation upon which to support their developing understanding of scientific inquiry (Howes, 2002).

These studies also suggest that preservice teachers can learn to more effectively critique and adapt curriculum materials through teacher education. Scaffolded opportunities for learning in science methods courses can help preservice teachers first develop awareness of particular criteria and then learn to apply them over time in their use of curriculum materials (Davis, 2006). Additionally, preservice teachers can learn to use educative features of curriculum materials to support their development at this crucial stage along the teacher professional continuum (Dietz & Davis, in press). Preservice teachers also cite the active use of curriculum materials as more important for beginning teachers than experienced teachers but acknowledge that more experienced teachers also have the capacity to learn from curriculum materials in two cases: when using new curriculum materials and when teaching new content (Forbes & Davis, 2008). These studies also provide evidence that preservice teachers' learning to use curriculum materials is fundamentally intertwined with their developing identity as teachers (Dietz & Davis, in press; Forbes & Davis, 2008).

Supporting Teachers' Use of Curriculum Materials

Teachers' knowledge, beliefs, and orientations play an important role in their use of curriculum materials, as do opportunities for collaboration with colleagues and the

nature of the curriculum materials themselves. Teachers can be supported to use curriculum materials effectively through the development of flexibly adaptive curricula (Cohen & Ball, 1999; Fishman & Krajcik, 2003; Schwartz, Lin, Brophy, & Bransford, 1999) designed to be educative for teachers as well as students (Ball & Cohen, 1996; Davis & Krajcik, 2005) and teacher communities constructed around the teacher-curriculum interactions (Fishman et al., 2003; Grossman, Wineburg, & Wollworth, 2001).

Flexibly adaptive curricula. Many curriculum developers have begun to acknowledge both the need for, and unavoidable reality of, local, classroom-based adaptation and have reoriented their efforts towards the design of ‘flexibly adaptive curricula’ (Cohen & Ball, 1999; Fishman & Krajcik, 2003; Schwartz et al., 1999). Underlying the notion of flexibly adaptive curricula is an assumption that curriculum adaptation and modification will occur and, as a result, curriculum materials should support context-dependent adaptation in ways that do not threaten elements of the curriculum considered by curriculum developers to be fundamental to the development of innovative science learning environments. The features that help make curriculum materials flexibly adaptive do so by making explicit the purposes of particular design features and promoting customization of instructional practice.

Such materials represent a balancing act between highly specified and highly developed curriculum materials (Cohen & Ball, 1999). Specification refers to how structured and explicit the materials are, while development is concerned with the robustness of the materials as a tool for teaching practice. If materials are overly specified but not well developed, or vice versa, they are not as useful for teachers. Beginning teachers, for example, often express a desire for more specified materials (Kauffman, Johnson, Kardos, Liu, & Peske, 2002). When specification is limited, however, elementary teachers may integrate reform practices with existing, more traditional approaches to teaching. Designing curriculum materials that attain such a balance may help increase the relatively short shelf-life of curricular reforms (Fishman & Krajcik, 2003).

Educative curriculum materials. Curriculum materials can also be designed to promote teacher learning as well as student learning (Ball & Cohen, 1996; Davis &

Krajcik, 2005; Schneider & Krajcik, 2002). Because teachers represent a critical pivot point between curriculum development and student learning, the curriculum development process should also take into account the need for teachers to learn through curriculum materials use. Such materials are particularly useful to preservice and beginning elementary teachers who have little classroom teaching experience and often rely heavily on the curriculum materials they have access to (Forbes & Davis, 2007; Grossman & Thompson, 2004).

However, curricular innovations occur with regularity in schools, including elementary schools (Forbes & Davis, 2007; Grossman & Thompson, 2004), meaning that experienced teachers often face the prospect of adopting new curricula along with less-experienced teachers. There is a need, then, for curriculum materials that can promote teacher learning across experience levels. Furthermore, not all teachers benefit equally or at all from resources designed to support their learning (Schneider, Krajcik, & Blumenfeld, 2005). Educative features may be optimally supportive when they are detailed and lesson specific (Davis & Krajcik, 2005; Schneider & Krajcik, 2002; Schneider, Krajcik, & Blumenfeld, 2005). A goal of curriculum development is to maximize the relative utility of all kinds of educative features so as to support teachers in not only in coming to recognize the need *to* adapt curriculum, but also in learning *how* to do so (Lloyd, 1999).

Curriculum-based teacher community: While beginning teachers often rely heavily on the curriculum materials they have, they can also expend significant time and energy searching for and mobilizing additional curriculum materials (Forbes & Davis, 2007; Grossman & Thompson, 2004; Kauffman et al., 2002; Southerland & Gess-Newsome, 1999; Valencia et al., 2006). Features of curriculum materials themselves can support teachers' curriculum design efforts. However, curriculum materials alone are not enough to promote science education reform (Davis & Krajcik, 2005; Fishman & Krajcik, 2003; Remillard & Bryans, 2004). It is also important that teachers have the opportunity to engage in collaborative work with colleagues around their use. As a result, many curriculum reform efforts include some sort of professional development for teachers focused on the use of new curriculum materials. Such experiences are materials-based and linked explicitly to teaching practice.

However, due to the finite timeframe of funding that supports such curriculum development projects, these experiences are usually short-term. The professional collaboration eventually ends and teachers are left to use materials alone in their classrooms. Unfortunately, as Grossman and colleagues (2001) note, “the simple fact is that the structures for ongoing community do not exist” (pg. 947) in American public schools. Isolated in this way, teachers may fall back on their own experiences as students, or apprenticeship of observation (Lortie, 1975), which “is an ally of continuity rather than change” (pg. 67). This is often the case for preservice teachers as well, who find that their classroom-based experiences afford limited opportunities to engage in intellectual dimensions of teaching practice (Sim, 2006). Preservice and beginning teachers therefore need opportunities to work critically with curriculum materials over time, particularly in collaboration with more experienced teachers (Grossman & Thompson, 2004).

Summary of Teachers and Curriculum Materials

Curriculum design processes that characterize the teacher-curriculum relationship are fundamentally influenced by teacher resources, available curriculum materials and their intrinsic features, and affordances and constraints of the contexts in which they occur. Teachers mobilize personal resources, including knowledge, beliefs, and identity, in evaluating, critiquing, modifying, and enacting the curriculum materials they use. Their use of these materials is influenced by the nature of the curriculum materials themselves, which can be designed to explicitly support teachers’ use of them. For preservice teachers, who at this point along the teacher professional continuum lack substantial subject matter knowledge and classroom experience, and are negotiating goals and expectations across multiple relevant settings, the teacher-curriculum relationship takes on a unique character. It is precisely at this point in teachers’ developmental trajectory that they can begin to learn to use curriculum materials effectively and develop frameworks for ongoing curriculum-specific learning through an emphasis on the use of curriculum materials in teacher education experiences.

A Situated Framework for the Teacher-Curriculum Relationship

A critical dimension of teachers’ learning is that they be able to mobilize and use their knowledge effectively in practice. Knowledge is therefore fundamentally tied to

notions of teaching expertise. For example, as Bransford and colleagues (2000) suggest, “experts have acquired extensive knowledge that affects what they notice and how they organize, represent, and interpret information in their environment” (pg. 31).

Specifically, for teachers to learn to engage in inquiry-oriented science teaching, they have to transform and translate representations of inquiry (text-based definitions, models, frameworks, etc.) into actual classroom practices. One dimension of teachers’ expertise, then, involves their mobilization of representations of inquiry, or their espoused inquiry frameworks, to effectively adapt science curriculum materials in ways that ultimately lead to inquiry-based classroom practice.

Unfortunately, despite the attention to knowledge for teaching over the past two decades, there is little consensus as to what knowledge lies at the heart of teaching, how to characterize and describe it, and how it relates more broadly to notions of teaching expertise. Because the relationship between beliefs and practice is an interactive one (Richardson, 1996), it is often difficult to differentiate between what teachers *know*, what they *believe*, and what they *do*. In many ways this lack of understanding is manifested in the oft-referenced disconnect between theory and practice, or formal knowledge and practical knowledge (Fenstermacher, 1994; Hiebert, Gallimore, & Stigler, 2002). Education scholars and researchers often discount the knowledge of practitioners as ‘craft knowledge’ – a sort of ill-informed, less robust, anecdotal, experience-based complex of understandings to which most often is attributed lower status. On the other hand, teachers often view the discourse of educational scholarship, particularly in the context of teacher education, as marginally relevant and significantly divorced from the daily realities of actual classrooms.

There is little disagreement that classroom experience is a crucial context for teachers’ development of expertise. As Richardson (1996) argues, “experience as a teacher is the only way to develop the practical knowledge that eventually makes routine at least some aspects of classroom practice and provides alternative approaches when faced with dilemmas” (pg. 13). Finding ways to translate this knowledge into public knowledge is essential for “knowing flexibly in and for teaching” (Ball & Bass, 2000), pg. 98). However, teachers, including highly effective science teachers, most often rely on tacit, routinized knowledge they struggle to articulate (Berliner, 1986; Roth, 1998).

As Hutchins (1995) notes, this is common in many activity settings, where ‘skilled performers’ often have a difficult time putting words to their expert performances. In teaching, it is the increasing routinization of knowledge in practice that some argue mark transitions from novice to expert teachers along the teacher professional continuum (Feiman-Nemser, 2001).

This issue is clearly an important one. If we are to understand how teachers interact with and use curriculum materials in light of their espoused inquiry frameworks, we must develop an understanding of how such a relationship unfolds in particular settings over time. To do so, I draw upon situated and activity-based perspectives on teacher learning and practice (Putnam & Borko, 2000).

Elements of a Situated Perspective on Teacher Learning and Practice

More recent work in cognitive science and learning theory seeks to deemphasize the dichotomization of the individual and the external world in theories of learning. Clearly there is value in diverse perspectives on knowing, learning, and activity (Anderson, Greeno, Reder, & Simon, 2000). Nonetheless, it is particularly useful to view human knowing, learning, and activity in a way that blurs the previously drawn boundaries between the self and the world (Hutchins, 1995). Such a view acknowledges the negotiated relationship between the individual and socio-material world, but neither adopts a positivist view of determinate, mechanistic, conditioned behavior or a wholly constructivist view of absolute and unconditional autonomy (Barab & Roth, 2006). A primary objective of situated learning theory is to account for participation in activity systems in which the separation between the individual and the socio-material environment breaks down.

Sociocultural and situated views of learning prioritize the social, cultural, and activity-based nature of learning. People engage in collective action in particular settings at particular times. Participation in these communities of practice (Lave & Wenger, 1991), activity systems (Engeström, 1987), or ecosocial systems (Lemke, 2000) is one characterized by the process of semiosis, or meaning-making. Regular patterns of meaning-making within such contexts are characterized as practices (Greeno et al., 1998). Activity settings are characterized by certain affordances and constraints which influence, but do not serve as sole determiners, of individuals’ participation and activity. The

question is not whether learning is situated and occurs through participation but rather how it does and what influence particular features of activity settings have on learning (Greeno et al., 1998; Putnam & Borko, 2000).

Through participation in established practices, participants become more effective participants and practitioners, moving from legitimate peripheral participation to more central participation by aligning their own skill sets to conditions afforded in the setting where the activity occurs (Barab & Roth, 2006; Lave & Wenger, 1991). Learning, then, can be defined as culminating changes in participation (Lemke, 1997). Additionally, through learning, individuals can not only become more central participants in established practices, but also become active agents in negotiating and fundamentally altering those practices (Engeström, 1987; Lave & Wenger, 1991).

Within such activities, groups of people engage in meaning-making through the use of tools that orient and link individuals, as well as groups of individuals, with the socio-material environment. Vygotsky (1978) distinguished between material tools and psychological tools. Material tools include physical objects used in particular activities. Psychological tools, on the other hand, include “various systems for counting; mnemonic techniques; algebraic symbol systems; works of art; writing; schemes, diagrams, maps, and technical drawings; all sorts of conventional signs” (Vygotsky, 1997, pg. 85). Norms of established social practice mediate the ways which these psychological tools are used. The nature of learning depends on the tools available to the individual. The tools that are available to the individual will be determined by the culture in which the individual is situated. Actions, thoughts, perceptions, memory, attention, and experience are therefore culturally-mediated.

Participants in particular practices reify their past experiences in the form of knowledge, beliefs, identities, and general orientations. These constructs do not exist as extant entities – rather, they are constructed and negotiated *through* activity and mobilized as tools *in* activity in light of norms and conditions of the contexts in which activities occur. For teachers, routinized knowledge constructed from previous experience serves as a guide for future practice. However, classrooms are inherently unpredictable and teachers are often faced with novel scenarios. When such situations arise, teachers are faced with new affordances and constraints, or new combinations of

them, and must navigate by reorienting knowledge in practice (Ball & Bass, 2000; Davis, 2003; Frykholm & Glasson, 2005; Schon, 1983; Sherin, 2002).

What is implied in this view of knowing and learning is that these constructs do not exist in the abstract, independent of the contexts in which they exist and occur. Following this logic, one might assert that expertise for teaching can *only* be developed through classroom practice. For example, as Ball and Bass (2000) point out, “no amount of pedagogical content knowledge can prepare a teacher for all of practice, for a significant proportion of teaching is uncertain” (pg. 89). While such an assertion can be reasonably derived from situated perspectives on learning, classroom-based and non-classroom-based experiences can both serve to support teacher learning (Putnam & Borko, 2000). In order for them to do so, however, fundamental characteristics of opportunities for teacher learning must be aligned across settings. Such experiences can help teachers develop frameworks for knowledge construction and the development of expertise that accounts for underlying affordances across settings (Barab & Roth, 2006; Zembal-Saul, Blumenfeld, & Krajcik, 2000). Another impetus for this research is to learn more about how to better support preservice teachers’ developing understanding of inquiry and use of science curriculum materials across university and elementary classroom settings.

Implications for Understanding the Teacher-Curriculum Relationship

Situated and sociocultural perspectives on teacher learning and practice have important implications for considerations of the teacher-curriculum relationship. More recent research on teachers and curriculum materials has utilized a tool- and activity-based approach to studying the ways in which teachers design with curriculum materials to engage in teaching practice. In the sections that follow, I discuss two key elements of this perspective on teachers’ use of curriculum materials.

Curriculum materials as artifacts and tools. Curriculum materials serve as both artifacts and tools, reified across communities of practice (Barab & Luehmann, 2003; Brown, 2009; Remillard, 2005). As artifacts, they represent the intentions of all who have been involved in their construction, from curriculum developers to teachers, and therefore entail “some effort to define, explain, interpret, and develop...meaning and

entailments for action” (Cohen & Ball, 1999, pg. 19). Curriculum materials are transformed into tools through their use by teachers and students in classroom settings.

As cultural artifacts that mediate human activity, curriculum resources have the potential to enable, extend, or constrain human activity. From this perspective, the use of curriculum resources can be viewed as the use of cultural tool. (Remillard, 2005, pg. 231)

The nature of curriculum materials as artifacts and tools also implies a temporal dimension (Cohen & Ball, 1999). Curriculum materials themselves represent instantiations of past and imagined, future classroom practice, as well as resources required to inform this activity. Their construction largely relies on within-lesson activity around a particular topically-related action, or ‘episodes’ (Lemke, 2000). These instances in turn compose lessons, which in turn compose related sequences of lessons, which compose units, which compose grade-level, disciplinary curricula and so forth. What differs most about the units of analyses is the timescales at which they influence activity.

Artifacts of science teaching practice, particularly curriculum materials iteratively developed over time by teachers in particular settings, can serve as functional, interpretable representations of the expertise they employ (Ball & Lampert, 1999; Loughran, Mulhall, & Berry, 2004; Loughran, Mulhall, Berry, Gunstone, & Mulhall, 2001; Marx, Blumenfeld, Krajcik, & Soloway, 1998). They can help ‘stop time’ (Rosebery & Puttick, 1998), thus providing teachers with an opportunity to situate communication about teaching practice in common contexts (Ball & Lampert, 1999). This idea hearkens back to what Shulman (1986) described as case knowledge, which consists of prototypes, precedents, and parables and is knowledge of well-documented, context-specific activity which teachers can apply to new situations in their classroom. Studying the practice of expert teachers, or the curriculum materials they develop to represent these practices, may help less experienced teachers learn to make their knowledge explicit (Berliner, 1986).

Pedagogical design capacity: The development of teaching expertise, and the artifacts of practice that represent such expertise, are fundamentally tied to the contexts in which teachers engage in teaching practices. Teachers become active agents in developing personal resources that increase their instructional capacity or *pedagogical design capacity* (Brown, 2002, 2009; Brown & Edelson, 2003). Pedagogical design

capacity is defined as teachers' abilities and competence to perceive and mobilize both personal teacher resources (knowledge, beliefs, identity, and orientations) and external curriculum resources to craft instruction and instructional contexts in light of instructional goals. Thus, it is concerned with the process through which teachers engage in teaching practice by negotiating their own ideas and orientations, the curricular tools at their disposal, and features of the classroom and school context. To engage in effective teaching practice, different teachers may require different types of resources and classroom contexts given their knowledge, beliefs, and identities. Conversely, given individual teachers' orientations toward science teaching practice, including their knowledge and beliefs, they will mobilize, draw upon, and use resources in different ways. The construct of pedagogical design capacity is useful in that it provides a way of evaluating how individual teachers perceive and mobilize instructional resources, including curriculum materials.

Pedagogical design capacity is characterized by a number of essential features (Brown, 2002, 2009; Brown & Edelson, 2003) that are aligned with situated views on learning and activity. First, pedagogical design capacity is not just a property of the individual teachers, but one of broader activity systems that include other people, artifacts, and tools. As such, capacity refers not only to a teacher's proclivity for certain forms of teaching practice given a certain set of affordances and constraints, but also to the entire system of which the teacher is a part. For example, while features and characteristics of a particular set of curriculum materials may afford and constrain classroom practice in given ways, pedagogical design capacity exists in the relationship between teachers, the curriculum materials, and other features of contexts. Therefore, second, individual teacher characteristics, the curriculum materials, and features of their context of use are most meaningful when considered in relation to one another. Third, pedagogical design capacity refers to situated instances of curriculum design. While the idea of pedagogical design capacity can serve as a broad, overlying theoretical framework for understanding teachers' use of curriculum materials, the particular nature of pedagogical design capacity in any given classroom context is a function of the individual teachers, the curriculum materials he or she used, and his or her students, and is therefore unique and context-dependent.

Pedagogical design capacity serves as a model for the collaborative and distributed process of curriculum design and can serve to help educational researchers better understand how teachers develop their capacity for instruction through the use of curriculum materials. As Brown (2002) argues, “while pedagogical content knowledge describes how teachers apply existing knowledge artifacts during instruction, it does not provide substantial description of such processes at the level of teachers’ interactions with the full range of instructional artifacts in the immediate instructional setting” (pg. 84). What pedagogical design capacity affords us is a way to account for more than teachers’ knowledge, beliefs, and orientations in their science teaching practice by not only accounting for “the ‘what’ of instructional capacity—that is, the subject matter knowledge, pedagogical content knowledge, goals, and beliefs that influence practice”, but also ‘how’ such facets are used” (Brown, 2002, pg. 452).

Summary of a Situated Framework for the Teacher-Curriculum Relationship

Situated and activity-based perspectives on knowing and learning provide education scholars an important tool through which to understand how teachers develop teaching expertise over time in particular classroom contexts. These theoretical perspectives emphasize the social, cultural, and practice-based nature of knowledge and knowledge construction, as well as the crucial role mediating tools and artifacts play in them. By focusing on deeply contextualized meaning-making, they also help account for why transfer of knowledge and skills across settings remains a challenge for formal education and how meaningful transfer might be better supported. Current scholarship and research on teachers and curriculum materials are consistent with such perspectives on learning and practice. This is especially the case with the roles curriculum materials fulfill as both artifacts and tools, their capacity to act as representations of teachers’ expertise, and the notion of pedagogical design capacity as a means of conceptualizing teachers’ use of curriculum materials.

Cultural-historical Activity Theory (CHAT)

In the previous section, I presented an overview of situated perspectives on teachers’ use of curriculum materials and learning. In this section, I discuss the theoretical and analytical framework I use in this study, cultural-historical activity theory (Engeström, 1987). CHAT is aligned with situated perspectives on knowing and learning

and provides a robust theoretical and analytical framework for characterizing teachers' use of curriculum materials in practice, as well as teacher learning (Grossman, Smagorinsky, & Valencia, 1999). Activity theory traces its roots back to Vygotsky but has only recently begun to garner attention in the United States. In more recent education research, it has served as a theoretical and analytical framework for studies of elementary science (Reveles, Kelly, & Duran, 2007), school leadership (Spillane, Halverson, & Diamond, 2004), teacher professional development (Yamagata-Lynch, 2007), identity development of preservice elementary teachers (Smagorinsky, Cook, Moore, Jackson, & Fry, 2004) and teachers and students in urban schools (Roth, Tobin, Elmesky, Carambo, McKnight, & Beers, 2004), and the use of common classroom artifacts and tools (McDonald, Le, Higgins, & Podmore, 2005). As Roth (2004) suggests, "the potential of cultural-historical activity theory for research practice and practice research has not yet been realized" (pg. 7).

Overview of Cultural-Historical Activity Theory

Learning is a byproduct of doing. However, appropriating a rote skill is a different form of learning than development novel ways to employ that particular skill to accomplish particular objectives. Engeström differentiates between these two forms of learning as 'learning actions' versus 'learning activity'. Learning actions are indicative of specific actions that, by themselves, do not constitute robust, developed practice. On the other hand, learning activity, which ultimately can result in expansive learning and the development of new forms of activity, is comprised of series of learning actions (Engeström, 1987; Tuomi-Gröhn & Engeström, 2003). Activity theory, then, is fundamentally concerned with learning activity that is socially- and culturally-mediated, as well as object-oriented. The fundamental unit of analysis in activity theory is human social activity itself, driven by a goal-orientation relevant to a particular need or motive as defined by members of a particular community.

As Engeström (1987) notes, activity theory is a "concept of activity based on material production, mediated by technical and psychological tools as well as by other human beings" (pg. 25). Activity undertaken by an individual or group (subject) whose particular motive(s) or need(s) impels action oriented toward a particular problem or purpose (object). Consistent with the foundations of cognitive science laid by Vygotsky,

such activity is also mediated by tools and artifacts (instruments) and by other human beings (community) within the activity system. The nature of activity as it develops is also structured and shaped by norms of the community (rules) and specialization or social stratification (division of labor). More concisely stated, “a central concern of activity theory is to understand the kinds of culturally defined futures that motivate peoples’ activity and the sorts of tools they develop in order to help mediate one’s progress towards those futures” (Grossman, Smagorinsky, & Valencia, 1999, pg. 5). These complex relationships can be visualized as in the CHAT activity triangle, a generalized model for analyzing social activity, which is shown in Figure 2.1.

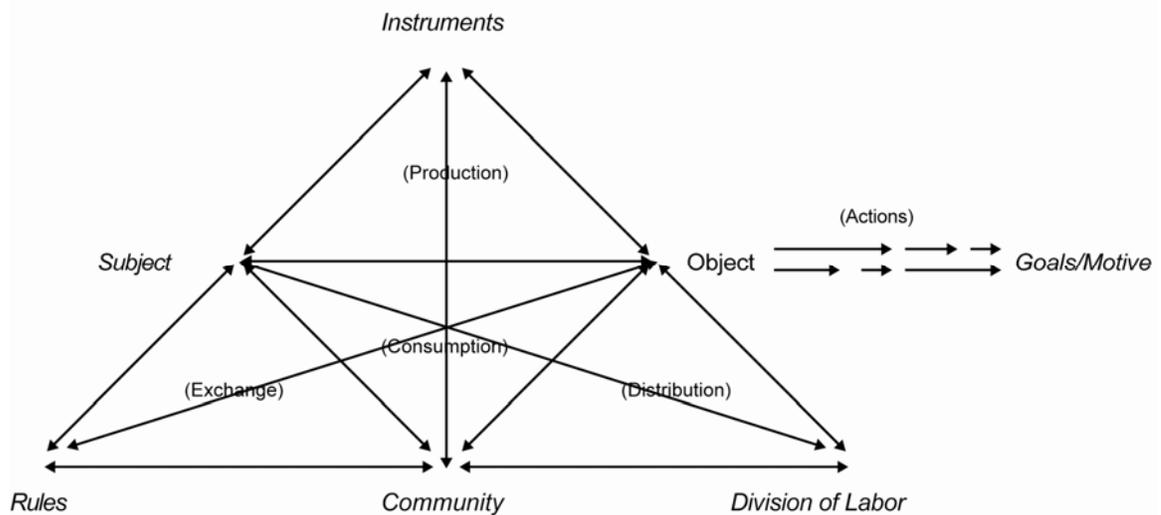


Figure 2.1. Cultural-Historical Activity Theory Model of Activity (Engeström, 1987; 2008)

The mediating influence of tools is a key assumption of activity theory, consistent with its origins in Vygotsky’s work. In Figure 2.1, the ‘production’ triangle represents the use of tools and instruments by an individual or group to accomplish certain objectives, independent of any social and/or cultural mediation. This is the essential model of tool-mediation proposed by Vygotsky, who articulated the importance of tools in transforming human activity from a direct to an indirect, or mediated relationship to the environment. Vygotsky (1978) argued that it is tool use that differentiates between elementary functions and higher psychological functions:

The central characteristic of elementary functions is that they are totally and directly determined by stimulation from the environment. For higher functions, the central feature is self-generated stimulation, that is, the

creation and use of artificial stimuli which become the immediate causes of behavior (pg. 39).

He further differentiated between technical tools and psychological tools. Technical tools are simply those material tools which help individuals accomplish a particular task.

Psychological tools, on the other hand, include representations and signs and are part of activity directed not just at an object but the larger ecosocial system in general.

Wartofsky (1979) distinguishes similarly between primary and secondary artifacts. As Engeström suggests, “the essence of psychological tools is that they are originally instruments for co-operative, communicative and self-conscious shaping and controlling of the procedures of using and making technical tools” (1987, pg. 18), thus reinforcing the inherent relationship between them. Within teaching, these two types of tools can be rearticulated as conceptual tools and practical tools employed in teaching practice (Grossman, Smagorinsky, & Valencia, 1999). Textbooks, for example, may serve as both types of tools when used by students in collaborative groups (McDonald et al., 2005). Often when teachers are critiqued and/or evaluated on their use of curriculum materials, it is assumed to be due to their conceptions of the materials. However, such apparently incompatible tool use may rather be due to “complex interactions between teachers’ goals and specific characteristics of curriculum materials” (Lloyd, 1999, pg. 25).

The basic CHAT triangle model can be applied to any activity. The specific activity that is the subject of analysis is referred to as the central activity. However, a given activity system, such as a classroom, is itself nested within broader networks of systems that contribute to the central activity (Engeström, 1987; Roth & Lee, 2007). This relationship is shown in Figure 2.2.

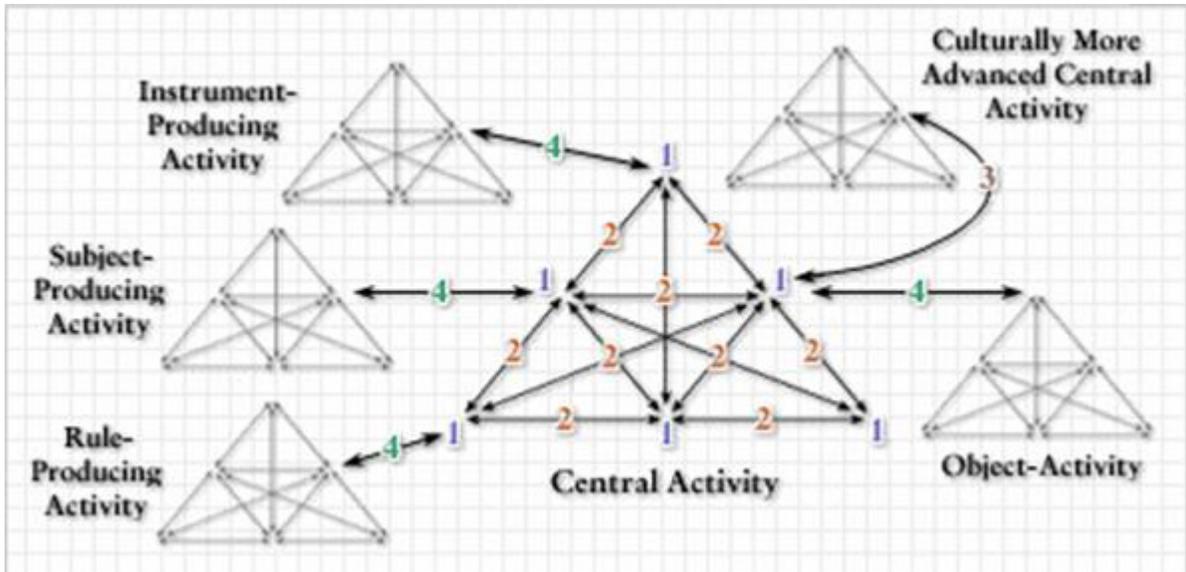


Figure 2.2. Four Levels of Contradictions in a Network of Human Activity Systems (Engeström, 1987)

Consider an example. A middle school student is working on an investigation using plants grown in the classroom to develop and understanding of patterns of genetic inheritance (central activity). The student is himself a product of previous learning experiences, both within and outside of school. These would be considered subject-producing activities. In his effort to interpret his results, he is wrestling with his understanding of Mendelian genetics and the Punnet Square, both relevant tools in this investigation and both of which themselves possess a long history of development within the scientific and science education communities (instrument-producing activities). He is also careful to adhere to expectations he knows his teacher has regarding inquiry, which have developed over the year for the student but which have developed over multiple years for the teachers (rule-producing activity). However, he is concerned about his understanding of Mendelian genetics because he knows he will have to be able to apply it on an upcoming test (object-activity). These relationships illustrate the ways in which any particular form of classroom activity is itself a function of other activities in other contexts.

Within and between activity systems, the harbinger of change is the presence of contradictions. These contradictions are tensions or conflicts that arise within or between activities due to the “the clash between *individual actions and the total activity system*”

(Engeström, 1987, pg. 30). In activity theory, there are four types of contradictions (Engeström, 1987), shown in Figure 2.2. First, participants in a given activity profess particular issues or problems. For example, a preservice teacher (subject) may wrestle with his or her own self-efficacy related to subject-matter knowledge. In CHAT, these issues are referred to as ‘need states’ that the individual must wrestle with in order to make decisions about how to engage in particular practices. More specifically, they are vague, ill-defined contradictions *within* each node of the activity triangle and are called *primary contradictions* (labeled ‘1’ in Figure 2.2).

As an activity system develops, participants’ need states are honed into what Engeström (1987) calls the ‘double bind’. The double bind represents a more defined problem than the need state and implies contradictions *between* particular nodes of the activity triangle rather than *within* them. These are secondary contradictions (labeled ‘2’ in Figure 2.2) that, for example, might arise when teachers experience difficulty using their espoused inquiry frameworks (tools) to evaluate and adapt curriculum materials (object). It is negotiation of these secondary contradictions and the development of new instruments that lead to new forms of activity.

However, as individuals engage in new forms of activity, additional contradictions often emerge between the old and the new ways of doing things. This often creates tensions between adherents to established practices and those who seek to engage in new practices. For example, tertiary contradictions (labeled ‘3’ in Figure 2.2) arise between competing objects and goals of an activity system. Teachers who construct summarized lesson plans (objects) to support their teaching (goal) may resist a new curriculum planning practice in which they are expected to produce more robust and detailed lesson plans (object) that also serve as a tool for professional communication and collaboration (goal).

Finally, objects developed in the central activity, in this case science lesson plans, most often act as tools in separate but related activities called the object activity. Use of the object as a tool in the object-activity, in turn, plays an important role in iterative cycles of object-production and expansive development emphasized in the central activity. In this way, the activity system is cyclical, acting as a feedback loop. However, tensions may develop between these two activities, often manifested in the boundary

objects that connect the two activities. Consider, for example, the well-researched discord that teachers often articulate between theory-oriented teacher education and the pragmatism of actual classroom teaching. These represent *quaternary contradictions* between the central activity and neighboring activities (labeled ‘4’ in Figure 2.2).

These contradictions are important because they lie at the heart of learning in and from practice. If no contradictions existed, a given activity or practice would remain indefinitely unchanged. Additionally, as Engeström (1999) notes, “the internal contradictions of the given activity system in a given phase of its evolution can be more or less adequately identified...and any model for the future that does not address and eliminate those contradictions will eventually turn out to be nonexpansive” (pg. 34-35). Learning occurs as a natural byproduct of contradiction-laden activity. The goal of such learning is the development of new, more advanced, and better articulated forms of the activity. Here, then, learning is evidenced in teachers’ engagement in more advanced forms of teaching practice, specifically the use of curriculum materials to engage in inquiry-oriented science teaching. These contradictions and their foregrounding in this study’s design are revisited in Chapter 3.

A Model for Preservice Elementary Teachers’ Curriculum Design

The teacher-curriculum relationship can be fundamentally characterized as design (Brown, 2009; Remillard, 2005) in which teachers and curriculum materials both contribute to the development of classroom learning environments and their constituent practices. Teachers engage in curriculum design through instructional planning in the *design* domain, curriculum enactment in the *construction* domain, and integration of repeated, coherent cycles of curriculum design over time, or *curriculum mapping* (Remillard, 1999). Teachers plan for instruction, instantiating imagined practice and resources in curriculum materials they develop. In this design arena, to use Remillard’s terminology, the curriculum materials themselves are the focus of curriculum planning in which teachers leverage their knowledge, beliefs, and orientations to produce instructional artifacts such as lesson plans. These instructional artifacts are then mobilized in actual classroom teaching practice, or Remillard’s construction domain, and support teachers to promote student learning. Based on the experience of enacting curriculum materials with students, teachers reinterpret and refine curriculum materials.

This relationship between teachers and curriculum materials represents the transposition of ‘doing’ and ‘representing what has and will be done’ inherent to iterative design processes (Engeström, 1987; Latour, 1999; Wenger, 1998).

Drawing on activity-theoretical constructs, specifically Engeström’s model of interacting activity systems (Figure 2.2), I propose a model for preservice teachers’ curriculum design for inquiry-oriented science teaching. This model foregrounds the curriculum planning and curriculum enactment activities in which the preservice teachers engage while also accounting for the programmatic contexts of the teacher education program. This model is shown in Figure 2.3.

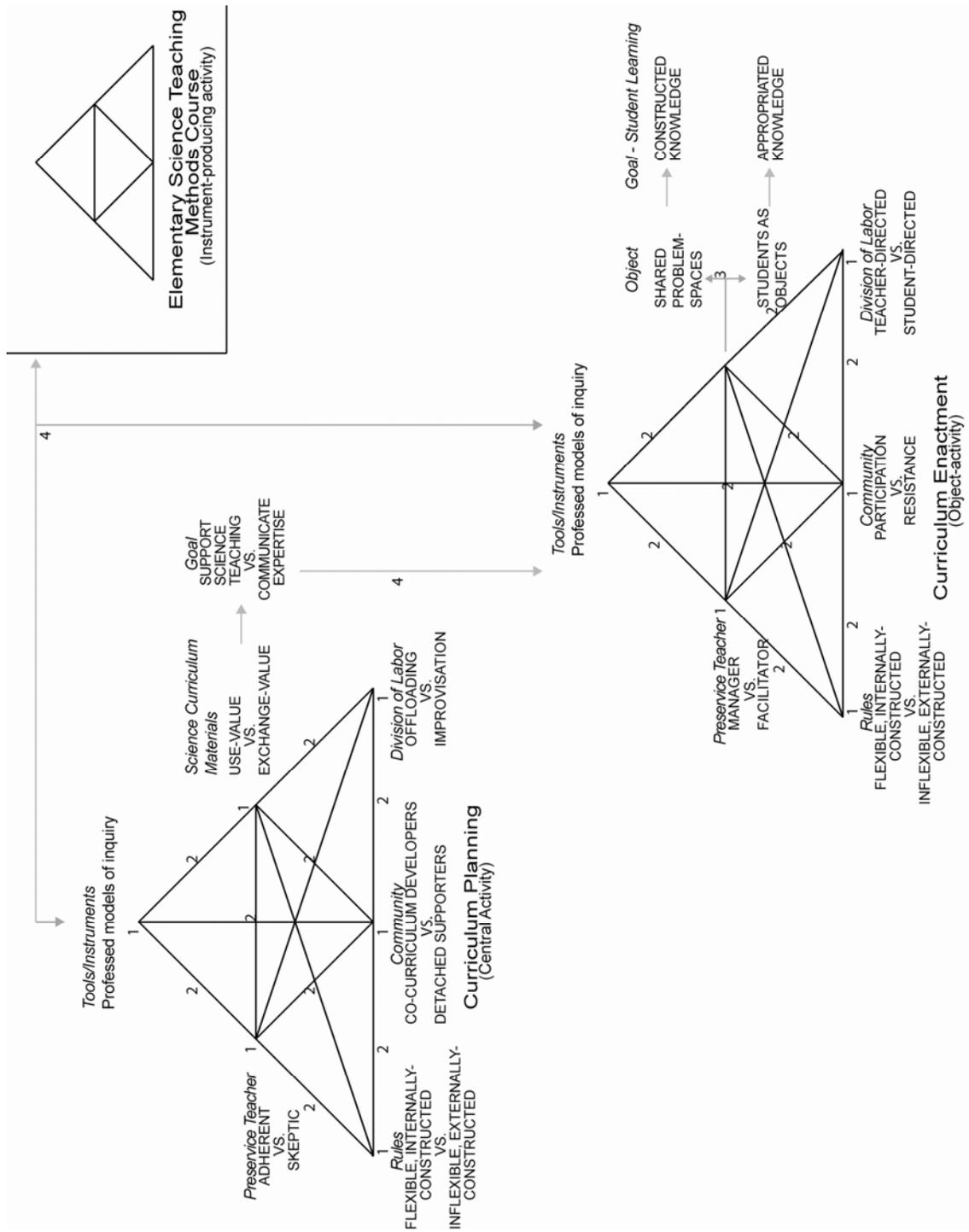


Figure 2.3. Activity-Theoretical Framework for Preservice Elementary Teachers' Curriculum Design for Inquiry

Given the programmatic context for this research, as well as the need to capture the potential evolution of the preservice teachers' teacher resources and curriculum design efforts over time, the essential model shown in Figure 2.3 requires elaboration. While the preservice teachers' curriculum planning (central activity) and curriculum enactment (object activity) remain the central focus of this study, other related activity systems are also expected to be important influences on the preservice teachers' engagement in curriculum design for inquiry-oriented science teaching. Additionally, to fully account for potential contradictions that drive the preservice teachers' learning in and from curriculum design, the model must also account for the dynamic nature of this process and how it changes over time.

In this model, I define three activities that are relevant to this study by using Engeström's (1987) model of interacting activity systems (Figure 2.2). The first two, curriculum planning (central activity) and curriculum enactment (object-activity), are foregrounded as constituting curriculum design for inquiry-oriented science teaching. The third, the elementary science methods course, is a fundamental instrument-producing activity within which the preservice teachers develop and refine their espoused inquiry frameworks. These activity systems are inherently interrelated, thus teachers must be able to travel effectively between them, work described by Grossman and colleagues (2001) as "moving from distributed cognition to cognition distributed" (pg. 975).

Production sub-process of curriculum planning. In the curriculum planning activity, preservice teachers mobilize their existing teacher resources (ideas, beliefs, and orientations toward teaching), as well existing curriculum materials, to develop lesson plans that serve as representations of imagined classroom practice. The curriculum planning phase is one in which the preservice teachers (subjects) work with curriculum materials in developing concrete instructional plans for science teaching (objects). This triadic relationship in which teachers' interactions with curriculum materials is mediated by their ideas and beliefs serves as the foundation for perspectives on the teacher-curriculum interactions. To understand the activity of curriculum design for inquiry, it is important to first conceptualize and investigate this fundamental relationship.

The three-part relationship between teachers, curriculum materials, and their teacher characteristics has been the emphasis of recent teacher-curriculum research and

has led to conceptual models of teacher-curriculum interactions (Brown, 2002, 2009; Remillard 2005). The degree to which teachers engage in design with curriculum materials can vary. Some teachers use curriculum materials in ways that closely mirror those intended by the curriculum developers. In this case, teachers *appropriate* existing curriculum materials (Remillard, 1999) and *offload* (Brown, 2002) much of the responsibility for pedagogical design to them. However, even when teachers believe that they are using curriculum materials as intended, they often enact them differently (Lloyd, 1999; Remillard & Bryans, 2004). Teachers more commonly interpret, critique, and adapt curriculum materials through a process of *invention* (Remillard, 1999) or *adaptation* and *improvisation* (Brown, 2002) rather than using them as extant artifacts.

I expand upon Brown’s (2002, 2009) and Remillard’s (2005) frameworks for teachers’ use of curriculum materials to conceptualize teachers’ curriculum design for inquiry as a three-dimensional model shown in Figure 2.4.

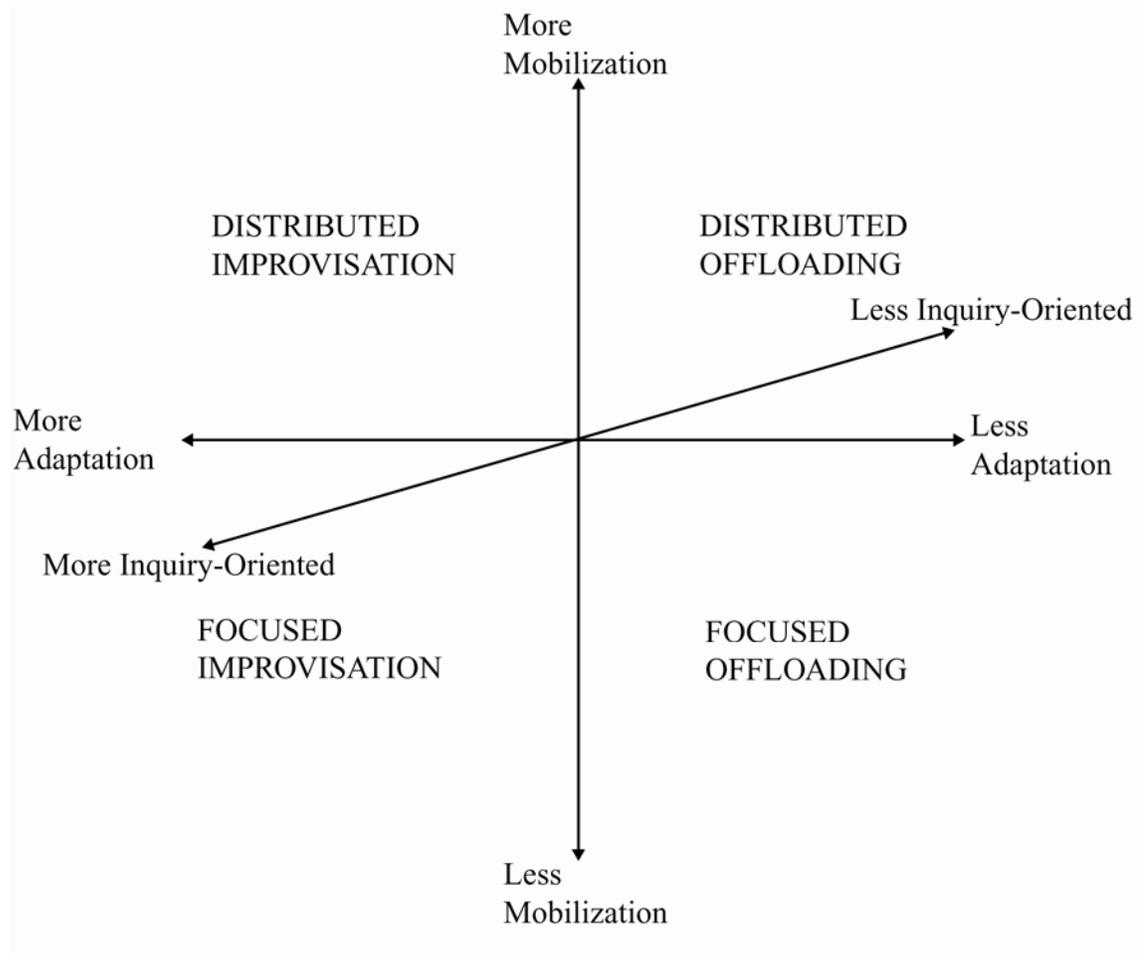


Figure 2.4. 3-Dimensional Model of Teachers' Curriculum Planning for Inquiry

While the triangle CHAT-based model (Figure 2.3) is effective at positioning actions and outcomes within the broader activity, it is limited in its ability to characterize actions and outcomes at a fine-grain level. This model in Figure 2.4, which allows for more focused study of actions and outcomes, draws upon Engeström's notion of 'working spheres' (2008), which highlight the object, strings of actions, and recurrent outcomes of a particular sub-process of activity. Such 'working spheres' have been proposed as an intermediate units between specific actions and the broader activity. In this case, focus is placed on the production triangle (sub-process) of curriculum planning where the object is the curriculum materials, actions are the mobilization and adaptation decisions preservice teachers make, and outcomes are how inquiry-based their lessons ultimately are. The purpose of the model in Figure 2.4 is to provide a more elaborate framework for understanding patterns in the preservice teachers' curriculum planning production (top triangle) that transcend specific actions but are not yet full representations of activity. This model also builds upon Engeström's (2008) 2-dimensional representation of working spheres by adding a third directly tied to the outcomes of interest, in this case how inquiry-based the preservice teachers' planned lessons are.

First, in their critique and adaptation of curriculum materials, teachers adapt curriculum materials in different ways and with varying frequencies. This dimension of the teacher-curriculum relationship can be viewed as a continuum that represents the degree of dependence or independence teachers maintain in relation to the curriculum materials they use. This dimension is illustrated by the horizontal axis of the model in Figure 2.4. Teachers who rely on existing curriculum materials 'as is' make fewer adaptations and exhibit a higher degree of curriculum dependence while teachers who actively modify existing curriculum materials exhibit a higher degree of curriculum independence. Even teachers who design science lessons 'from scratch' likely rely on some curricular resources, such as content resources or scientific representations, though they may not rely on existing lesson plans or representations of classroom practice. Much of the current research that has discussed this continuum has focused on teachers'

use of single set of curriculum materials and would therefore be represented by this dimension of the model in Figure 2.4.

However, second, there is another crucial dimension of the teacher-curriculum relationship. Teachers not only adapt curriculum materials, but also often mobilize a variety of different curricular resources. In the model in Figure 2.4, this dimension is represented by the vertical axis. At one end of this continuum is what has thus far been emphasized in teacher-curriculum research – situations in which teachers modify a single set of curriculum materials that was already available. The other end of this continuum involves more curriculum mobilization and represents situations in which teachers mobilize multiple curricular resources. In this way, we can account for the diversity and frequency of curriculum materials teachers use as well as the modifications they make to them.

By articulating these two dimensions of curriculum materials use, four broad patterns can be used to broadly characterize teachers' curriculum design efforts, represented by the four quadrants in Figure 2.4. For any instance in which teachers use curriculum materials to engage in instruction, the curriculum design process can be characterized as distributed or focused improvisation or offloading. Teachers who engage in *distributed improvisation* mobilize a wider variety of curriculum materials and actively adapt them. Teachers who engage in *distributed offloading* similarly use many different curricular resources but make fewer adaptations to them. Teachers who engage in *focused improvisation* use fewer curriculum materials but heavily modify and adapt those they do use. Finally, teachers who exhibit *focused offloading* use few curriculum materials and make few to no changes to them.

Finally, and perhaps most importantly, the curriculum design decisions that teachers make can be both productive and unproductive. Such local modifications may well reflect teachers' local, context-rich knowledge and therefore best reflect the needs of a particular class of students situated within a particular setting. Others may be benign or neutral (Pintó, 2004), having little if any overall impact. On the other hand, teachers may make changes to curriculum materials and/or enact them in ways that are less effective (Collopy, 2003; Remillard, 1999; Schneider, Krajcik, & Blumenfeld, 2005). Teachers'

adaptations can, for example, ‘demote’ the goals of curriculum developers (Pintó, 2004) and or not fully account for the needs of students.

Last, then, I include a third dimension to model in Figure 2.4 that characterizes the inquiry-orientation of the lesson plans developed through engagement in this curriculum design process. This third dimension provides a standard by which to assess how productive or unproductive teachers’ curriculum design decisions are in respect to inquiry-oriented science instruction, a fundamental emphasis of science education reform (AAAS, 1993; NRC, 1996, 2000). One goal of this study is to investigate relationships between patterns of preservice elementary teachers’ curriculum design for inquiry-oriented science teaching and the inquiry-orientations of the science lessons they construct.

Cultural mediation of the curriculum planning production sub-process. It is necessary to position the production working spheres from the uppermost triangle of curriculum planning described in the previous section within the broader activity. To return to the broader model in Figure 2.3, the curriculum planning production sub-process is mediated by structures and guidelines provided by the methods course (rules/norms), the preservice teachers’ peers, methods instructor, and cooperating teachers (community), as well as the inherent roles the preservice teachers and other associated community members fulfill (division of labor).

Object-activity of curriculum enactment. The instrument-producing activity represents the preservice teachers’ use of these instructional plans and associated science curriculum materials in elementary classrooms, where lesson plans developed in curriculum planning serve as crucial tools in teachers’ classroom teaching. The curriculum enactment phase represents the classroom-based activity system in which teachers (subjects) use curriculum materials (instruments) to construct shared problem-spaces (objects) with students (community). These interactions are influenced by classroom- and school-based regulations, as well as norms of professional teaching (rules/norms), cooperating teachers (community), and the ways in which the preservice teachers, cooperating teachers, and students actively negotiate their roles in classroom activity (division of labor).

Instrument-producing activity of the methods course. The third triangle in Figure 2.3 represents the elementary science methods course. An important goal of this study is to characterize the preservice teachers' espoused inquiry frameworks, how they instantiate their espoused inquiry frameworks in the science lesson plans they develop and enact, and how doing so contributes to ongoing refinement of their espoused inquiry frameworks. While the preservice teachers develop their espoused inquiry frameworks through science teaching practice, the treatment of inquiry-oriented science teaching and learning as a concept in the science methods course also contributes to the elaboration of the preservice teachers' inquiry models. Additionally, during the methods semester, the triangles for the methods course and curriculum planning triangles will be very similar, with the same rules, community members, and divisions of labor mediating how the preservice teachers learn about what inquiry-oriented science teaching is (instrument-producing activity) and translate their espoused inquiry frameworks into instructional plans for science teaching (central activity). As such, to again draw upon Engeström's model of interacting activity systems (Figure 2.2), the methods course must also be accounted for as a key instrument-producing activity in which they preservice teachers develop and refine their espoused inquiry frameworks during the fall semester.

The dimensions of these three interacting activity systems are summarized in Table 2.1.

Table 2.1

Summary of Dimensions of Curriculum Design and Enactment Activity Systems

	Methods course	Curriculum Planning	Curriculum Enactment
Subject	Espoused orientations, self-efficacy, and confidence	Espoused orientations, self-efficacy, and confidence	Espoused orientations, self-efficacy, and confidence
Instruments/Tools	Reform-based inquiry frameworks for engaging in curriculum design for inquiry-oriented science teaching	Espoused inquiry frameworks	Curriculum materials
Object	Espoused inquiry frameworks	Curriculum materials	Students
Rules/Norms	Structure of the methods course assignments, requirements for lesson plan formats, etc.	Structure of the methods course assignments, requirements for lesson plan formats, etc.	Professional norms, school- and classroom-based rules, etc.
Community	Methods instructors, cooperating teachers, other preservice teachers, field instructors, etc.	Methods instructors, cooperating teachers, other preservice teachers, field instructors, etc.	Cooperating teacher, other teachers and administrators, field instructors, etc.
Division of Labor	Roles of teachers in modifying curriculum materials, tensions between roles of preservice teachers, methods instructors, and other parties in curriculum design, etc.	Roles of teachers in modifying curriculum materials, tensions between roles of preservice teachers, methods instructors, and other parties in curriculum design, etc.	Negotiations between preservice teachers and cooperating teachers, role of students and teachers in inquiry-oriented practice, etc.

A key instructional goal for the methods semester is to support the preservice teachers in developing approaches to curriculum planning and enactment that are consistent with the model of inquiry-oriented science teaching promoted in the methods course. It is therefore important to be able to characterize the ways in which their curriculum planning (central activity) and curriculum enactment (object-activity) evolve over the course of the study as their espoused inquiry frameworks change. To do this, it

is necessary to also include representations of more culturally-advanced forms of curriculum planning and curriculum enactment in the model for preservice teachers' curriculum design for inquiry.

The preservice teachers' curriculum design activities involve the use of both symbolic and material tools to achieve sought-after objectives relevant to some focus of the activity. Of particular concern here are the preservice teachers' espoused inquiry frameworks and the science lesson plans they construct and enact. The development of their espoused inquiry frameworks is one major focus of the elementary science methods course. These conceptual inquiry frameworks, which are symbolic tools, are then put to use in curriculum planning and enactment which, in turn, further contribute to their development. However, cultural-historical activity theory is a materialist theory that assumes people use and transform tangible artifacts through their efforts. Here, science lesson plans are the physical tools of concern, as artifacts that preservice teachers develop and then use as tools to mediate their classroom teaching. Because these artifacts and tools are employed across activities and facilitate participation across community lines, they serve as 'boundary objects' (Lave & Wenger, 1991). Such boundary objects are those that teacher educators expect preservice teachers to learn about and transfer to classroom practice. As such, teacher educators serve as what Wenger (1998) describes as 'brokers' who fulfill challenging but significant roles in multiple communities of practice, partly through facilitating the construction of boundary objects. As brokers, the task of teacher educators is to support preservice teachers' learning to develop and enact science curriculum materials in effective ways.

Implications of CHAT for Research on Teaching

Cultural-historical activity theory holds great promise as a theoretical and analytical tool through which to study teaching and learning in formal settings. This is especially true for research on teacher learning (Grossman, Smagorinsky, & Valencia, 1999), which occurs across settings within various institutions over long periods of time. An activity-theoretical perspective facilitates analysis of practice with a focus on learning in and from practice. First, it highlights the importance of learning in context (Putnam & Borko, 2000). Teachers learn from classroom practice but these are not the only settings in which they go about their work. Especially in respect to preservice teachers, who

traverse multiple activity settings on their way to becoming full-time, practicing teachers, accounting for these unique settings in which learning occurs is essential. Such a perspective also prioritizes the importance of tools, whether curriculum materials or others, that teachers use to structure and guide practice. In this way, the CHAT model provides a mechanism through which to attend to both individuals and the contexts in which they learn and develop.

Summary

In this chapter, I have presented the existing research base and theoretical framework in which this study of preservice elementary teachers' curriculum design for inquiry is grounded. To engage in inquiry-oriented teaching practice, teachers need to learn to mobilize their espoused inquiry frameworks and science curriculum materials to design science learning environments that best support student learning. This is particularly true for preservice elementary teachers, who often articulate less well-defined conceptions of inquiry and exhibit less robust pedagogical design capacities for science teaching. However, to learn how to better support preservice teachers' learning and development of pedagogical design capacity for science, more research is needed, especially that which embedded in rich theoretical frameworks. Next, then, in Chapter 3, I present the research methods used in this study. In doing so, I describe the programmatic context of this research, the study design and its alignment with tenets of cultural-historical activity theory, and both quantitative and qualitative methods of data collection and analysis.

CHAPTER 3

RESEARCH METHODS

In Chapter 2, I presented the rationale for this study, the corpus of research upon which it is based, and the theoretical framework within which it is grounded. In Chapter 3, I present the objectives, design, and methodology of the study itself. First, I present my research questions. Second, I describe the instructional and programmatic context in which this study took place. Next I discuss the design of the study and how it is aligned with both my research questions and theoretical framework. Finally, I describe the data collected, how these data were analyzed, and how evidence from these data were used to address each of my research questions.

Research Questions

The primary question that drives this study is *how do preservice elementary teachers learn to engage in curriculum design for inquiry?* To address this question, I ask the following specific research questions:

4. Are preservice elementary teachers able to mobilize and adapt science curriculum materials to make them more inquiry-based?
 - a. What curriculum design decisions do preservice elementary teachers make?
 - b. Do their curriculum design decisions lead to more inquiry-oriented instructional artifacts?
5. Why do preservice elementary teachers mobilize and adapt science curriculum materials in ways that they do, particularly in light of their espoused inquiry frameworks?
 - a. What are their espoused inquiry frameworks?
 - b. What goals do they articulate for curriculum design for inquiry?
 - c. What contradictions (i.e., tensions) do they identify, both within and across curriculum design settings, in relation to their goals?

- d. How do they attempt to resolve these contradictions through their curriculum design decision-making in an effort to meet their goals?
6. How do preservice elementary teachers' espoused inquiry frameworks and curriculum design practices for inquiry change over time?

Instructional Context

This study took place during the 2007-2008 academic year and involved preservice teachers in two sections of the elementary science teaching methods course (EDUC 421) in the undergraduate elementary teacher education program at the University of Michigan. The four-term, cohort-based program of professional study is centered on strong academic preparation that leads to a B.A. degree in education, as well as recommendation for elementary teaching certification in the state. The undergraduate teacher education program is designed to promote the development of preservice teachers' pedagogical, subject-matter, and pedagogical content knowledge, and is aligned with foundational tenets of teacher education reform (e.g., INTASC, 1992; NCATE, 1987) and subject-specific standards documents (e.g., AAAS, 1993; NCSS, 1994; NCTM, 1991; NRC, 1996, 2000).

Students take a variety of discipline-specific courses from outside the School of Education in fulfillment of subject matter requirements for academic majors and minors. These courses are taken primarily in their first two years of university coursework prior to admission to the teacher education program. Upon admission to the School of Education, and during their first year in the undergraduate elementary teacher education program, preservice teachers take courses in educational psychology, foundations of education, literacy, an introductory course in elementary teaching, as well as a social studies teaching methods course. During the second year, coursework is composed of science and math teaching methods courses in the fall semester and a traditionally-structured, full-time, 14-15 week student-teaching experience during the winter semester. During each of the first three semesters of the program, preservice teachers spend at least six hours per week in K-6 classrooms under the tutelage of an experienced mentor teacher. By the conclusion of the program, students have generally had classroom placements in a variety of school settings. The goal of these experiences is to provide

substantial field-based experiences (in addition to student teaching) in a variety of unique school and classroom settings.

This research is focused on the fourth and final year of the teacher education program, specifically the elementary science teaching methods course (fall semester) and subsequent student teaching experience (winter semester). The science methods course builds on current research and practice to prepare preservice teachers to promote elementary school students' science learning. The course has historically been taught by Professor Elizabeth Davis, who has served as coordinator of the elementary science methods courses for several years, and a number of doctoral and/or postdoctoral students in science education. The methods instructors participate in weekly collaborative planning sessions and work closely to retain a degree of uniformity between sections that contributes to course and programs goals while leaving some flexibility for each instructor to address the needs of his or her particular cohort of students. In the Fall of 2007 there were the two instructors for the course, myself and another science education doctoral student. Both of us have been directly involved with the methods course each fall term since arriving at the University of Michigan in the fall of 2004. I taught a section of the course in the Fall of 2005 and have apprenticed in the course in the Fall of 2004 and 2006. We began collaborative planning for the course in April of 2007.

For the past four years, the science methods course itself has been designed around three explicit learning goals for the preservice teachers: developing an understanding of scientific inquiry and inquiry-oriented science teaching; learning to anticipate and address students' ideas, including their prior knowledge and alternative (non-scientific) ideas; and developing the ability to effectively critique and adapt science curriculum materials. For the Fall of 2007, these goals were reorganized. Overarching meta-goals for the course continued to emphasize inquiry-oriented science teaching and the use of science curriculum materials. However, we also employed a more specific set of criteria, loosely derived from the Project 2061 criteria for the evaluation of curriculum materials (Kesidou & Roseman, 2002), which were used to frame the scope and sequence of the methods course. These criteria are:

1. Learning goals alignment
2. Providing a sense of purpose

3. Eliciting and interpreting students' ideas
4. Engaging students in experiences with phenomena and representations
5. Promoting students' thinking about experiences and ideas
6. Assessing students' ideas
7. Supporting all students

These criteria were not only used in critiquing and adapting science curriculum materials over the course of the semester, but also in analyses of and discussions about examples of teaching practice and other activities in the methods course.

Through participation in the science methods course, preservice teachers develop familiarity with current science standards documents, such as the AAAS *Benchmarks* (1993), the *National Science Education Standards* (NRC, 1996), the *Michigan Curriculum Framework* (MDE, 1996), as well as numerous science curriculum programs. They prepare to teach inquiry-oriented lessons by engaging in investigations involving asking questions, making predictions, conducting experiments, collecting data, making observations, developing explanations, and communicating findings. They learn how to anticipate, identify, and address students' ideas in science, develop teaching skills by preparing an in-depth science investigation plan, build on existing curriculum materials gain experience in preparing, teaching, critiquing, and analytically reflecting on elementary school science lessons while working with elementary students in local schools. These experiences are designed to help preservice teachers become increasingly autonomous, reflective professionals as they move toward the student teaching semester.

Finally, in order to support preservice teachers' learning to engage in effective science teaching in the methods course, we rely heavily on the CASES online environment (Davis, Smithey, & Petish, 2004). CASES is an online resource that supports preservice and new elementary teachers while also serving as a vehicle for research on teachers' learning. CASES includes inquiry-oriented lesson and unit plans, science content background, information about students' alternative ideas in science, educative guidance aimed specifically at new teachers, an online journal, and an online discussion space. The curriculum materials provided on CASES are designed to be educative for teachers; that is, they are intended to promote not just student learning, but

also teacher learning (Davis & Krajcik, 2005). CASES has been used as a cornerstone of the elementary science methods course since 2001.

In the methods course, the preservice teachers learn about specific inquiry practices and draw upon their understanding of these practices to engage in various professional tasks. While various inquiry models and frameworks exist, the one emphasized in the methods course is that which is articulated in *Inquiry and the National Science Education Standards* (NRC, 2000). This framework includes five essential features of inquiry:

1. Learners are engaged by scientifically oriented questions.
2. Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions.
3. Learners formulate explanations from evidence to address scientifically oriented questions.
4. Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding.
5. Learners communicate and justify their proposed explanations.

As a complement these five essential features of inquiry, the preservice teachers were also introduced to three-part inquiry framework that serves to summarize and encapsulate these five essential features of inquiry for *Inquiry and the National Science Education Standards*. This second framework, which is explicit in the CASES online environment and curriculum materials as 'QEC', involves engaging students in scientifically oriented questions (Q), gathering evidence and producing explanations based from that evidence (E), and communicating their findings (C). While the five essential features of inquiry remained the emphasis in the majority of class discussions and assignments, the preservice teachers were encouraged to also articulate and use the QEC inquiry framework where helpful. As illustrated later in the findings, both inquiry frameworks played an important role in the preservice teachers' curriculum design for inquiry.

Participants

Between the two sections of the course, there were 50 preservice elementary teachers taking the science methods course in the fall of 2007. All were traditional

fourth-year seniors (about 21 years old) in their final year of college. At the beginning of the methods semester, each student was presented with an opportunity to either agree or not agree to participate in any research undertaken during the term. This was done online, in private, as part of registering to use CASES. For students who did not agree to participate in research, no artifacts produced by them were used as data for the study. This consent process determined how many preservice elementary teachers from the two sections of the methods course were included in the total study sample. In the Fall of 2007, all preservice teachers from my section of the course (section 1) agreed to participate in research. In the other section of the course (section 2), four of 28 preservice teachers chose not to participate. Data for this study are therefore drawn from 46 preservice teachers in two sections of the course ($n_1=22$, $n_2=24$). These 46 preservice teachers comprise the overall study population.

Characteristics of the Population

In a survey administered to the preservice teachers at the beginning of the semester, they responded to a number of demographic questions, as well as questions regarding their self-efficacy for science teaching, preferences, perceived qualifications, and abilities to engage in curriculum design in the context of elementary science teaching. The 46 preservice teachers in the study were primarily female (89%) and Caucasian, consistent with demographic trends for elementary teachers in the United States (National Center for Education Statistics, 2003). In the sections that follow, I present summary statistics that provide an overview of additional characteristics of the preservice teachers in the methods course.

Major and science courses. The majority of students reported being language arts majors (43.5%). Approximately 11% reported being science majors, 28% reported being mathematics majors, and 15% reported being social studies majors. A majority of teachers reported being mathematics minors (37%), though nearly 20% reported being science minors. 11%, 11%, and 15% reported being social studies, language arts, and fine arts minors, respectively. Cumulatively, just over one quarter of the preservice teachers (26%) were either science majors or minors. Additionally, the preservice teachers reported taking anywhere from 2 to 15 science courses in high school and college. While the mean number of science courses taken was 7 ($SD = 2.87$), nearly 60%

reporting taking 6 or fewer science courses. Not surprisingly, preservice teachers who were science majors or minors tended to report taking significantly more science classes than those who were not science majors or minors, $t(42) = -3.94, p < .001, d = 0.87$.

Feelings about science teaching. In the beginning of the semester survey, the preservice teachers were asked ‘how do you feel about science teaching?’ and responded using a 5-point Likert scale that ranged from ‘very confident’ to ‘very nervous’. Approximately one-third of the preservice teachers reported feeling ‘OK’ about science teaching while another third reported feeling ‘somewhat nervous’. Of the remaining third, 6.5%, 21.7%, and 4.3% reported feeling very nervous, pretty confident, and very confident, respectively. The preservice teachers’ reported feelings about science teaching did not differ by their status as science majors or minors $\chi^2(4, N = 45) = 5.8, p = .215$. Preservice teachers who were science majors/minors were equally as likely to report being nervous about science teaching as non-science majors/minors. However, there was a significant effect of the number of science courses they reported taking on their reported feelings about science teaching, $F(11, 31) = 2.28, p = .035, \omega^2 = 0.43$. The more science courses they reported having taken, the more confident they felt about teaching science.

Subjects preferred and feel qualified to teach. In the beginning of the semester survey, the preservice teachers were also asked ‘which subjects do you feel most qualified to teach?’ and ‘which subjects would you prefer to teach?’. Just over one-quarter (26.1%) reported feeling qualified to teach science while 34.8% reported preferring to teach science. The percentage of preservice teachers who reported preferring to teach science varied significantly by those who reported feeling qualified to teach science, $\chi^2(1, N = 46) = 30.44, p < .001$. Or, those who reported feeling qualified to teach science were more likely than those who did not to report preferring to teach science. The percentage of preservice teachers’ status as science majors or minors was strongly related to both their preference to teach science, $\chi^2(1, N = 46) = 16.30, p < .001$, and their perceived qualification to do so, $\chi^2(1, N = 45) = 19.55, p < .001$. Science majors/minors were much more likely to feel qualified and prefer to teach science than non-science majors/minors. Lastly, preservice teachers who had taken more science courses also reported feeling more qualified to teach science, $F(1, 41) = 27.73, p < .001$,

$\omega^2 = 0.62$, and more often reported preferring to do so, $F(28, 15) = 26.66, p < .001, \omega^2 = 0.57$.

Perceived ability to engage in curriculum design for elementary science. Finally, on the beginning of the semester survey, the teachers were asked to rate their ability to ‘adapt and design science curricula to meet the needs of your students’, again using a 5-point Likert response scale that ranged from ‘very good’ to ‘very poor’. Over half (56.5%) rated their ability as ‘good’ while only 10.9% rated their ability as ‘very good’. The remaining 29.5% described their abilities as ‘fair’ or ‘poor’. The preservice teachers’ perceived abilities to engage in curriculum design for science teaching were not significantly related to their status as science majors and minors, $\chi^2(3, N = 44) = 1.84, p = .61$, the reported number of science classes, $F(11, 30) = 5.91, p = 0.56, \omega^2 = 0.13$, their feelings about science teaching, $\chi^2(12, N = 44) = 15.74, p = .20$, their perceived qualification to teach science, $\chi^2(3, N = 44) = 4.40, p = .221$, or their preference for teaching science, $\chi^2(12, N = 44) = 2.83, p = .419$.

Selection of Focal Group

Early in the methods course semester, I identified seven preservice teachers from my section of the methods course and invited them to participate in a more in-depth study centered around their science teaching both during the methods semester and the subsequent student teaching semester. These seven preservice teachers were to comprise the focal group of study for the qualitative portion of the study.

Determining which individuals I approached about participating depended on numerous factors. First, it was important to identify prospective participants with whom I had established a positive relationship and perceive to be authentically motivated by the potential for professional development inherent to this activity and possess a reasonably reflective disposition towards teaching. More specifically to the topic of this research, I sought to work with preservice teachers who held varying perspectives towards science teaching and the use of curriculum materials. I hoped to capture differences in their professional contexts by studying preservice teachers whose schools varied in terms of their community placement, student populations, emphasis on science teaching, and available materials with which to teach science. This sampling approach represents a balance between maximum-variation sampling and typical-case sampling (Patton, 2001),

or between the selection of highly variant participants and those who are more representative of the population as a whole. This plan followed a similar selection approach I undertook in research on preservice elementary teachers' development of curricular role identity in the elementary science teaching methods course (Forbes & Davis, 2008).

All seven preservice teachers I originally invited to participate in the research agreed to do so. Approximately one month into the semester, I asked one preservice teacher to end her participation in the study due to concerns about her academic performance in the course. Full data was collected from the other six preservice teachers during the fall semester. During the winter semester when the preservice teachers were student-teaching full-time, two additional preservice teachers chose to drop out of the study. One was no longer teaching science in her placement classroom. The other felt as though she was overwhelmed professionally and needed to focus on her classroom responsibilities. The data for the qualitative portion of this study is therefore drawn from four preservice elementary teachers followed over the course of the 2007-2008 academic year.

Preservice Teacher Profiles

Before turning to a description of my data collection and analyses, I first provide descriptive profiles of each of the four preservice teachers in the focal group. These four preservice teachers were placed in different elementary schools in different grade levels, used unique science curriculum materials, and were subject to unique, setting-specific affordances and constraints. The preservice teachers also varied in terms of their past experiences with science and general interest in science and science teaching. In the sections that follow, I describe and provide relevant background information for each preservice teacher.

Kelly. Kelly was a Caucasian female preservice teacher from a middle-class community in the state. Overall, Kelly was positively inclined toward science teaching. She noted that “everything has some sort of an explanation behind it and I have always enjoyed learning about those explanations” (Journal 9/4). Kelly described a memorable science teacher she had had as a student, saying,

...my AP biology teacher...he was one of the greatest teachers ever...he was so excited and exuberant and off the wall and like related new news in the science field and how that related to what we were learning and how like the newest findings from scientists today, and did show science is related to every other subject. How it's all interconnected. You could tell...this was stuff he was really interested in, just wanted to share it with us. He was just really excited about science and that's what I remember why he was a good teacher. (FI1)

Though she wrote that "science has always been one of my favorite subjects", she also acknowledged that "I like some science subjects more than others" (Journal 9/4). Kelly wrote that "teaching science as inquiry is important" and that "inquiry-based science matches well with my definition of effective science teaching" (Journal 9/10). Prior to taking the science methods course, Kelly had not yet had an opportunity to teach science.

During the study, Kelly was placed in a fourth-grade classroom at an elementary school within the university community. However, the elementary teacher who formally served as her mentor teacher did not teach science. Rather, the fourth-grade teachers at this school distributed the teaching of science where certain teachers who served as science teaching specialists. As such, Kelly went to another fourth-grade teacher's classroom during the methods semester in order to teach science. Later, during student teaching, Kelly actually became the unofficial fourth-grade science teacher and was responsible for teaching science to three different classes in her mentor teachers' classroom. As such, she had the opportunity to teach the same science lesson three times each during her student teaching semester.

The school in which Kelly was placed had recently adopted new science curriculum materials from a major commercial publisher. The year in which the study took place was the first in which these science curriculum materials had been used by the teachers at this elementary school. Kelly drew upon these new science curriculum materials exclusively to plan and enact her science lessons throughout the year. The scope and sequence of the new science curriculum involved returning to the same unit repeatedly throughout the year. As a result, each of the four science lessons Kelly taught during the study was from a unit on decomposition. All but her first lesson were heavily investigation-based, involving either setting up or making sense of data from experiments involving fungi. Kelly expressed satisfaction with the curriculum materials, saying "it's a great curriculum" (FI2).

Lauren. Lauren was a Caucasian female preservice teacher from a relatively affluent, upper-middle-class community near a major metropolitan area in the state. Lauren had actually begun her teacher education at another university but transferred back to the university in which this study took place. Lauren said that while “I used to love science when I was younger” (F11), she also wrote that since then, “my attitude towards science has generally been negative” (Journal 9/4). She described multiple science courses in high school and college that were negative experiences for her, saying, “I got to high school and I had the same teacher for honors bio and honors chem. and she was the worst. Like she made it so intimidating, and nothing was fun, like nothing was exciting, and since then I would really have such negative connotations to science and science classes. I hated bio. and chem. in college too because of it. And that really actually realized how big of a role a teacher can play in affecting whether or not a student likes or dislikes a certain subject” (F11). Lauren acknowledged that her goal for the year was “to become more enthusiastic about science” (Journal 9/4). She also indicated her interest in teaching science as inquiry, writing “inquiry-based science teaching is crucial” (Journal 9/11). As with Kelly, Lauren had not taught science prior to taking the science methods course.

During the study, Lauren was placed in a third-grade classroom at an elementary school within the university community. The students in Lauren’s placement classroom were more diverse than those in the other three preservice teachers’ classes. Her class included recent immigrants of African, Middle-Eastern, and Asian descent and at least four languages in addition to English were spoken in the classroom. Lauren’s mentor teacher was a self-described science enthusiast with many years of teaching experience. During the methods semester, another preservice teacher from another teacher education program was completing her student teaching in Lauren’s placement classroom.

As in the case of Kelly, the teachers at the school in which Lauren was placed had just begun using brand new science curriculum materials from a major commercial publisher. Lauren used these curriculum materials throughout the year to engage in curriculum design for inquiry. During the methods semester, Lauren taught a lesson on habitats and another on the moon. During student teaching, she taught two lessons from a light unit. Coincidentally, the first three lessons Lauren taught were introductory

lessons from the beginning of their respective units, which became an obstacle for Lauren in her attempt to engage in curriculum design for inquiry. None of Lauren's lessons involved more traditional experiments or investigations. Lauren expressed increasing dissatisfaction with the structure and organization of the new science curriculum over the course of the year.

Mike. Mike was a Caucasian male preservice teacher from a working-class community in a nearby state. More so than the other three preservice teachers, Mike self-identified as a scientist and science enthusiast. He noted that "I personally find science very interesting [and] enjoy exploring how things work" (Journal 1, 9/4). Throughout the study, Mike referenced his strong subject-matter preparation and grasp of epistemologies underlying scientific practice. This ultimately translated to Mike's perspective on effective science teaching, about which he wrote "I think teaching science as inquiry is very important" (Concluding Journal 12/04). As with Kelly and Lauren, Mike had not had an opportunity to teach science prior to the science methods course.

During the study, Mike was placed in two different elementary classrooms. During the methods semester, he worked in a third-grade classroom in an elementary school within the university community. However, Mike's mentor teacher took an extended leave of absence, leaving Mike with a long-term substitute teacher. While this situation did afford Mike many more opportunities to teach science, he also received little in the way of mentorship and support, ultimately prompting his decision to switch placement classrooms between the methods and student teaching semesters. During student teaching, he was placed in second-grade classroom in an elementary school in a nearby suburban community. His second mentor teacher was highly experienced, though not particularly interested in science and science teaching.

As with Kelly and Lauren, Mike used brand new science curriculum materials from a major commercial publisher in his first placement. These were the same as were used by Lauren, though Mike taught different lessons than did she. Mike's first two lessons were from a unit on habitats. During student teaching, Mike used different kit-based science curriculum materials at his new placement school, which he reported being effective. His third lesson was from a unit on plants while his fourth was from an astronomy unit. Unlike Kelly, and like Lauren, none of Mike's lessons involved

traditional experiments. However, two of them did involve modeling investigations that gave students explicit opportunities to engage in inquiry practices.

Aliza. Aliza was a Caucasian female preservice teacher from a relatively affluent, upper-middle-class community near a major metropolitan area in the state. Lauren noted that she “really liked science” and that science “is vital for students to learn” (Journal 9/4). Aliza noted said that “I think I had some really great science teachers when I was little” and had experiences as a student of science that influenced her orientations toward science as a teacher. She said, “the elementary school that I went to there was a lot of focus on, ok, if you’re doing a science experiment, you have to know what it is that you’re trying to find and have a hypothesis, and design the experiments with steps, and know your materials, and all this. And I guess just the way that I think about science” (FI2). Aliza’s orientations toward science and science teaching were also significantly influenced by a job she held as an undergraduate lab assistant in a plant lab on campus. This was particularly the case in regard to elements of inquiry, which she had first-hand opportunities to witness in context of authentic scientific practice. Aliza had a strong grasp of inquiry as a model of science instruction from the beginning of the year and noted that “I do think teaching science as inquiry is important” (Journal 10/2).

During the study, Aliza was placed in a 4th-grade classroom at an elementary school within the university community. Lauren’s mentor teacher was highly experienced and, while not a strong science enthusiast, was supportive of Aliza’s science teaching. Aliza developed a strong relationship with her mentor teacher over the year and valued her feedback and guidance highly. During the methods semester, another preservice teacher from another teacher education program was completing her student teaching in Aliza’s placement classroom, similar to Lauren.

As with the other preservice teachers, Aliza used brand new science curriculum materials from a major commercial publisher in her classroom placement. During the methods semester, Aliza taught two science lessons from the same unit on decomposition from which Kelly taught her first two lessons. These were both more traditional experiments involving plant growth. However, during the student teaching semester, Aliza taught an entire unit on rocks and minerals. This unit was not from the new curriculum but rather from an existing, district-developed science curriculum that was

being enacted in fourth grade for the last time before being moved to 3rd-grade the following year. Aliza's two lessons during student teaching were less investigation-based than those she taught during the methods semester, particularly her fourth lesson.

Data Collection

This mixed-methods study involves two interrelated components. The first is a quantitative analysis of preservice elementary teachers' use of science curriculum materials in curriculum design for inquiry. This involves data collected from preservice elementary teachers in both sections of the elementary science teaching methods course (n=46). The second component is an in-depth case study of four preservice teachers. This qualitative component of the study allows for a more substantive analysis of these preservice teachers' learning to use curriculum materials and, because it spans the methods semester and subsequent student-teaching semester, allowing for analyses over time and across contexts. The mixed-methods approach I employ here is consistent with methods employed in previous research on science curriculum development and implementation (Fishman et al., 2003; McNeill, Lizotte, Krajcik, & Marx, 2006; Schneider, Krajcik, Marx, & Soloway, 2001; Seethaler & Linn, 2004; Songer, Lee, & Kam, 2002; White & Frederiksen, 1998; Williams, Linn, Ammon, & Gearhart, 2004; Williams & Linn, 2002).

In this section I describe the data I collected and how they were used. I first present an overview of my data collection, and then discuss each data source in detail, including its purpose, format, ways in which it was used, and relative strengths and weakness. Finally, I provide the timeline for data collection.

Overview of Data Collection

Knowledge construction and learning involves both doing and representing (Engeström, 1987; Latour, 1999; Wenger, 1998). Since education research is itself a form of knowledge construction, I draw on a wide variety of data sources to characterize teachers' *practices* and how they *reify* what they know and have learned. I collected data from a variety of sources associated with the preservice teachers' use of science curriculum materials, including self-report, observational, and subject-produced artifacts. An overview of data sources and their purpose in this study is presented in Table 3.1.

Table 3.1
Overview of Data Sources

	Data Sources	Description	Purpose
Artifacts	Reflective teaching assignments and lesson plans (LP)	Lesson plans, curriculum materials, reflections, and associated artifacts used in the reflective teaching assignments	To assess how preservice teachers modify existing curriculum materials to develop science lessons
	Journal Entries (J)	Journal entries in the methods course focused on preservice teachers' ideas about and orientations toward inquiry-oriented science teaching and science curriculum materials	To assess preservice teachers' ideas about and orientations toward inquiry-oriented science teaching and science curriculum materials
	Other artifacts from methods course (OA)	Additional artifacts, such as online discussion threads, other journal entries, and other course assignments collected during the fall semester.	Provide additional data, where relevant, to inform description of preservice teachers' use of science curriculum materials over time.
Interviews	Formal Interviews (FI)	Formal interviews emphasizing preservice teachers' ideas about and orientations toward inquiry-oriented science teaching and science curriculum materials	Administered at the beginning and end of each semester to assess preservice teachers' ideas about and orientations toward inquiry-oriented science teaching and science curriculum materials
	Planning Interviews (PI)	Interviews focused around pre- and post-enactment planning of science lessons and emphasizing planning decisions and rationales for those decisions.	Before and after each enacted science lesson to explicitly link curriculum design decisions to their underlying rationales.
	Observational Data (O)	Observations of preservice teachers' enacted science lessons (4 lessons each)	Assess preservice teachers' enactment of science lessons and degree of similarity between planned and enacted lessons
	Planning Discussions (PD)	Collaborative instructional planning with peers during the methods course	Before and after each enacted reflective teaching assignment science lesson during the methods course. Data to illustrate how preservice teachers articulate and justify curriculum design decisions.
	Survey (S)	CASES survey completed by preservice teachers at the beginning of the semester.	To provide broad measures of preservice teachers' major/minors and education, as well as self-efficacy and orientations toward science teaching

In Table 3.1, those data used in the portion of the study involving the whole group of preservice teachers (n=46) are shaded. For the case studies of the four preservice teachers, all data sources were used.

I next discuss each of my data sources in detail, including their purpose, format, use, and strengths and weaknesses.

Reflective Teaching Assignments and Lesson Plans

Purpose. During the methods semester, the preservice teachers were asked to plan and develop, teach, and reflect upon two science lessons. These assignments, called *reflective teaching assignments*, are the two most substantial tasks in which the preservice teachers engage in the methods course. From an instructional standpoint, the purpose of the reflective teaching assignments is to afford the preservice teachers an opportunity to gain experience planning, enacting, and reflecting upon inquiry-oriented science teaching using a variety of science curriculum materials. Specifically, the preservice teachers are asked to take an existing science lesson or set of science curriculum materials, critique them, modify them to develop an inquiry-oriented lesson, enact this lesson in their placement classrooms, and reflect on their teaching. In completion of this assignment, the teachers submit the following artifacts: the original science lesson and/or curriculum materials they used, the lesson plan and lesson rationale they develop, a reflective journal through CASES, and a small sample of student work. For this study, the reflective teaching assignments not only provide a representation of classroom practice, but also, through the lesson plan rationales, evidence for their justification for particular instructional decisions related to inquiry.

Format and questions. The formats for the lesson plan, lesson plan rationale, and post-enactment reflective journal are included in Appendices A-C. The lesson plan format is designed to be consistent with those the preservice teachers have used in other methods courses in the undergraduate elementary teacher education program. The lesson plan rationale consists of a number of scaffolds designed to support the preservice teachers in articulating their decision-making related to the mobilization and modification of science curriculum materials for inquiry. The post-enactment reflection similarly provides a number of prompts that are designed to support them to revisit these decisions based on their experience enacting the lesson. During the student teaching semester, the lesson plans the preservice teachers developed varied in substance and organization.

Use and procedure. Each preservice teacher completed two reflective teaching assignments for the science methods course. While intended to be enacted in their

placement classrooms, many of the activities scheduled for the methods course directly contributed to the development of these instructional plans and post-enactment knowledge construction. Artifacts produced through the reflective teaching assignments are the data source I used to make claims about the whole group of preservice teachers in both sections of the course. For the focal group of teachers, and in addition to the variety of other data sources described below, I used these artifacts to characterize their use of curriculum materials during the fall semester. As they transitioned to student teaching during the winter semester, the lesson plans they produced evolved. However, they did continue to develop lesson plan rationales to accompany their lesson plans. I asked teachers from the focal group to continue to provide me with science lesson plans they developed during student teaching.

Strengths and weaknesses. The greatest strength of the artifacts associated with the reflective teaching assignments is that they allow for descriptive analyses of curriculum design processes in which the preservice teachers engage for authentic classroom teaching and an opportunity for the preservice teachers to provide justifications for their curriculum design decisions. Drawing on reflective teaching artifacts from preservice teachers in both sections of the course also provides a sufficient population size from which to perform quantitative analyses. One limitation to these artifacts is that it is not feasible to also include prompts that encourage them to discuss their ideas about and orientations toward inquiry and science curriculum materials in an abstract sense separate from the curriculum design task at hand. These data sources are therefore not sufficiently able to capture relevant ‘teacher characteristics’ but only to infer what their inquiry models are, to the degree possible, from their mobilization of their espoused inquiry frameworks to justify design decisions. Second, it was not logistically possible to observe 90+ lessons the preservice teachers enacted during the methods semester. I therefore had to rely on self-report for information about what actually happened during lesson enactment for the whole group of preservice teachers.

Journal Entries

Purpose. From an instructional standpoint, the purpose of the journal entries was to provide the preservice teachers an opportunity to articulate their ideas about inquiry and the use of science curriculum materials, two of the primary emphases of the methods

course. From a research standpoint, the purpose of these journal entries was to provide evidence for broad trends the preservice teachers' thinking about inquiry-oriented science teaching, the use of science curriculum materials, and the use of the former to inform the latter.

Format and questions. The journal assignment is provided in Appendix D. These journal entries are scaffolded reflections in which the preservice teachers were asked a general question and then provided a number of specific prompts to scaffold their reflective writing. They were provided hard copies of the journal assignment in class and submitted them online through the CASES website. They completed the same journal assignment at the beginning and at the end of the methods semester.

Use and procedure. In the methods course students discussed inquiry-oriented science teaching, viewing examples of inquiry-oriented practice, and compared inquiry to other instructional strategies. They also critiqued existing lessons using particular instructional criteria. The first journal assignment was used as a means through which the preservice teachers could reflect on inquiry and the use of science curriculum materials between an initial introduction to these two ideas and activities and a more thorough, ongoing treatment of them during the semester. They completed the second journal entry prior to their last class meeting.

Strengths and weaknesses. The two primary strengths of the journal entries are a) the preservice teachers responded to questions directly related to the research questions I ask and b) comparing the two journal entries over the course of the semester afforded me the opportunity to characterize change over time. The primary weakness is the grain size or level of depth at which I was able to characterize the preservice teachers' models of inquiry through this data source. Any instrument designed to assess teachers' extant models or frameworks related to a particular construct could be very in-depth. Here, I was limited in the degree to which I could assess the whole group of preservice teachers' inquiry models by the scope of my study and the need for these journal entries to also serve an important instructional purpose. For the focal group of preservice teachers, I characterize their inquiry models in more substantive ways using additional data sources.

Other artifacts

Purpose. Throughout the methods semester, the preservice teachers completed a number of course assignments in addition to those described already, including a series of lesson critiques, reflective journal entries on their own experiences as science learners, hypothetical narrative images of inquiry embedded in CASES curriculum materials, and descriptions of their placement classroom context, as well as online discussion threads. For the preservice teachers in the focal group, these artifacts served as additional data sources where relevant. They were not designed to explicitly support this research but nonetheless yielded insight into the teachers' thinking and practice related to the use of curriculum materials for inquiry.

Format and use. The course assignments were completed by the preservice teachers at points throughout the semester and varied in format. For the sake of brevity, I have not included all the additional course assignments in the appendices. Each assigned task was unique and therefore possessed different strengths and weaknesses. For the focal group of preservice teachers, these course assignments were used as secondary data sources to further inform analyses on primary data sources, such as interviews and lesson-specific artifacts.

Interviews

Purpose. Interviews were conducted with the focal group of teachers during the fall and winter semesters. These interviews allowed me to ask specific questions regarding the preservice teachers' inquiry models, as well as how they employed their inquiry models in specific stages of curriculum design for inquiry.

Format and questions. I conducted a series of semi-structured interviews (Patton, 2001) with each of the focal group preservice teachers over the course of the fall and winter semesters. I used two specific types of interviews, protocols for which are included in Appendices E and F. The first, the formal interview, was primarily designed to assess and characterize the preservice teachers' espoused inquiry frameworks. The second, the planning interview, was conducted prior to and following the enactment of their reflective teaching assignment lessons during the methods semester and two science lessons during their student teaching semester. The planning interviews focused primarily on how teachers translated their inquiry models into teaching practice through

their curriculum planning and enactment and how, in turn, lesson enactment contributed to the evolution of the preservice teachers' inquiry models.

Use and procedure. I conducted three formal interviews with the preservice teachers over the course of the year: at the beginning of the methods semester, at the end of the methods semester, and again at the end of the student-teaching semester. I also conducted pre- and post-planning interviews with each of them around each of the science lessons. Since they developed and taught two science lessons during the methods semester (their two reflective teaching assignments) and two science lessons during student teaching, I did four pre-planning and four post-planning interviews each with each teacher over the course of the study. The formal interviews and planning interviews took place either on campus, at the preservice teachers' placement schools, or over the phone. All interviews were audiorecorded and transcribed.

Strengths and weaknesses. The main strength of the interviews is that they allowed me to explicitly ask the preservice teachers particular questions, their answers to which directly informed my research questions. Second, the two types of interviews and protocols were designed to assess their inquiry models in the abstract (formal interviews) as tied directly to curriculum design in which they were employed as tools (planning interviews). The main weakness of the interviews is that they were self-report and, at least in the case of the formal interviews, administered somewhat less frequently than would have been preferred to capture subtle shifts in the preservice teachers' espoused inquiry frameworks.

Observations

Purpose. For each preservice teacher in the focal group, I observed their two enacted reflective teaching lessons during the methods semester and two enacted science lessons during the student teaching semester. The purpose of these observations was to, first, provide evidence of how the enacted lesson compared to the planned lesson and, second, to provide observational data with which to triangulate evidence from other data sources.

Format and questions. The observation protocol is included in Appendix G. While informed by existing observation protocols for science teaching (Luft, 1999), I designed it specifically to serve my own needs in this study. The observation protocol is

designed primarily to capture ways in which the preservice teachers' enacted lessons differed from their planned lessons, particularly in respect to additional curriculum materials that are used or not used and real-time, in situ adaptations the preservice teachers made to their lesson during enactment.

Use and procedure. In using the protocol, I asked each of the preservice teachers to send me electronic copies of their lesson plan prior to teaching it. I incorporated their lesson plan into the observation protocols in the left-hand column. During the observed lesson, I recorded fieldnotes, paying close attention to the parts of the lesson plan that are enacted differently than planned.

Strengths and weaknesses. The main strength of the observations is the opportunity they afford me to characterize the enactment stage of the preservice teachers' curriculum design for inquiry. They are descriptive in nature, in that they allow me to more aptly characterize, first, the degree of similarity between the preservice teachers' planned and enacted lessons, as well as the ability to note specific changes, and, second, characterize what is actually happening in the classroom as the enacted lesson progresses. In this same sense, the primary weakness of the observations is that they do not, by themselves, provide any evidence as to why events in the classroom unfold as they do.

Planning Discussions

Purpose. As part of reflective teaching assignments during the methods semester, the preservice teachers had an opportunity to co-plan and debrief their enacted lessons in class with groups of their peers. From an instructional standpoint, this activity served an important community-oriented function in that the preservice teachers were given an opportunity to articulate their rationales for curriculum design decision-making, hear their peers' rationales, and engage in substantive discussions about their curriculum design decisions. For purposes of research they served a similar function as the lesson plan rationales and interviews but provide evidence of principled curriculum design decision-making in a discursive context unlike the other data sources.

Format and questions. The assignments and scaffolds used in the methods course to guide and support co-planning and debriefing discussions are included in Appendix H. In co-planning, each preservice teacher was given an opportunity to discuss his or her lesson, including the curriculum materials used and adaptations made. A primary

function of these co-planning sessions was to prompt the preservice teachers to translate criterion-based decision-making into rationales for how such decisions contribute to making their lesson more or lesson inquiry-oriented. The debriefing sessions were similarly structured, but emphasized additional hypothetical changes to the lessons based on the preservice teachers' experiences enacting them.

Use and procedure. For co-planning, the preservice teachers completed, as homework, a critique of the lesson plans the use to develop their reflective teaching lessons. Their completed homework was used to scaffold co-planning discussions in class. In general, they discussed strengths and weaknesses of the lesson, the criteria by which they support their claims, and potential changes they will make in their modified lesson. Following enactment, discussions focused on these changes, how the lesson played out, and their rationales for additional modifications they would make to their lessons. In my class, the focal preservice teachers were placed in co-planning and debriefing groups together. These discussions, which occurred before and after both reflective teaching assignments, were audiorecorded.

Strengths and weaknesses. The main affordance of this activity and the data it yields is the evidence it provides through discursive, community-based interactions. Again here, as with other data sources, the preservice teachers are asked to articulate their rationales for curriculum design decisions for inquiry-oriented science teaching. By itself, this data source is insufficient as evidence for what decisions they actually make to the lesson that is enacted. However, it provides insight into why they make particular decisions and how they negotiate these decisions with their peers.

CASES Survey

Purpose. As described earlier in this chapter, at the beginning of the semester preservice teachers in the elementary science teaching methods course were asked to complete a survey on the CASES website. This survey has been used for the past seven years since CASES was developed and began being used in the methods course. Results from this survey instrument are used to continually refine the course to best meet the needs of preservice teachers in the undergraduate elementary teacher education program. Here, in this research, it provides measures of particular teacher characteristics of interest.

Format and questions. The survey is available online to registered users of the CASES online environment. The survey itself is substantial and consists of a wide variety of questions. These include background and demographic information, measures of self-efficacy and preferences for teaching and curriculum materials' use, as well as technology use.

Use and procedure. In this study, selected items from the survey were subjected to quantitative analyses in order to provide a more thorough description of the population. In general, these include are broad measures of preservice teachers' preferences and self-efficacy for science teaching, perceived ability to modify and adapt curriculum materials, as well as reported major/minor and number of science courses taken in secondary and post-secondary education.

Strengths and weaknesses. As with all self-report measures, there is no way to provide corroborating evidence for the preservice teachers' responses to survey items. This is particularly true for the preservice teachers' reported status as science major/minors within the teacher education program and how many science courses they've taken over the years. However, many of the other items of interest are measures of personal characteristics, such as self-efficacy, for which self-report measures are appropriate.

Timeline

I collected data during the fall and winter semesters of the 2007-2008 academic year, first in the elementary science teaching methods course and later during the student teaching semester. The data sources were previously outlined in Table 3.1. A summary of my data collection schedule is presented in Table 3.2 below. This table is organized around data sources and the discrete occurrences of science teaching over the methods and student teaching semester.

Table 3.2
Data Collection Schedule

	Fall Semester				Winter Semester				
	Sept	Oct	Nov	Dec	Jan	March	April	May	
Lesson Plans	RT1		RT2		Lessons 3 and 4 (timing varied)				
Interviews	FI1	PI	PI, PI	PI	FI2	PI	PI, PI	PI	FI3
Observations	x		x		Observed lessons 3 and 4				
Journals	Ongoing				Ongoing				
Survey	x								
Other Artifacts	Ongoing				Ongoing				

Note. Data collected for the whole group of preservice teachers is shaded. See Table 3.1 for descriptions of data sources.

Data collection was largely organized around the discrete occurrences of science teaching over the methods and student teaching semester. The four preservice teachers in the focal group planned and enacted four science lessons during the year – two in the methods course for their reflective teaching assignments (RT1 and RT2) and two during the student teaching semester of their own choosing (Lesson 3 and Lesson 4). The two reflective teaching assignments in the fall occurred in October and November. The timing of the two science lessons during student teaching varied depending on when the preservice teachers were teaching science. For each of these lessons, they completed a pre- and post-enactment interview (Pre-Enact [1, 2, 3, or 4] and Post-Enact [1, 2, 3, or 4]), as well as a lesson plan rationale, and submit lesson plans and instructional artifacts. I also observed each of their enacted lessons (Lesson [1, 2, 3, or 4] Enactment).

Additionally, the preservice teachers participated in three formal interviews over the course of the year: one at the beginning of the methods semester (FI1, September), one between the end of the methods semester and beginning of student teaching (FI2, December-January), and one at the end of the year (FI3, May). They also completed the survey at the beginning of the methods semester (September). Finally, throughout the year, they produced journal entries (Journal, [date]) and other artifacts.

Data Analysis

In this section I discuss how the data I collected was coded and analyzed. First, I provide an overview of analytical methods I employed and which data sources are used to address specific research questions. Next, I discuss how both quantitative and qualitative

methods are employed to analyze specific data to answer specific research questions. Finally, I discuss how I employed these analytical methods for each data source.

Overview of Data Analysis

Since this is a mixed-methods study, I employed both quantitative and qualitative analyses. I performed quantitative analyses on lesson plans and associated artifacts produced for the reflective teaching assignments by the whole group of preservice in the two sections of the course. This data was used to characterize the types and number of science curriculum materials the preservice teachers used and adaptations they made to their science lessons, as well as the inquiry-orientation of the lessons they developed.

Data collected from the focal group of preservice teachers was similarly coded to, more generally, map their curriculum design for inquiry over time and across contexts. The goal of this more in-depth study of the focal preservice teachers was to provide a richer, more substantive account of how they engaged in curriculum design for inquiry, how this process evolved, and, most importantly, why they made the design decisions that they did. I used data sources that were also used in the quantitative analyses of the whole group of teachers but, in addition, I used a substantial set of interviews, additional artifacts from the methods semester, and observations of their lesson enactments. I analyzed these data thematically for content in an effort to draw out, substantiate, and articulate relevant themes. I first turn to my quantitative analyses.

Quantitative Analyses

Quantitative analysis for this study involved lesson plans and other instructional artifacts from preservice teachers in both sections of the elementary science methods course (n=46). These lesson plans and instructional artifacts were from the two reflective teaching assignments completed by the preservice teachers over the course of the semester. The purpose of the quantitative analyses was to characterize the types and frequencies of curriculum materials the preservice teachers use, the types and frequencies of adaptations the preservice teachers make, and how inquiry-oriented their initial and revised science lesson plans are. Quantitative findings provide an aggregate background against and within which to situate the qualitative analyses of data from the focal group of preservice teachers.

Quantitative data coding. Three coding keys or rubrics were developed for this component of the study. To characterize the types and frequencies of science curriculum materials the preservice teachers used, I employed the coding key in Table 3.3.

Table 3.3
Coding Key for Types of Curriculum Materials

Type of Curriculum Materials	Description
Existing lesson plan (LP)	Preservice teacher uses an existing lesson plan to develop the science lesson he or she enacts.
Stand-alone investigation, experiment, or activity (AIE)	Preservice teacher uses stand-alone investigation, experiment, or activity to develop the science lesson he or she enacts.
Textbook (T)	Preservice teacher uses a textbook to develop the science lesson he or she enacts.
Content resource (science background information) (CR)	Preservice teacher uses a content resource to develop the science lesson he or she enacts.
Video/DVD (VD)	Preservice teacher uses video to DVC to develop the science lesson he or she enacts.
Models, graphs, or images (MGI)	Preservice teacher uses a separate model, graph, or image to develop the science lesson he or she enacts.
Trade book (story) (TB)	Preservice teacher uses a trade book to develop the science lesson he or she enacts.
Computer software (CS)	Preservice teacher uses computer software to develop the science lesson he or she enacts.
Student worksheet (SW)	Preservice teacher uses a student worksheet to develop the science lesson he or she enacts.
Other (O)	Preservice teacher uses a curricular resource not captured in the other categories to develop the science lesson he or she enacts.

To characterize the types and frequencies of changes preservice teachers make to these curriculum materials, I employed the coding key in Table 3.4.

Table 3.4
Coding Key for Types of Adaptations to Curriculum Materials

Types of Changes	Description
Insertions (Ins)	Adds a new element to the lesson plan
Deletions (Del)	Deletes an element of the existing lesson plan
Substitutions (Sub)	Substitutes a new element for an existing element of a lesson plan
Duplications (Dup)	Includes an existing element from the lesson plan in another part of the lesson plan
Inversions (Inv)	Switches the order or placement of 2 or more existing elements of a lesson plan
Relocations (Rel)	Moves an existing element in the lesson plan to different location in lesson

These codes are consistent with how other researchers have characterized teachers' adaptations to curriculum materials (e.g., Drake & Sherin, 2006).

Lastly, in order to assess the inquiry-orientation of the science lessons the preservice teachers developed, I employed the inquiry scoring rubric included in Table 3.5.

Table 3.5
Inquiry Scoring Rubric for Lesson Plans

	3	2	1	0
Lesson engages students in scientifically oriented questions	Lesson uses investigation question that is feasible, worthwhile, contextualized, meaningful, ethical, and sustainable. Inv. questions and other questions are in 'how' rather than 'why' form. Inv. Question is answerable in light of the lesson activities and other questions explicitly scaffold students' investigation and sense-making.	Lesson uses investigation question that meets at least some of the criteria for effective inv. questions. Inv. Question may be in 'why' or 'how' form. Question is at least to some extent answerable in light of the lesson activities. Lesson provides at least some additional questions teachers may use to reasonably support students' investigation and sense-making.	Minimal evidence of use of scientific question and questioning. Investigation question may be present but meet few to no criteria for effective investigation questions. Questions may be in 'why' rather than 'how' form. Lesson makes unproductive suggestions for additional questions teachers can use to support students. Questions are likely not answerable in the classroom contexts.	No evidence
Lesson engages	Students collect,	Students do 2 out of 3 of	Students do 1 out of 3 of	No

students in gathering, organizing, and analyzing and data	organize, and analyze data/evidence. Opportunities to gather, organize, and analyze evidence are linked to the investigation question and/or phenomenon under investigation.	the following: collect, organize, and analyze data/evidence. Opportunities to gather, organize, and analyze evidence are at least somewhat linked to the investigation question and/or phenomenon under investigation.	the following: collect, organize, and analyze data/evidence. Opportunities to gather, organize, and analyze evidence are marginally linked to the investigation question and/or phenomenon under investigation.	evidence
Lesson engages students in formulating explanations from evidence to address scientifically oriented questions.	Opportunities to construct explanations are connected to the evidence and data collected. Claims can be supported by evidence collected. Opportunities to construct explanations are connected to the investigation question and/or phenomenon under investigation.	Opportunities to construct explanations are less explicitly connected to the evidence and data collected and the investigation question and/or phenomenon under investigation or lesser degrees of both. Claims may be supported by evidence collected.	Opportunities to construct explanations are either marginally connected to the evidence and data collected and the investigation question and/or phenomenon under investigation or, in one case or the other, not at all linked. Claims are likely not to be able to be supported with evidence collected.	No evidence
Lesson engages students in evaluating their explanations in light of alternative explanations	Lesson supports students to engage in dialogues, compare results, or check their results with those proposed by the teacher or instructional materials. Lesson supports students to do so in ways that are highly likely to lead students to explanations that are consistent with currently accepted scientific knowledge and the lesson's standards-based learning goals.	Lesson supports students to evaluate their explanations by comparing to at least one alternative explanation. Lesson supports students to do so in ways that are reasonably likely to lead students to explanations that are consistent with currently accepted scientific knowledge and the lesson's standards-based learning goals.	Lesson supports students to evaluate explanations without taking alternative explanations into account. Lesson is unlikely to lead students to explanations that are consistent with currently accepted scientific knowledge and the lesson's standards-based learning goals.	No evidence
Lesson engages students in communicating and justifying their explanations.	Lesson provides students with opportunities to share and justify their question, procedures, evidence, proposed explanation, and review of alternative explanations.	Lesson provides students with opportunities to share AND justify some aspect of their question, procedures, evidence, proposed explanation, and review of alternative explanations.	Lesson provides students with opportunities to share OR justify some aspects of their question, procedures, evidence, proposed explanation, and review of alternative explanations.	No evidence

This scoring rubric in Table 3.5 is explicitly designed to capture crucial elements of inquiry as defined in current science education reform (Grandy & Duschl, 2007; NRC,

1996, 2000) and is informed by existing rubrics for the evaluation of science curriculum materials (Kesidou & Roseman, 2002) and science teaching (Bodzin & Beerer, 2003).

Quantitative data analysis. In research question 1, I asked ‘what curriculum design decisions to preservice teachers make?’. I use quantitative analyses to address this question, as well as relationships between their curriculum design decisions, the inquiry scores of their lessons, and individual teacher characteristic variables. Quantitative analyses were based on numerical and categorical data provided directly by the preservice teachers, as well as the quantification of qualitative data (Chi, 1997). Coding reports were produced for each preservice teacher’s reflective teaching assignment documents. These reports summarized the types and frequencies of curriculum materials used and adaptations made, as well as an inquiry score for both their existing and revised lesson plans. For this coding, inter-rater reliability was performed with a colleague. For the codes in Tables 3.3, 3.4, and 3.5, coding consistency for the preservice teachers’ reflective teaching assignments ranged from 65% to 100%, averaging 82% agreement prior to discussion. After discussion, 100% agreement was reached. These quantified data, as well as survey data, were imported into SPSS for statistical analysis.

Quantitative analysis involved a number of steps. The first set of quantitative analyses focused on providing descriptive statistics and establishing statistically-significant relationships between variables. Using t-tests, chi-square tests, and ANOVA, I investigated relationships between individual teacher characteristics provided in the survey. Then, I provided descriptive statistics for the types and frequencies of both curriculum materials used and adaptations made to them for the preservice teachers’ two reflective teaching assignments. Additionally, I investigated relationships between patterns of curriculum materials use in the first and second reflective teaching assignments using Pearson correlations. Next, I investigated the inquiry scores of the preservice teachers’ science lessons, both before and after adaptation. I used t-tests, ANOVA, and Pearson correlations to compare these inquiry scores within and across the two reflective teaching assignments. For all statistical tests, I have provided measures statistical significance. Also, consistent with recent emphasis on reporting statistical power as well as significance (Hortin & Sheriff, 1981; Olejnik & Algina, 2003; Thompson, 2007; Trusty, Thompson, & Petrocelli, 2004; Zientek, Capraro, & Capraro,

2008), I report effect sizes for statistical results. Additionally, I performed independent samples t-tests to determine if any significant differences existed between the two sections of the course and report these where appropriate.

Second, I created a hierarchical linear regression model to provide explanatory power to trends in the preservice teachers' curriculum design for inquiry. The dependent or outcome variable was the post-adaptation inquiry scores of the preservice teachers' revised science lessons in the first and second reflective teaching assignments. In this regression model, I used three predictor variables: the inquiry score of the curriculum materials the preservice teachers initially used to develop their lesson, a composite variable for the types and frequencies of curriculum materials they used and adaptations they made, and a composite variable for self-efficacy and preferences for science teaching. These groups of variables are consistent with theoretical models of the teacher-curriculum relationship that foreground dynamic interactions teachers have with curriculum materials based on their own views and features of the curriculum materials themselves (Remillard, 2005). I used hierarchical regression modeling because the variables are added to the model one at a time such that the cumulative effect of independent variables on the outcome variable can be ascertained. This model, which is more fully explained in Chapter 4, met the requirements of linearity, independence, homoscedasticity, and normality (Osborne & Waters, 2002).

Qualitative Analyses

Qualitative analysis for this study involved interviews, lesson plans and other instructional artifacts, and other data collected from the four preservice teachers in the focal group. These data were collected throughout the year and were primarily centered around four science lessons the preservice teachers planned and enacted, including the two reflective teaching assignments from the methods course. The purpose of the qualitative analyses is to provide rich, in-depth case studies that illuminate underlying rationales for the preservice teachers' curriculum design decision-making, particularly as related to their espoused inquiry frameworks. These qualitative analyses are also explicitly grounded upon and embedded in the CHAT-based framework described previously.

Qualitative data coding. To code the data collected as part of the qualitative portion of this study, I developed an additional coding key, which is provided in Table 3.6.

Table 3.6
Coding Key for All Research Questions

Categories	Curriculum Planning Codes	Curriculum Enactment Codes
Preservice Teacher	Espoused feelings of self-efficacy, confidence, subject-matter knowledge, etc. (PT)	
Object	Lesson plan and curriculum materials (CM-DLP)	Lesson enactment object (Ob-CE)
Outcome/Goal	Preservice teachers' goals/motives for curriculum design (O/G-CP)	Preservice teachers' goals/motives for curriculum enactment (O/G-CE)
Instrument(s)		
Asking scientifically-oriented questions	Espoused ideas about the role of questions and questioning in inquiry-oriented teaching (IQ)	
Gathering and organizing data/evidence	Espoused ideas about the role of gathering and organizing data and evidence in inquiry-oriented science teaching. (IDGOA)	
Constructing explanations from evidence	Espoused ideas about the role of constructing evidence-based explanations in inquiry-oriented science teaching. (IE)	
Evaluate explanations in light of competing evidence	Espoused ideas about the role of evaluating explanations in light of competing evidence in inquiry-oriented science teaching. (IEE)	
Communicate and justify explanations	Espoused ideas about the role of communicating and justifying explanations in inquiry-oriented science teaching. (IC)	
Inquiry-General	Espoused ideas about inquiry-oriented science teaching in general. (IG)	
Instruments/Tools (other)	Subject-matter knowledge, physical materials, etc. (Inst-CP)	Subject-matter knowledge, physical materials, etc. (Inst-CE)
Rules	Structure of the reflective teaching assignments, requirements for lesson plan formats, etc. (Rules-CP)	Professional norms, school- and classroom-based rules, etc. (Rules-CE)
Community	Methods instructors, other preservice teachers, field instructors, etc. (Comm-CP)	Cooperating teacher, other teachers and administrators, field instructors, etc. (Comm-CE)
Division of Labor	Who does what? Roles of teachers in modifying	Who does what? Negotiations between

	curriculum materials, tensions between roles of preservice teachers, methods instructors, and other parties in curriculum design, etc. (DofL-CP)	preservice teachers and cooperating teachers, role of students and teachers in inquiry-oriented practice, etc. (DofL-CE)
Instrument-producing Activity	Methods course (IPA-CP)	Curriculum Planning (CP)
Object-activity	Elementary classroom (OA)	N/A
Culturally-advanced Form of Activity	Advanced forms of curriculum planning (AA-CP)	Advanced forms of curriculum enactment (AA-CE)

I employed this coding key to characterize the focal preservice teachers' curriculum planning and curriculum enactment contexts, the preservice teachers' use of their espoused inquiry frameworks and curriculum design in their development and enactment of science lesson plans, and how their espoused inquiry frameworks and curriculum design practices changed over the course of the year. The coding key is also based upon and explicitly aligned with the CHAT-based model I presented in Chapter 2 (Figure 2.4).

The core component of this coding key is a set of codes related to inquiry and a set related to science curriculum materials which, consistent with my CHAT-based model of preservice teachers' curriculum design for inquiry-oriented science teaching, represent tools and objects. The first five inquiry codes are essential features of inquiry promoted in *Inquiry and the National Science Education Standards* (NRC, 2000). These include asking scientifically-oriented questions, gathering and organizing data and evidence, making evidence-based explanations, comparing explanations, and communicating and justifying. I have also included an additional code to capture inquiry-related themes discussed by the teachers that are not explicitly addressed in the NRC's 5-part framework. Second, the coding key accounts for curriculum materials of interest in the study.

The coding key is also aligned with the CHAT-based model I presented in Chapter 2 (Figure 2.3). First, in addition to codes for inquiry and science curriculum materials, the coding key also includes codes that account for cultural dimensions of the curriculum design and enactment settings. Specifically, I include codes for the individual preservice teacher, his or her goals and motives, as well as rules and norms, community, and division of labor that influence curriculum design and enactment. However, the

nature of these cultural dimensions, as well as the role of the teachers' inquiry model, and the curriculum materials he or she uses, differ between the curriculum planning and curriculum enactment contexts. I therefore include, second, a separate column of codes that will help differentiate between curriculum planning and enactment as represented by the curriculum planning and curriculum enactment triangles in my proposed model (Figure 2.4).

I coded formal interviews, pre- and post-enactment interviews, lesson plan rationales, journal entries, and additional data sources using the coding key in Table 3.6. Other data sources, such as audiotaped planning discussions and group interactions from the methods course, were not coded. However, they were used to provide confirming or disconfirming evidence once initial claims had been generated.

Qualitative data analysis. In research questions 2 and 3, I asked why preservice teachers make the curriculum design decisions that they do, particularly in light of their espoused inquiry frameworks, and how their espoused inquiry frameworks and curriculum design practices evolve over time. Consistent with the CHAT-based framework of this study, answering these two questions involved characterizing the preservice teachers' goals, contradictions or tensions they articulated within and across curriculum planning and enactment contexts, and how they attempted to resolve these contradictions through their curriculum design decision-making. I performed qualitative analyses of data from the focal group of four preservice teachers to address these research questions.

Qualitative analysis involved standard qualitative research methods, broadly characterized by an iterative process of coding, reduction, displaying, and verification of data (Marshall & Rossman, 1999; Miles & Huberman, 1994; Strauss & Corbin, 1998), that were directed towards the development of case studies (Yin, 1994). To analyze the coded data from the focal group of four preservice teachers, I engaged in a stepwise process of data representation and reduction, the goal of which was to provide empirical evidence for claims made regarding my research questions. First, after coding each separate data source, I produced artifact-specific coding reports to summarize dominant trends in the data. These data source summaries were primarily used to specify descriptive trends, such as how many and what types of curriculum materials preservice

teachers used, how many and what types of adaptations they made to them, and what factors were most significant to them in their curriculum design efforts. The goal of these data summaries was to provide lesson-specific narratives that served as a first step to identifying and tracing apparent themes in the qualitative data.

Second, in conjunction with developing lesson-specific summaries for each preservice teacher, I also used NVivo query functions to produce matrix code queries for all codes in Table 3.6. These code queries illustrated the number of instances in which individual codes overlapped, providing a measure of which codes were important in a lesson-specific curriculum design cycle for a given preservice teacher. Identifying overlapping codes was critical to identifying contradictions that preservice teachers articulated within and across curriculum planning and enactment contexts.¹

Ultimately, the goal of data analysis was to provide evidence for how the preservice teachers engaged in curriculum design for inquiry, perhaps in fundamentally novel ways, to alleviate the contradictions they articulated. It was therefore important to provide evidence for how the preservice teachers mobilized and adapted existing science curriculum materials in curriculum planning and curriculum enactment. Toward this end, third, I used the coding matrix presented in Table 3.7.

¹ However, not all coding relationships represented in the matrices and case reports are contradictions. For example, the specific way in which a preservice teacher conceptualizes the role of organizing and gathering data (IGDOA) might be supported by his or her interactions with other preservice teachers (Comm-CP) prior to enacting his or her science lesson. Rather than a contradiction, this represents an affordance of the curriculum planning context that is less likely to result in tensions that require resolution in ongoing curriculum design for inquiry-oriented science teaching. Contradictions are more clearly defined problems that often lead to actions oriented towards the resolution of the contradiction. It was important to be able to distinguish those relationships that actually are contradictions and from those that are articulated as affordances by the preservice teachers in their curriculum design efforts. To do this I drew on the coded data from the matrices and the case reports to identify those relationships that indicated problems or tensions the preservice teachers were facing.

Table 3.7
Contradictions and Preservice Teachers' Curriculum Design Decision-Making for a Given Cycle of Curriculum Design for Inquiry

Contradictions	Types of Curriculum Materials											Types of Changes to Curriculum Materials			
	Existing lesson plan (ELP)	Stand-alone investigation, experiment, or activity (AIE)	Textbook (T)	Content resource (science background information) (CR)	Video/DVD (VD)	Models, graphs, or images (MGI)	Trade book (story) (TB)	Computer software (CS)	Student worksheet (SW)	Other (O)	Insertions (Ins)	Deletions (Del)	Substitutions (Sub)	Duplications (Dup)	Inversions (Inv)
Pre-Enactment															
1. Codes															
Change															
Contradiction															
Evidence															
Post-Enactment															
2. Codes															
Change															
Contradiction															
Evidence															

The primary affordance of Table 3.7 was to explicitly link the contradictions each preservice teacher articulated to his or her curriculum design decision-making. The coding matrix in Table 3.7 also affords the ability to account for multiple contradictions influencing a specific curriculum design cycle, helping identify those contradictions that drove the preservice teachers' adaptations.²

Fourth, once relationships between contradictions and curriculum design decisions for a particular lesson were identified (using the coding matrix in Table 3.7), it was necessary to return to the CHAT-based model from Figure 2.3 and map these contradictions onto the model itself. I therefore produced a model for each teacher's science lesson that illustrated contradictions they articulated. While doing so was

² For example, a preservice teacher might cut some parts of a post-investigation sense-making element of an existing lesson (Del) because she realizes that time constraints in her placement classroom (Rules-CE) limit her ability to engage in a substantive whole-class discussion (IC).

similarly descriptive in nature, it provided a second representation of those contradictions that a given preservice teacher was articulating for any curriculum design cycle.

Through this stage, qualitative analysis focused on each science lesson the preservice teachers’ planned and enacted. However, an important goal of this study is to trace the preservice teachers’ learning and evolution of their curriculum design practices over time. Fifth, then, I built upon analyses of the preservice teachers’ lesson-specific curriculum design to analyze how preservice teachers negotiated lesson-specific contradictions over time. In order to answer research question 3, comparisons were made across these cases to characterize the ways in which the preservice teachers either did or did not learn to engage in fundamentally new forms of curriculum planning and enactment of inquiry-oriented science lessons. The first step of this effort involved characterizing successive stages of the preservice teachers’ curriculum design decision-making. To do this, I used the coding matrix in Table 3.8.

Table 3.8
Contributions of a Contradiction to Preservice Teachers’ Curriculum Design Decision-Making over Time

	Types of Curriculum Materials	Types of Changes to Curriculum Materials
	Existing lesson plan (ELP) Stand-alone investigation, experiment, or activity (AIE) Textbook (T) Content resource (science background information) (CR) Video/DVD (VD) Models, graphs, or images (MGI) Trade book (story) (TB) Computer software (CS) Student worksheet (SW) Other (O)	Insertions (Ins) Deletions (Del) Substitutions (Sub) Duplications (Dup) Inversions (Inv)
Contradiction		
Curriculum Planning and Enactment Events		
1.	Codes	
	Description	
	Evidence	
2.	Codes	
	Description	
	Evidence	

The coding matrix in Table 3.8 is a modified version of the coding matrix in Table 3.7, both of which were designed to explicitly link the contradictions that preservice teachers articulated to the specific curriculum design decisions that they made. Use of this coding matrix also relied on the contradictions identified using the coding matrix in Table 3.6. At this stage of analysis, however, the goal was to trace the influence of *a given contradiction* over time rather than map *all contradictions* influencing a particular curriculum planning and enactment cycle. Therefore, a separate coding matrix (Table 3.8) was produced for *each* contradiction the preservice teachers articulated over the course of the study as it pertained to their curriculum planning and enactment. Evidence provided for each curriculum planning and enactment cycle illustrated specific features and stages of the contradiction and of the preservice teachers' related decision-making.³

Sixth, after having analyzed the relationships between contradictions and the preservice teachers' curriculum design decisions over time, I constructed complete cases for each of the four preservice teachers in the focal group. These comprehensive cases illustrated the preservice teachers' espoused inquiry frameworks, curriculum design goals and decisions, articulated contradictions within and between curriculum planning and curriculum enactment, relationships between all three, and their evolution over the course of the study.

Finally, seventh, based on findings from each of the cases, I performed cross-case analysis of the focal preservice teachers to identify relevant patterns and themes. Emphasizing cross case themes helped illustrate consistent trends across the four preservice teachers' use of science curriculum materials over the course of the study. As definitive patterns emerged through coding, the data was reduced to isolate and illustrate key factors. I tested emergent themes by actively seeking conflicting data that contradicted my developing interpretations. This process continued until dominant themes were refined and substantiated. I have organized the presentation of my findings

³ The length of time and number of cycles needed to resolve a contradiction may vary. A preservice teacher may adequately resolve a particular contradiction through the planning and enactment of one science lesson while other contradictions may persist throughout the year and never be resolved even after the preservice teacher plans and enacts the five science lessons I will focus on in this study. Understanding how given contradictions persist to varying degrees will be crucial to explaining how preservice teachers engage in curriculum design processes over time.

in Chapter 5 around both my CHAT-based theoretical model and dominant themes present in the qualitative findings.

A number of different methods were employed to enhance the validity of conclusions, particularly member-checking and data triangulation, (Johnson, 1997; Krefting, 1991; Miles & Huberman, 1994). Though conceptions of validity differ across paradigmatic lines (Donmoyer, 2001), I employed these methods to insure that findings were consistent with the curriculum design experiences of the preservice teachers rather than to derive and present universal, albeit defensible, ‘truths’ about the nature of this work (Patton, 2001). Member-checking was a natural extension of this research and I remained in contact with the four preservice teachers throughout the year after data collection, soliciting feedback from them on the developing cases so as to insure my own interpretations were consistent with theirs. For perceived inconsistencies, I worked with the preservice teacher(s) to negotiate shared meaning around their experiences and portray them in a way with which they are in agreement.

Data Analysis by Data Source

In the sections that follow, I discuss how analyzed the data I collected to answer my 3 research questions. A summary of data sources by research question is included in Table 3.9.

Table 3.9
Data Sources by Research Question and Participant Sample

		Artifacts			Interviews		Other	
		LP	J	OA	FI	PI	O	PD
RQ1	<i>What curriculum design decisions do preservice elementary teachers make?</i>	Whole group	x					
		Focal group	x	x	x	x	x	x
RQ2	<i>Why do preservice elementary teachers make the curriculum design decisions that they do, particularly as related to their developing understanding of inquiry-oriented science teaching?</i>	Focal group	x	x	x	x	x	x
RQ3	<i>How do their espoused inquiry frameworks and curriculum design practices for inquiry-oriented science teaching evolve over time?</i>	Focal group		x	x	x	x	x

Reflective teaching assignments and lesson plans. The lesson plans, lesson rationales, and reflective journal entries the preservice teachers produced for the reflective teaching assignments in the methods course were coded using coding keys in Tables 3.3, 3.4, and 3.5. Codes from the coding keys in Tables 3.3 and 3.4 were used to identify the types and frequencies of curriculum materials they mobilized and the types and frequencies of adaptations they made in developing their reflective teaching lessons. Coding the lesson rationales, in which the preservice teachers explicitly listed the curriculum materials they used and adaptations they made, lesson plans, and reflective journals allowed for triangulation across data sources. The goal of this descriptive analysis was to be able to accurately describe how the preservice teachers gathered and used science curriculum materials to develop the lesson they enacted.

I also scored the reflective teaching lesson plans on a scale of 0-4 for their inquiry-orientation using the inquiry scoring rubric included in Table 3.5. The goal of this evaluative analysis is to provide a normative assessment of how well each of the preservice teachers' reflective teaching lessons addressed the essential dimensions of inquiry.

Finally, for the focal preservice teachers, written responses in the lesson plans, lesson plan rationales, and post-enactment reflections were coded using the coding key presented in Table 3.6. The purpose of this analysis was to connect curriculum design decisions to the preservice teachers' underlying rationales. The design decisions themselves have already been characterized in coding for the types and frequencies of curriculum materials the preservice teachers use and the changes they make to them (Tables 3.3 and 3.4). To make observed relationships between these design decisions and relevant constructs from Table 3.6 explicit, I used coding query tables produced by NVivo.

Journal Entries. I coded and analyzed the journal entries completed by the focal preservice teachers. These were coded using the coding key in Table 3.6, paying close attention to the subset of inquiry codes highlighted in the table. Resulting data informed case studies of the focal preservice teachers.

Other artifacts. Additional artifacts were used to inform case studies of the focal group of preservice teachers. These included additional instructional artifacts, informal notes and observation made by the preservice teachers, photos and images, as well as other. Instead of transcribing and coding these data, I draw upon them as secondary data sources to provide confirmatory or disconfirming evidence to developing claims from analysis of primary data.

Interviews. Formal interviews were explicitly designed to elucidate the preservice teachers' espoused inquiry frameworks use of science curriculum materials. These interviews were coded using the coding key from Table 3.6. For the planning interviews, I used the coding key in Table 3.6 and coding matrices produced in NVivo to capture the ways in which the preservice teachers link their ideas to particular curriculum design decisions. Resulting data informed case studies of the focal preservice teachers.

Observations. Analyses of the preservice teachers' enacted lessons also focused on describing how they used science curriculum materials and how inquiry-oriented their enacted lessons were. I only observed enacted lessons for preservice teachers in the focal group so these data were primarily descriptive (to be informed by prior and subsequent interviews). Similar to the coding of the preservice teachers' lesson plans and rationales, I coded observations of enacted lessons for the focal group of preservice teachers using

the two coding keys in Table 3.3 and 3.4, as well as score their enacted lessons for inquiry (Table 3.5). Resulting data informed case studies of the focal preservice teachers.

Planning discussions. I used audiorecorded in-class planning discussions by the focal preservice teachers in my section of the course. These planning and debriefing discussions around the preservice teachers' two reflective teaching assignments were designed to provide them opportunities to describe lessons, enactment of their lessons, and rationales for curriculum design decision-making. Instead of transcribing and coding these data, I draw upon them as secondary data sources to provide confirmatory or disconfirming evidence to developing claims from analysis of primary data. Resulting data informed case studies of the focal preservice teachers.

Data Analysis Summary

In these sections, I have described quantitative and qualitative analytical methods used to carry-out this mixed-methods study. In summary, using lesson plans and course artifacts from the whole group of preservice teachers, quantitative analyses were performed to characterize the types and number of science curriculum materials the preservice teachers used and modifications they made to them, as well as the inquiry-orientation of the lessons they developed. Using these and other data, I employed qualitative methods to analyze the underlying rationales for preservice teachers' curriculum design decisions, particularly as related to their espoused inquiry frameworks, and how these evolved over the course of the year. Through these two data collection and analytical approaches, I address each of my three research questions in the Chapters 4 and 5.

Methods Summary

In this chapter, I have described the research methods underlying my study design, data collection, and data analyses. The mixed-methods approach utilized here allows for varied data representation and analyses, thus strengthening the evidence and claims I make. Results from the quantitative portion of this study provides aggregate, descriptive measures of the preservice teachers' mobilization and adaptation of curriculum materials. The qualitative portion provides rich, in-depth evidence of these four preservice teachers' engagement in curriculum design for inquiry. The methods

used are explicitly aligned with the CHAT-based framework for preservice teachers' curriculum design for inquiry, which I presented in Chapter 2 (Figure 2.3) and provide both descriptive and explanatory power to the study. In the next chapter, I begin reporting results from these analyses, beginning with quantitative findings from the preservice teachers' reflective teaching lessons during the methods semester.

CHAPTER 4

PRESERVICE ELEMENTARY TEACHERS' MOBILIZATION AND ADAPTATION OF SCIENCE CURRICULUM MATERIALS DURING THE SCIENCE METHODS COURSE

In Chapter 4, I present findings from the quantitative study of 46 preservice teachers' first and second reflective teaching assignments from the undergraduate elementary science teaching methods course. These findings are presented to address research question 1, in which I asked, 'are preservice elementary teachers able to mobilize and adapt science curriculum materials to make them more inquiry-based?'. Consistent with the CHAT-based framework for this study, this analysis is first and foremost concerned with illustrating the preservice teachers' curriculum planning actions and the outcomes of those actions in terms of inquiry. Findings help characterize the essential production processes of curriculum planning (Figures 2.3 and 2.4), or the preservice teachers' working spheres (Engeström, 2008) of curriculum planning for inquiry.

In the sections that follow, I first provide descriptive statistics for the types and frequencies of science curriculum materials the preservice teachers used and the adaptations they made to them. Next, I present results that show how the preservice teachers' curriculum design efforts resulted in more inquiry-oriented planned science lessons and explore relationships between these variables. Finally, I present findings from hierarchical linear regression analyses to explore the influence of science curriculum materials and the preservice teachers' curriculum design decisions on the inquiry scores of their revised science lessons.

Preservice Teachers' Curriculum-Design Decisions

In this section I present results from the preservice teachers' first and second reflective teaching assignments (RT1 and RT2). I first discuss the types and frequencies of science curriculum materials they used and then the types and frequencies of adaptations they made to them.

Types and Frequencies of Curriculum Materials Used

Trends in the types and frequencies of curriculum materials used by the preservice teachers were similar across the two reflective teaching (RT) assignments. In both RT assignments, the preservice teachers predominantly used existing lesson plans and student worksheets in their science lessons. These results are presented in Figure 4.1 and Table 4.1.

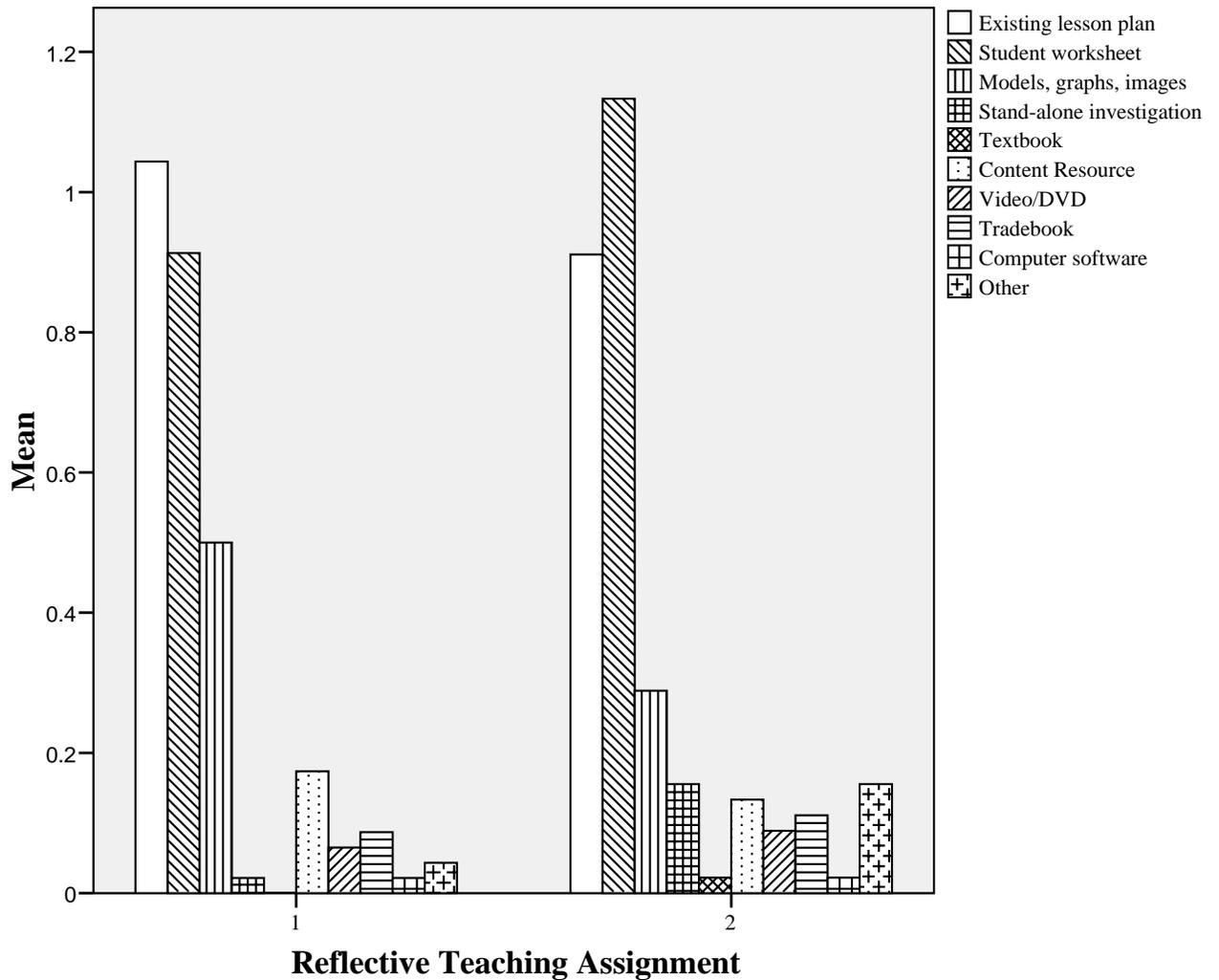


Figure 4.1. Mean Number of Curriculum Materials Used by Preservice Teachers in Reflective Teaching Assignments 1 and 2

Table 4.1

Frequencies and Percentages of Curriculum Materials Used by Preservice Teachers in Reflective Teaching Assignments ($n_{RT1} = 46$, $n_{RT2}=45$)

	Frequencies				
	RT	0	1	2	3 or more
Existing lesson plan	1	3 (6.5%)	38 (82.6%)	5 (10.9%)	-
	2	9 (20%)	31 (68.9%)	5 (11.1%)	-
Student worksheet	1	11 (23.9%)	28 (60.9%)	7 (15.2%)	-
	2	10 (22.2%)	24 (53.3%)	7 (15.6%)	4 (8.9%)
Models, graphs, images	1	35 (76.1%)	8 (17.4%)	3 (6.6%)	-
	2	39 (86.7%)	5 (11.1%)	1 (2.2%)	-
Stand-alone investigation	1	45 (97.8%)	1 (2.2%)	-	-
	2	38 (84.4%)	7 (15.6%)	-	-
Textbook	1	46 (100%)	-	-	-
	2	44 (97.6%)	1 (2.2%)	-	-
Content Resources	1	38 (82.6%)	8 (17.4%)	-	-
	2	39 (86.7%)	6 (13.3%)	-	-
Video/DVD	1	43 (93.5%)	3 (6.5%)	-	-
	2	41 (91.1%)	4 (8.9%)	-	-
Tradebook	1	42 (91.3%)	4 (8.7%)	-	-
	2	41 (91.1%)	3 (6.7%)	1 (2.2%)	-
Computer software	1	45 (97.8%)	1 (2.2%)	-	-
	2	44 (97.6%)	1 (2.2%)	-	-
Other	1	44 (95.7%)	2 (4.3%)	-	-
	2	38 (84.4%)	7 (15.6%)	-	-

In the first reflective teaching assignment, all but three of the preservice teachers, or 93.5%, used existing science lesson plans ($M=1.04$, $SD=0.419$). Five preservice teachers, or 10.9%, used more than one existing lesson plan to plan their science lessons. Also, over 76% of the preservice teachers used some form of student worksheet ($M=0.91$, $SD=0.626$). There was no statistically-significant difference between the mean number of existing lesson plans and student worksheets used by the preservice teachers, $t(45) = 1.29$, $p = 0.22$, $d = 0.24$. The next most frequently-used type of curriculum material was models, graphs, or images, which were used by just under 25% of the preservice teachers in RT 1 ($M=0.5$, $SD = 1.38$). The difference between the number of models, graphs, or images used by the preservice teachers and the number of existing lesson plans was statistically-significant, $t(45) = 2.6$, $p = .013$, $d = 0.53$, though not so for student worksheets, $t(45) = -1.9$, $p = .055$, $d = 0.38$. The remaining types of curriculum materials were used by less than 20% of the preservice teachers.

In the second reflective teaching assignment, only 80% of the preservice teachers used existing lesson plans ($M=0.91$, $SD=.557$), approximately 13% fewer than in RT1. However, 77.8% of the preservice teachers used student worksheets ($M=1.13$, $SD=0.92$), a similar percentage as in RT1. There was no statistically-significant difference between the number of preservice teachers who used existing lesson plans and those who used students worksheets in RT2, $t(45) = -1.7$, $p = .096$, $d = 0.29$. As with RT1, the next most frequently-used type of curriculum material was models, graphs, or images, which were used by under 15% of the preservice teachers in RT 2 ($M=0.29$, $SD = 1.82$). The difference between number of models, graphs, or images used by the preservice teachers was significantly less than both the number of existing lesson plans, $t(45) = 3.08$, $p = .004$, $d = 0.65$, and student worksheets, $t(45) = -3.4$, $p = .001$, $d = 0.78$. The remaining types of curriculum materials were used by less than 10% of the preservice teachers.

Frequencies of curriculum materials used. In each of their reflective teaching assignments, the preservice teachers mobilized a number of existing curriculum materials to plan and develop their science lessons. An overview of the total number of unique curriculum materials they used in each reflective teaching assignment is presented in Figure 4.2.

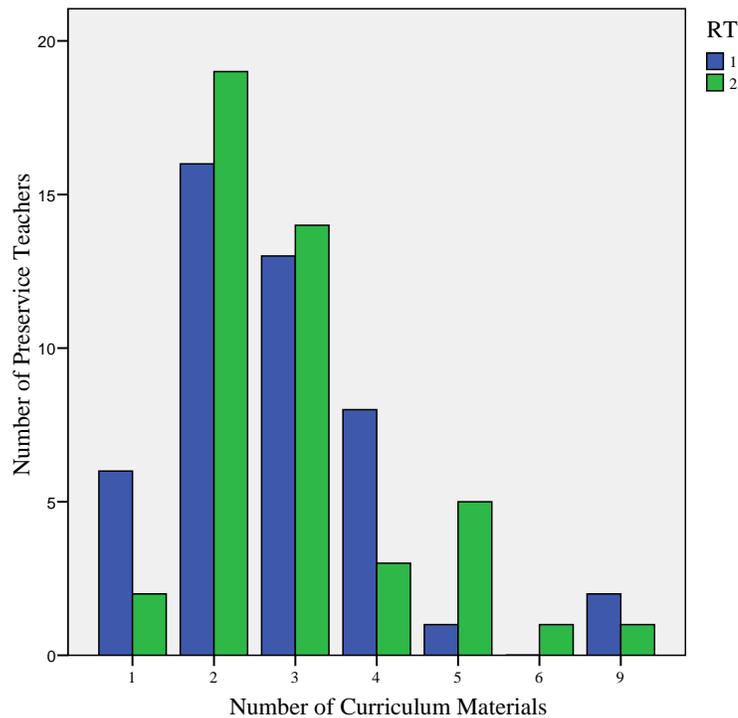
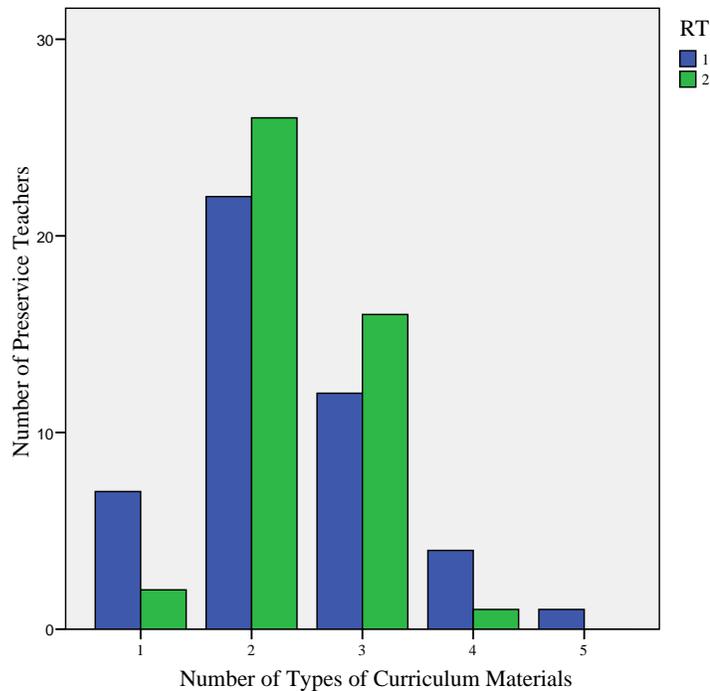


Figure 4.2. Frequencies of Curriculum Materials Used by Preservice Teachers in Reflective Teaching Assignments 1 and 2.

In the first reflective teaching assignment the preservice teachers used an average of 2.89 (SD = 1.668) unique curriculum materials to plan their science lessons. In the second RT assignment, the preservice teachers used an average of 2.96 (SD = 1.492) existing curriculum materials. Though the preservice teachers used slightly more curriculum materials in the second RT assignment, the difference between the number of curriculum materials used in RT assignments 1 and 2 was not statistically significant, $t(45) = -0.234, p = 0.816, d = 0.04$. Additionally, the number of curriculum materials used in RT1 and RT2 was only weakly and insignificantly correlated, $r(45) = .272, p = 0.071$, suggesting that the preservice teachers did not necessarily tend to use the same number of curriculum materials in their second RT assignment as in their first.

Types of curriculum materials used. In addition to analyzing the total number of curriculum materials the preservice teachers used, I also investigated the number of unique *types* of curriculum materials they used⁴. An overview of the number of types of unique curriculum materials they used in each assignment is presented in Figure 4.3.



⁴ For example, a preservice teacher may have used 4 total curriculum materials to plan her lesson. However, if one was a lesson plan and the other three were student worksheets, she only used two unique types.

Figure 4.3. Number of Types of Curriculum Materials Used by Preservice Teachers in Reflective Teaching Assignments 1 and 2.

In the first RT assignment the preservice teachers used an average of 2.36 (SD = 0.933) unique types of curriculum materials to plan their science lessons. In the second RT assignment, the preservice teachers also used an average of 2.36 (SD = 0.609) types of existing curriculum materials. The mean number of types of curriculum materials they used was therefore the same in both RT assignments. As with the total number of curriculum materials previously, the number of types of curriculum materials used in RT1 and RT2 was weakly and insignificantly correlated, $r(45) = .292, p = 0.051$, suggesting that the preservice teachers did not necessarily tend to use the same number of types of curriculum materials in their second RT assignment as in their first.

Comparing frequencies and types of curriculum materials used. The preservice teachers used a greater total number of curriculum materials than they did unique types of curriculum materials in both RT 1, $t(45) = -2.77, p = 0.008, d = 0.53$, and RT2, $t(44) = -3.01, p = .004, d = 0.39$. What this suggests is that preservice teachers often used more than one curricular resource of a particular type in a given RT assignment. For example, many preservice teachers used multiple student worksheets in a single lesson. Additionally, preservice teachers who used more curriculum materials also tended to use a greater number of types of curriculum materials, both in RT 1, $r(46) = .661, p < .001$, and RT2, $r(46) = .443, p = .002$. These relationships suggest that the more curriculum materials a preservice teacher used, the more likely he or she was to also use a greater variety of types of curriculum materials.

Summary. The preservice teachers predominantly used existing lesson plans and students worksheets in their curriculum design for inquiry. They tended to use roughly three distinct science curriculum materials for each reflective teaching assignment. However, they did not always use an equal number of different *types* of science curriculum materials, which suggests they often used more than one of the same type of curriculum material to plan a given lesson. Within each reflective teaching assignment, preservice teachers who used more science curriculum materials to plan their lessons also tended to use more types of science curriculum materials. However, across reflective teaching assignments 1 and 2, they did not necessarily use similar numbers or types of science curriculum materials.

In addition to mobilizing and using specific types and frequencies of curriculum materials, the preservice teachers also adapted them in particular ways. I next turn to their curricular adaptations.

Types and Frequencies of Adaptations Made

Recall from Chapter 3 that the preservice teachers' curricular adaptations were coded as insertions, deletions, substitutions, duplications, inversions, and relocations. Trends in the types and frequencies of adaptations made by the preservice teachers were similar across both RT assignments. In both assignments, the preservice teachers predominantly added, or inserted, new elements into existing science curriculum materials or substituted new elements for existing elements in the science curriculum materials they used. These results are presented in Figure 4.4 and Table 4.2.

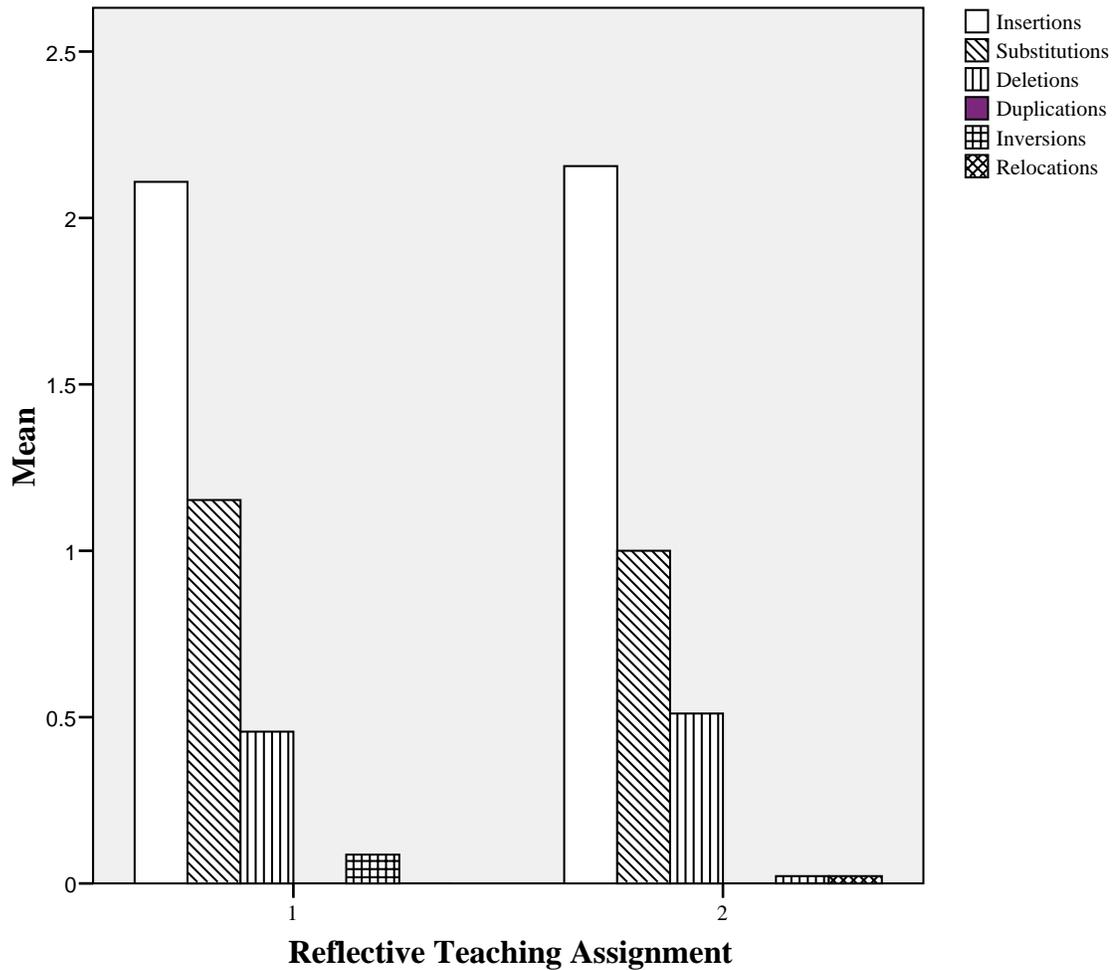


Figure 4.4. Mean Number of Adaptations Made by Preservice Teachers in Reflective Teaching Assignments 1 and 2

Table 4.2

Frequencies and Percentages of Adaptations Made by Preservice Teachers in Reflective Teaching Assignments ($n_{RT1} = 46$, $n_{RT2}=45$)

	Frequencies					
	RT	0	1	2	3	4 or more
Insertions	1	3 (6.5%)	15 (32.6%)	13 (28.3%)	6 (13.0%)	9 (19.6%)
	2	4 (8.9%)	10 (22.2%)	13 (28.9%)	12 (26.7%)	6 (13.3%)
Deletions	1	30 (65.2%)	12 (26.1%)	3 (6.5%)	1 (2.2%)	-
	2	29 (64.4%)	9 (20%)	7 (15.6%)	-	-
Substitutions	1	17 (37%)	10 (21.7%)	15 (32.6%)	3 (6.5%)	1 (2.2%)
	2	14 (31.3%)	21 (46.7%)	6 (13.3%)	4 (8.9%)	-
Duplications	1	46 (100%)	-	-	-	-
	2	45 (100%)	-	-	-	-
Inversions	1	43 (93.5%)	2 (4.3%)	1 (2.2%)	-	-
	2	44 (97.8%)	1 (2.2%)	-	-	-
Relocations	1	46 (100%)	-	-	-	-
	2	44 (97.8%)	1 (2.2%)	-	-	-

In the first RT assignment, all but three of the preservice teachers, or 93.5%, inserted new elements into the lesson plans they used, for a mean of 2.11 insertions per preservice teacher ($SD = 1.34$). They made significantly more insertions than any other type of adaptation, $t(46) = 6.97$, $p < .001$, $d = 0.79$. Also, 63% of the preservice teachers substituted new lesson elements for existing lesson elements in their lesson plans, for a mean of 1.15 substitutions per preservice teacher ($SD = 1.07$). This was significantly more than any other type of adaptation except insertions, $t(46) = -3.74$, $p = .001$, $d = 0.75$. Just over 35% of the preservice teachers deleted elements from their lessons, for a mean of 0.46 deletions per preservice teacher ($SD = 0.72$), which was significantly more than any other type of adaptation except insertions and substitutions, $t(46) = 3.38$, $p = .001$, $d = 0.65$. Only three teachers made inversions and none of the teachers made duplications or relocations.

In the second RT assignment, all but four of the preservice teachers, or 91.1%, inserted new elements into the lesson plans they used, for a mean of 2.16 insertions per preservice teacher ($SD = 1.22$). The preservice teachers made significantly more insertions than any other type of adaptation, $t(45) = 4.55$, $p < .001$, $d = 1.08$. Also, 68.9% of the preservice teachers substituted new lesson elements for existing lesson elements in their lesson plans, for a mean number of 1.0 substitutions per preservice teacher ($SD =$

0.91), which was significantly more than any other type of adaptation except insertions, $t(45) = -3.1, p = .003, d = 0.59$. Just over 35% of the preservice teachers deleted elements from their lessons, for a mean number of 0.51 deletions per preservice teacher ($SD = 0.76$), which was significantly more than any other type of adaptation except insertions and substitutions, $t(45) = 4.17, p < .001, d = 0.90$. Only one teacher made inversions and/or relocations, and no teachers made duplications.

In sum, the preservice teachers primarily inserted, or added, new elements into their RT lessons to make them more inquiry-oriented. To a lesser extent, they also substituted or deleted elements in the curriculum materials they used, though they rarely or never inverted, duplicated, or relocated existing lesson elements. What this suggests is that the preservice teachers were more likely to add or remove lesson elements than to rearrange existing lesson elements. However, to characterize the preservice teachers' curriculum design for inquiry, it is also necessary to analyze the frequencies of their adaptations, to which I turn next.

Frequencies of adaptations made to curriculum materials. An overview of the total number of unique adaptations the preservice teachers made in each assignment is presented in Figure 4.5.

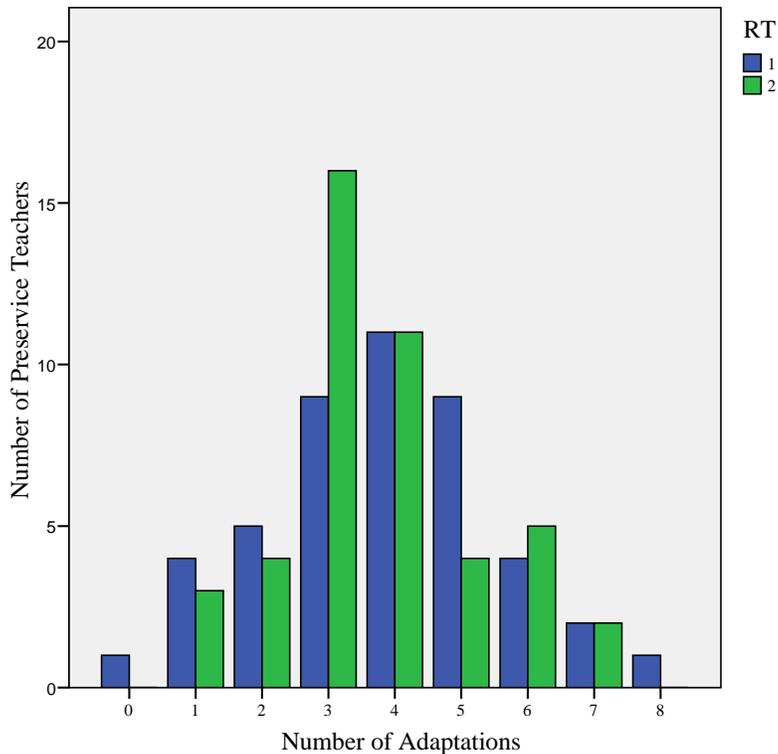


Figure 4.5. Frequencies of Adaptations Made by Preservice Teachers in Reflective Teaching Assignments 1 and 2.

In the first RT assignment the preservice teachers made an average of 3.78 (SD = 1.744) unique adaptations to the curriculum materials they used to plan their science lessons. In the second RT assignment, the preservice teachers made an average of 3.71 (SD = 1.487) adaptations. Though the preservice teachers made slightly more adaptations in their first reflective teaching assignment than the second, the difference was not statistically significant, $t(45) = 0.277, p = 0.78, d = 0.04$. However, the number of adaptations made in RT1 and RT2 was moderately correlated, $r(45) = .509, p < .001$. This suggests that the preservice teachers who made more adaptations in RT1 tended to also be the ones who made more adaptations in RT2, and vice versa.

Types of adaptations made to curriculum materials. In addition to analyzing the total number of adaptations the preservice teachers made, I also investigated the number of unique types of adaptations they made. For example, a preservice teacher may have made 3 total adaptations to plan her lesson. However, if one was a deletion and the other two were insertions, she only made two unique types. An overview of the number of types of unique adaptations they made in each assignment is presented in Figure 4.6.

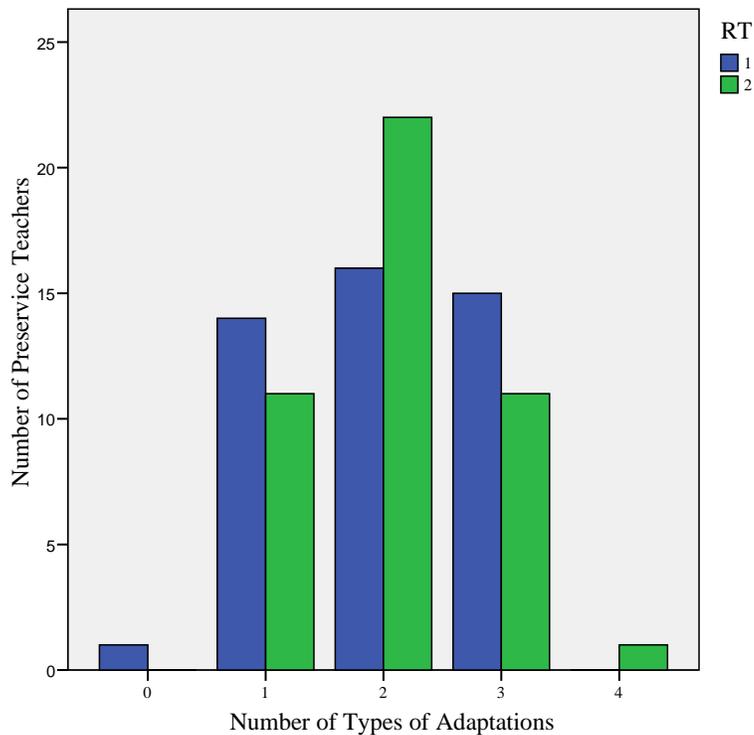


Figure 4.6. Number of Types of Adaptations Made by Preservice Teachers in Reflective Teaching Assignments 1 and 2.

In the first reflective teaching assignment the preservice teachers made an average of 1.96 ($SD = .852$) unique types of adaptations to the curriculum materials they used to plan their science lessons. In the second reflective teaching assignment, the preservice teachers made an average of 2.04 ($SD = .767$) unique types of adaptations. Though the preservice teachers made slightly more types of adaptations in their second reflective teaching assignment than the first, the difference was not statistically significant, $t(45) = -0.628, p = 0.533, d = 0.10$. However, the number of types of adaptations made in RT1 and RT2 was weakly correlated, $r(45) = .316, p = 0.034$. This suggests that the preservice teachers who made more types of adaptations in RT1 tended to also be the ones who made more types of adaptations in RT2, and vice versa.

Overall, the preservice teachers made a greater total number of adaptations than unique types of adaptations to the curriculum materials they used, both in RT 1, $t(45) = -9.40, p < 0.001, d = 1.34$, and RT2, $t(44) = -9.13, p < 0.001, d = 1.41$. What this suggests is that preservice teachers often made more than one adaptation of a particular type in a given RT assignment. Additionally, preservice teachers who made more adaptations also tended to make more types of adaptations, both in RT 1, $r(46) = .678, p < .001$, and RT2,

$r(46) = .569, p < .001$. These correlations suggest that the more adaptations a preservice teacher made, the more likely he or she was to also make a greater variety of types adaptations.

Summary. The preservice teachers predominantly added new elements to the science lesson plans they used to plan their science lessons. They tended to make between three and four distinct adaptations in each reflective teaching assignment. However, they did not tend to make an equal number of different types of adaptations, which suggests they often made more than one type of adaptation to the lesson plans they used to plan their science lessons. For example, the preservice teachers often inserted multiple new elements into their lesson plans. Within each reflective assignment, preservice teachers who made more adaptations also tended to make more types of adaptations. Across RT assignments, the preservice teachers who made more adaptations and more types of adaptations in RT1 tended to do so again in RT2.

Inquiry Orientations of Pre- and Post-Adaptation Curriculum Materials

In order to answer ascertain whether or not the preservice teachers developed more inquiry-oriented science lessons through their curriculum design decisions, I also scored their science lessons for elements of inquiry before and after adaptation. Across the two reflective teaching assignments the preservice teachers completed, trends in the inquiry scores of their initial curriculum materials, their final, revised lessons, and the difference between the two were consistent. In both reflective teaching assignments, the preservice teachers were able to modify existing science curriculum materials to make them more inquiry-oriented. An overview of these findings is shown in 4.7.

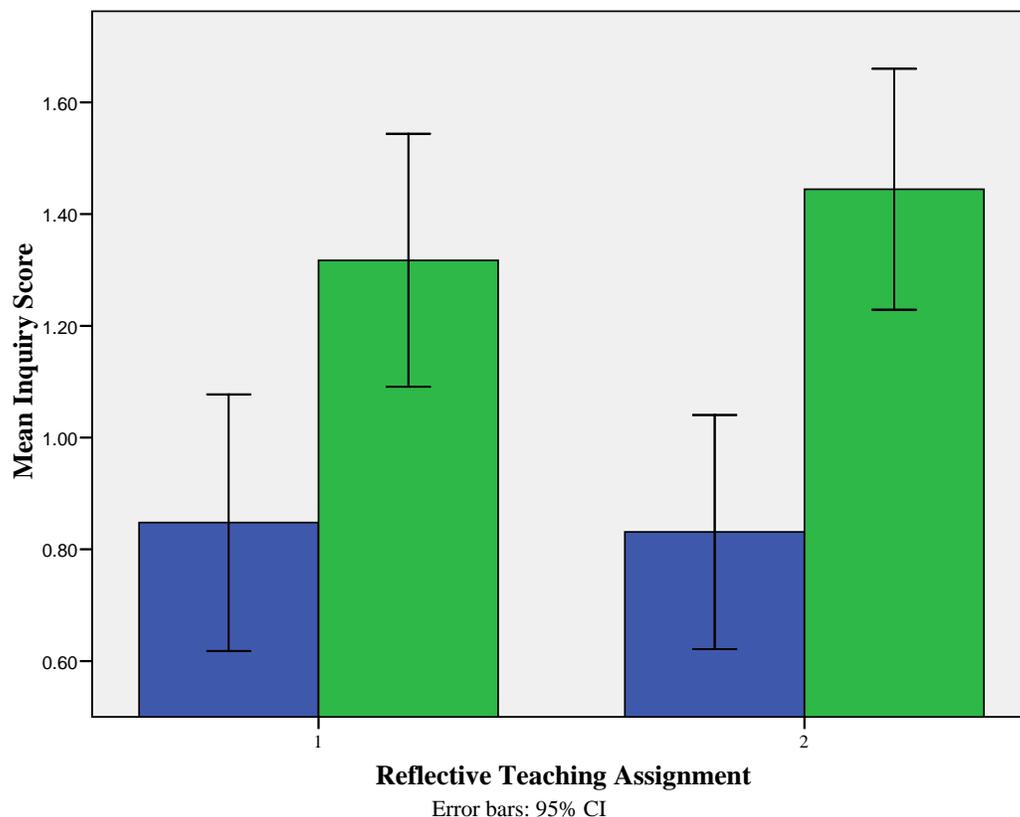


Figure 4.7. Pre- and Post-Adaptation Inquiry Scores of Preservice Teachers' Lesson Plans in Reflective Teaching Assignments 1 and 2.

In the next three sections, I describe the inquiry scores of the curriculum materials the preservice teachers used, the post-adaptation inquiry scores of their modified lessons, and changes in their inquiry scores.

Inquiry Scores of Initial Curriculum Materials

In both reflective teaching assignments, the curriculum materials the preservice teachers used to plan and develop their lessons were not highly inquiry-oriented ($M < 1$ on a 4-point scale)⁵. In the first reflective teaching assignment, the curriculum materials they used had an average inquiry score of 0.85 ($SD = 0.77$) while those they used in the second reflective teaching assignment were even slightly less inquiry-oriented than those they used in the first ($M = 0.83$, $SD = 0.70$). However, the difference between these inquiry scores was not statistically significant, $t(45) = 0.239$, $p = 0.79$, $d = 0.05$,

⁵ These inquiry scores represent a mean score for all five essential elements of inquiry (NSES, 2000) in any given science lesson or group of science curriculum materials. Many lessons were particularly inquiry-oriented for one or two elements of inquiry but not for the remainder, suggesting individual lessons may emphasize a subset of inquiry practices rather than all of them.

suggesting that the curriculum materials the preservice teachers initially used in both reflective teaching assignments, on average, were similarly inquiry-oriented.

Inquiry Scores of Revised Lessons

In both reflective teaching assignments, the preservice teachers modified these existing curriculum materials to construct revised science lessons that were more inquiry-oriented than the original ones. In the first reflective teaching assignment, the average inquiry score for the preservice teachers' revised lessons was 1.32 (SD = 0.76) and, in the second reflective teaching assignment, the mean inquiry score of the preservice teachers' revised lessons was 1.44 (SD = 0.72). While the inquiry scores of the preservice teachers' revised lessons were slightly higher in the second reflective teaching assignment, this difference was not statistically significant, $t(45) = -0.757, p = 0.11, d = 0.14$. This suggests that the preservice teachers were equally able to effectively adapt science lessons they used in both reflective teaching assignments to make them more inquiry-oriented.

Change in Inquiry Scores

In both reflective teaching assignments, the preservice teachers' adaptations either increased or had no impact on the inquiry scores of the science lesson plans they used. In the first reflective teaching assignment, the average change in inquiry score was 0.46 (SD = 0.43) a significant increase, $t(46) = -7.5, p < .001, d = 0.61$. Similarly, in the second reflective teaching assignment, the average change in inquiry score was 0.61 (SD = 0.61), also a statistically-significant increase, $t(45) = -6.75, p < 0.001, d = 0.87$. There was no statistically-significant difference in the change in inquiry scores between RT1 and RT2, $t(45) = -1.30, p = .20, d = 0.17$. In only three cases across both RT assignments did their adaptations result in less inquiry-oriented lessons than those with which they began.

Results also suggest that the preservice teachers' capacities to make their lessons more inquiry-oriented were independent across the two reflective teaching assignments. Preservice teachers who had higher post-adaptation inquiry scores for their RT1 lessons were equally as likely as preservice teachers who had lower post-adaptation inquiry scores on the RT1 lessons to have higher post-adaptation inquiry scores on their RT2 lessons, $r(45) = 0.241, p = .11$. Or, in other words, a preservice teacher whose revised lesson in RT1 was less inquiry-oriented was equally as likely to have a RT2 lesson that

was more inquiry-oriented. The overall change in inquiry scores between the first and second reflective teaching assignments were not significantly correlated, $r(45) = 0.06$, $p = 0.71$. This finding suggests that the preservice teachers who significantly increased the inquiry scores of their science lesson in one reflective teaching assignment did not necessarily do so in the other reflective teaching assignment, and vice versa.

Finally, in their reflective teaching assignments, the preservice teachers were also asked to assess how inquiry-oriented they felt their revised science lessons were. As shown in Appendix B, response options included 'very', 'somewhat', 'not very', and 'not at all' inquiry-oriented. Differences between the preservice teachers' self-assessment of the inquiry-orientation of their revised lessons and the post-adaptation inquiry scores were not statistically-significant, either in RT1, $F(3, 42) = 1.71$, $p = .180$, $\omega^2 = 0.09$, or RT2, $F(2, 42) = 3.00$, $p = .061$, $\omega^2 = 0.21$. This finding shows that the preservice teachers were able to accurately assess the inquiry-orientation of their revised lessons in both reflective teaching assignments.

Summary

This analysis suggests that across the first and second reflective teaching assignments, there was little difference between the inquiry-orientation of the existing curriculum materials the preservice teachers used and adapted or between their revised lesson plans. In both assignments, they were able to make adaptations that did result in statistically-significant increases in the overall inquiry-orientation of their lessons. However, their abilities to do so were largely independent across reflective teaching assignments. Additionally, the preservice teachers were able to accurately assess how inquiry-oriented their lessons were in both reflective teaching assignments.

Effect of Curriculum Materials and Preservice Teachers' Curriculum Design Decisions on Inquiry Scores and Change in Inquiry Scores

I created a hierarchical linear regression model to determine whether there were relationships between the preservice teachers' curriculum design decisions and the inquiry scores of their revised lesson plans. I used hierarchical multiple regression because the predictor variables are added to the model one at a time such that the cumulative effect of these variables on the outcome variable can be ascertained. The primary purpose of this analysis is to provide a degree of statistical explanatory power for

how the types and frequencies of curriculum materials the preservice teacher used, the types and frequencies and adaptations they made, as well as the inquiry score of the initial lesson plans and/or curriculum materials they used affected the inquiry scores of their revised lessons.

Description of Regression Model

I used three predictor variables in my regression model, each of which I added to the model in stepwise fashion. For my first and third predictor variables, I used composite, calculated scores, one for the curriculum materials the preservice teachers used and the other for the adaptations they made⁶. These individual scores were calculated by averaging the total number and total number of types of both curriculum materials and adaptations. As such, they do not directly reflect real-world phenomena but are composite, proxy measures of the preservice teachers' overall mobilization and adaptation of curriculum materials. For my second predictor variable, I include the inquiry scores of the original lesson plans and/or curriculum materials the preservice teachers used to engage in curriculum planning. This provides a measure of how inquiry-based these curriculum materials were to begin with. These three variables are consistent with theoretical models of the teacher-curriculum relationship that foreground dynamic interactions teachers have with curriculum materials based on their own views and features of the curriculum materials themselves (Brown, 2009; Remillard, 2005).

It would have been preferable to include each of my coded variables for types of curriculum materials and types of adaptations (from Tables 3.3 and 3.4) into this regression model rather than the composite, calculated scores. However, this would have resulted in 15-20 predictor variables. Due to my relatively small sample size, the use of so many independent variables would not have been appropriate. In order to maintain statistical power, many quantitative researchers suggest erring on the side of caution in decisions about the number of predictor variables to include in multiple regression models. Conflicting guidelines persist in the literature, particularly in the use of regression models for explanation vs. prediction (Kelley & Maxwell, 2003; Knofczynski & Mundform, 2008; Maxwell, 2000; Milton, 1986; Sawyer, 1982). For example, many

⁶ Using these individual variables (i.e., # of curriculum materials and # of types of curriculum materials, # of adaptations and # of types of adaptations) directly in the regression model would not have been appropriate since, as shown previously, each of these sets of two variables were significantly correlated.

rules of thumb exist regarding the number of predictor variables to use in a regression model in light of sample size, ranging from less than 10:1 to 400:1 (see [Maxwell, 2000] and [Green, 1991] for a more thorough review of these rules of thumb).

Milton (1986) provides a formula for calculating effective sample size for multiple regression, $n = k + 1 + [t^2(1 - R^2) / \Delta r_j^2]$. This formula for sample size (n) is a function of the number of predictor variables (k), desired t-statistic (t^2), anticipated coefficient of determination (R^2), and the minimum additive influence on r^2 (Δr_j^2) of the final predictor variable added to the model. In my regression, I employ 3 predictors ($k = 3$), need to achieve the commonly-accepted significance level of 0.05 ($t^2 = 2$), anticipate a minimum R^2 of 0.2 (40%), and expect that the final predictor added to my model and contributing at least 3% of additional explained variance be significant at the 0.05 level ($\Delta r_j^2 = 0.03$). Using these values, Milton's (1986) formula suggests a necessary sample size of $n = 44$. Given my sample size of 46, I therefore employ three predictor variables, two of which are composite, calculated measures, in my regression model.

In the regression model below, the three independent variables are added stepwise to determine the degree to which they each affect the outcome variable sequentially. The order of addition to the model is based in theory as well as a practical understanding of the curriculum design process in this study. First, the preservice teachers mobilized curriculum materials to use in planning their two reflective teaching assignments. Therefore, the composite variable for 'curriculum materials' is first to be added to the model. Second, these curriculum materials, once selected and mobilized, afforded a certain level of inquiry through their design. Thus, the second predictor variable added to the model is 'inquiry pre', or the inquiry score of the lesson plans and curriculum materials the preservice teachers used. Finally, third, the preservice teachers made adaptations to these lessons to varying degrees. The last predictor variable added to the model is therefore the composite variable for 'adaptations'.

Finally, in Table 4.3 below, I present the unstandardized regression coefficients, significance levels for each of the independent variables, as well as the coefficient of determination (R^2) and change in R^2 . These statistics are included for both the first and second reflective teaching assignments the preservice teachers completed.

Regression Analysis Results

For the regression model, I used the inquiry scores of the preservice teachers' revised lessons as the outcome variable. Table 4.3 includes the results of this analysis.

Table 4.3

Effect of Teachers' Curriculum Materials' Use on Post-Adaptation Inquiry Scores of Lessons ($n_{RT1}=45, n_{RT2}=44$)

Independent Variables	RT1			RT2		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Curriculum Materials	-0.117	0.005	-0.006	0.312*	0.175	0.100
Inquiry Pre Adaptations	-	0.838***	0.861***	-	0.574***	0.655***
	-	-	0.093	-		0.196*
Constant	1.622***	0.595*	0.334***	0.615	0.504	0.071
R ²	0.032	0.718***	0.739***	0.161*	0.44***	0.470
Change in R ²	-	0.686***	0.021	-	0.279***	0.066*

* $p < 0.05$, *** $p < 0.001$

The first independent variable added to the model was the composite variable for the curriculum materials the preservice teachers used (Model 1). In the first reflective teaching assignment, curriculum materials was not a statistically-significant predictor for the inquiry scores of their revised lessons, $F(1,44) = 1.475, p = 0.231$, and explained only 3.2% of the variance of the post-adaptation inquiry scores of the preservice teachers' lessons. However, in the second reflective teaching assignment, curriculum materials was a statistically-significant predictor for the inquiry scores of their revised lessons, $F(2,43) = 8.274, p = 0.006$ and accounted for 16.1% of the variance of the post-adaptation inquiry scores of the preservice teachers' lessons. This suggests that the preservice teachers' decisions about the types and frequencies of curriculum materials to use in the reflective teaching assignment did not significantly affect the post-adaptation inquiry scores of their RT1 lessons, but did in their RT2 lessons.

The second independent variable added to the model was the inquiry score of the lesson plans and curriculum materials the preservice teachers used (Model 2). In the first reflective teaching assignment, the addition of the pre-adaptation inquiry scores of the curriculum materials the preservice teachers used were statistically-significant for the inquiry scores of their revised lessons, $F(2,43) = 54.86, p < 0.001$. Alone, 'inquiry pre', or the pre-adaptation inquiry score of the preservice teachers' lessons, explained 68.6%

of the variance in post-adaptation inquiry scores of their revised lessons. Combined with the types and frequencies of curriculum materials the preservice teachers used, the two predictor variables in Model 2 accounted for a combined 71.8% of the variance in the post-adaptation inquiry scores of the preservice teachers' lessons. In the second reflective teaching assignment, this trend was repeated, though to a lesser extent. In RT2, pre-adaptation inquiry scores were statistically-significant for the inquiry scores of their revised lessons, $F(2,42) = 16.528, p < 0.001$. Alone, 'inquiry pre' accounted for 27.9% of the variance in post-adaptation inquiry scores of the revised lessons. Combined with the types and frequencies of curriculum materials the preservice teachers used, the two predictor variables in Model 2 accounted for a combined 44% of the variance in the post-adaptation inquiry scores of the preservice teachers' lessons. This suggests that how inquiry-oriented the curriculum materials were that preservice teachers used had a highly significant effect on how inquiry-oriented their revised lessons were, though to a lesser extent in RT2 than RT1.

The third and final independent variable added to the model was the composite variable for the preservice teachers' adaptations (Model 3). In the first reflective teaching assignment, the addition of adaptations to the model was statistically-significant for the inquiry scores of their revised lessons, $F(3,42) = 39.65, p < 0.001$. Adaptations explained 2.1% of the variance in post-adaptation inquiry scores of the preservice teachers' revised lessons while, combined, the three predictor variables accounted for a combined 73.9% of the variance in the post-adaptation inquiry scores of the preservice teachers' revised lessons. In the second reflective teaching assignment, the addition of adaptations was statistically-significant for the inquiry scores of their revised lessons, $F(3,41) = 14.02, p < 0.001$. Adaptations explained 6.6% of the variance in post-adaptation inquiry scores of the preservice teachers' revised lessons while, combined, the three predictor variables accounted for a combined 47% of the variance in the post-adaptation inquiry scores of the preservice teachers' revised lessons. This suggests that the adaptations the preservice teachers made did not alone have significant effects on how inquiry-oriented their revised lessons were in RT1. They did, however, have a significant effect on post-adaptation inquiry scores in RT2, albeit a relatively small effect.

In summary, the regression analysis for the post-adaptation scores of the preservice teacher's lessons indicate that the singlemost significant determinant was the inquiry scores of the lesson plans and/or curriculum materials they began with. In RT1, neither of the other two predictor variables, curriculum materials and adaptations, were significant contributors to explanations of the variance of post-adaptation inquiry scores of the preservice teachers' lessons. However, in RT2, both were significant. Additionally, in RT2, the explanatory power of the pre-adaptation inquiry scores, as well as the regression model overall, decreased substantially. This suggests that predictor variables *not* included in the regression model became much more significant influences on how inquiry-oriented the preservice teachers' revised lessons were.

Summary of Quantitative Results

In Chapter 4, I have presented quantitative findings from the two reflective teaching assignments completed by all preservice teachers in both sections of the undergraduate elementary science teaching methods course. Consistent with the CHAT basis of this study, these findings illuminate the curriculum planning production sub-process by providing evidence for the nature of the object(s) with which the preservice teachers worked (curriculum materials), the specific curriculum design actions they took (curriculum mobilization and adaptation), and the outcomes of those actions in terms of how inquiry-based their planned science lessons were. The preservice teachers predominantly used the most common forms of curriculum materials – lesson plans and various forms of student worksheets – and predominantly added or substituted new elements into these lesson plans. Through these curriculum planning actions, the preservice teachers were able to produce more inquiry-oriented lessons. These findings also begin to provide some explanation for the outcomes of curriculum planning. As shown in the results of regression analysis, the post-adaptation inquiry scores of the preservice teachers' lessons (outcomes) were highly influenced by how inquiry-based the lesson plans were that the preservice teachers initially used.

However, results from the regression analysis also suggest that the overall effect of the curriculum materials the preservice teachers used and curriculum design decisions that they made a) did not fully account for the post-adaptation inquiry scores of their lessons and b) was much less in the second RT assignment than the first. This suggests

that other factors not accounted for in the regression model impacted their curriculum design decisions and, ultimately, how inquiry-based their lessons were. Because they are limited to characterizing the production sub-process of the preservice teachers' curriculum planning for inquiry, the findings presented in Chapter 4 do not provide insight into what these additional factors might be. To investigate the preservice teachers' full engagement in the activity of curriculum design for inquiry, and to provide more in-depth explanations for why they made the curriculum design decisions that they did, I draw upon cases studies of four preservice teachers studied over the entire year. In doing so, I focus not only on the production sub-process of curriculum planning for inquiry (as in Chapter 4), but also on how curriculum planning production was culturally-mediated, how the constructed artifacts of curriculum planning (i.e., lesson plans) were used in curriculum enactment, and how the preservice teachers' curriculum design for inquiry evolved over the course of the year. These findings are presented next in Chapters 5 and 6.

CHAPTER 5

CURRICULUM PLANNING FOR INQUIRY: FOUR PRESERVICE ELEMENTARY TEACHERS' INSTANTIATION OF INQUIRY IN PLANNED SCIENCE LESSONS

In the previous chapter, I presented quantitative findings from the analyses of the preservice teachers' reflective teaching assignments during the methods semester. These results help characterize the production sub-process of the curriculum planning activity. Specifically, they shed light on the specific curriculum design decisions the preservice teachers made and how inquiry-based the products of their curriculum planning activity, or their lesson plans, were. They also show that the curriculum materials with which the preservice teachers worked had a highly significant influence on how inquiry-based their planned lessons ultimately were.

While these findings are illuminating, they do not provide in-depth explanations for *why* preservice elementary teachers made the curriculum design decisions that they did, nor an accounting of how preservice teachers' curriculum design practices evolved over time. In Chapters 5 and 6, I present findings from the CHAT-based case studies of four preservice elementary teachers carried out over the science methods semester and student teaching semester. In these case studies, the production sub-processes of curriculum planning, the results of which are emphasized in Chapter 4, are elaborated upon by situating them within the broader activity systems in which they reside. The findings presented in Chapters 5 and 6, then, address research question 2, in which I ask, "why do preservice elementary teachers mobilize and adapt science curriculum materials in ways that they do, particularly in light of their espoused inquiry frameworks?", and research question 3, in which I ask, "how do preservice elementary teachers' espoused inquiry frameworks and curriculum design practices for inquiry-oriented science teaching evolve over time?".

In the remainder of Chapter 5, I focus on the preservice teachers' early inquiry models and learning in the science methods course, as well as how they adapted curriculum materials in light of their espoused inquiry frameworks, and how their curriculum planning activities were culturally-mediated. These activities are shown below in Figure 5.1.

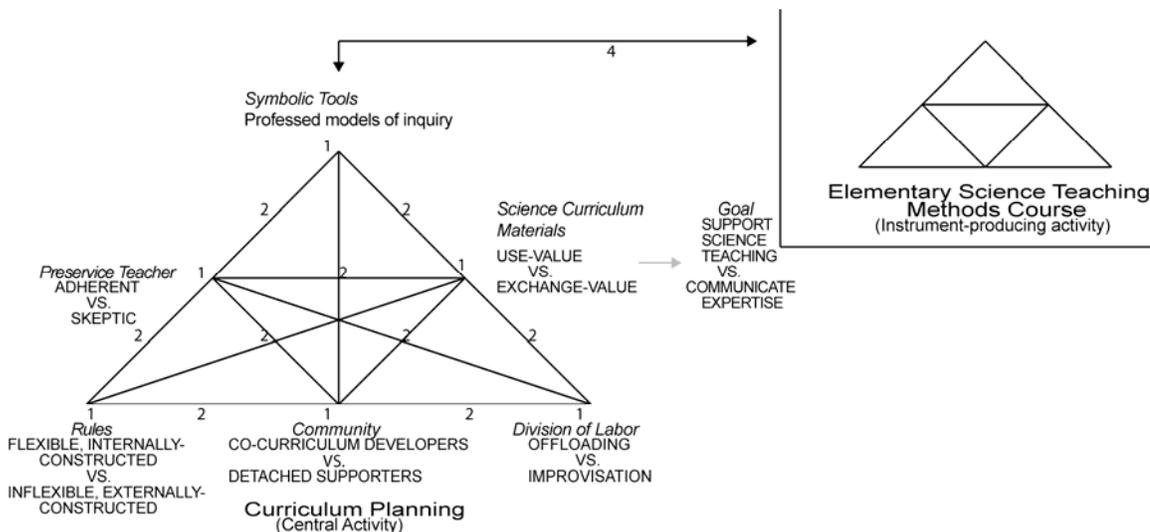


Figure 5.1. Preservice Elementary Teachers' Curriculum Planning for Inquiry

As already stated, the results presented in Chapter 4 were situated within the top (production) triangle of curriculum planning in Figure 5.1. The case study findings presented in Chapter 5 extend the findings from Chapter 4 in a number of ways. First, I explore the four preservice teachers' espoused inquiry frameworks, how they developed in the context of the methods course, and how they mediated the preservice teachers' curriculum planning. Second, I account for the influence of culturally-mediating elements of curriculum planning (rules, community, divisions of labor) in the preservice teachers' curriculum planning. Both of these are necessary to more fully account for the actions and outcomes of the preservice teachers' curriculum planning for inquiry consistent with my CHAT-based framework.

In the sections that follow, I focus on presenting results that illustrate the influence of the methods course on the preservice teachers' espoused inquiry frameworks and their curriculum planning (as shown in Figure 5.1). I first discuss the preservice teachers' articulated goals for curriculum design. Next, I discuss the preservice teachers'

early inquiry models and first curriculum planning attempts, how both evolved during the methods course, and the specific inquiry practices that, over time, the preservice teachers emphasized in planning their lessons. Then, I present findings that illustrate how the preservice teachers' mobilized their espoused inquiry frameworks to critique and adapt the curriculum materials they used. Finally, I discuss how this process was culturally-mediated.

Preservice Teachers' Goals for Curriculum Design

Curriculum design is a goal-oriented activity. As shown in Figure 5.1, curriculum design is focused on the attainment of particular goals or objectives through work on the specific object of those activities. The preservice teachers here sought to accomplish certain goals and objectives through their curriculum design efforts. Early in the study, the preservice teachers worked to accomplish dual goals in their curriculum planning for inquiry (i.e., the central activity). On the one hand, they were asked to develop particular types of lesson plans for the express purpose of communicating their expertise to their instructor and peers in the methods course. However, they also sought to develop the types of lesson plans that they believed would best serve as tools to engage students in inquiry in the classroom. As Kelly wrote about curriculum planning, for example, "the teacher should see if doing the activity would really help him/her reach his/her goal for the lesson" (Journal, 9/10/07). To the four preservice teachers, each of these unique goals required different types of lesson plans to accomplish. In the end, however, the need to communicate their expertise through their lesson plans ended with the conclusion of the methods course, thus allowing the preservice teachers to develop the types of lesson plans they felt best suited their own needs to enact inquiry in the classroom.

Goals for curriculum planning tended to complement and reflect goals for curriculum enactment. As such, curriculum planning and curriculum enactment served as complementary activities. In terms of curriculum enactment, the preservice teachers' goals revolved around engaging students in inquiry. The two primary goals the preservice teachers articulated for their classroom teaching initially were to make science fun and engaging for students, as well as to promote student learning.

Early in the semester, the preservice articulated goals for curriculum enactment that focused on students' engagement and enjoyment of science. Kelly, for example,

noted that her goal was “to really hold the kids’ interest” because “I think science is so interesting, I just hope I can convey that in a good way to students so they can find it equally interesting” (FI1). Similarly, Mike wrote that “by making science fun it allows for every student to enjoy it...students who are engaged in activities are more likely to be enthused with a subject” (Journal, 9/10/07). Aliza also noted that “I’m pretty motivated to just hold the students’ interest...and get them engaged in the lesson...I would consider my lessons somewhat creative because I don’t want things to be boring for the students” (FI1). For the four preservice teachers, then, a paramount objective for their science teaching was to make science engaging, interesting, and fun for students.

However, while emphasizing making science engaging and enjoyable for students, the preservice teachers also focused on student learning as a goal for science teaching and learning. Mike wrote explicitly that “the goal for teaching science in the elementary classroom is teaching the concepts.” (Journal, 9/4/07) while Kelly said in her lessons, “I want there to be one overarching idea that [students] take away” (FI1). For Aliza, there was evidence that she viewed student learning predominantly through the lens of assessment. For example, she wrote at the beginning of the year, “I want to ensure comprehension for all students, and plan useful assessments to test for this comprehension” (Journal, 9/4/07). The emphasis on student learning was consistently evident for each of the four preservice teachers.

While the preservice teachers initially articulated these two goals for science teaching, over time a shift occurred in that they began to perceive students’ engagement in science not as an end unto itself but rather a precondition for student learning. In discussing effective, inquiry-based science, Kelly argued that “if you’re all scattered [students are] not going to take much away from [the lesson]” (FI1). Aliza similarly suggested her goals for curriculum design were twofold, saying it is “most important to me that you’re addressing the learning goals” but also that “you’re establishing a sense of purpose for the students so they don’t feel like it’s just pointless...and they can find some sort of meaning and connection to the lesson” (Aliza, Post-Enactment Interview 4).

In many ways, this was an important development that occurred in conjunction with the evolution of the preservice teachers’ espoused models of inquiry, as discussed more thoroughly later in this chapter. For example, as Lauren suggested about engaging

students in inquiry, “kids aren’t going to learn unless they’re doing it and actively engaged in it” (FI1). The preservice teachers’ focus for accomplishing both of these important goals began to revolve around engaging students in inquiry. This was a central theme for Kelly, as I illustrate later in the chapter. However, it was a consistent theme across the four preservice teachers. Mike, for example, noted that early in the year that his use of investigation questions was focused on engaging students rather than promoting their learning. He said, “the investigation question, originally when I thought about it, I was thinking I guess more kid-friendly instead of like learning goals[-oriented]” (FI2). Mike noted that “originally I wanted to make the question exciting for students” and “to pique their interest” (FI2). However, Mike began to realize the investigation question was an important tool to “bring out more of the learning goals” (FI2) and that he had been “missing how to get students to use and analyze data, and then how to communicate it to their peers (FI2).

In sum, the preservice teachers articulated goals for curriculum design that were twofold: to make science engaging and interesting for students and to promote student learning. Over time, and in conjunction with their learning about inquiry, the preservice teachers began to prioritize student engagement as a necessary first step to promoting student learning and how inquiry practices could help accomplish both goals.

Curriculum Planning for Inquiry

After describing the preservice teachers’ goals for curriculum design in the previous section, I now turn explicitly to the curriculum planning activity (central activity). In Figure 5.1, the preservice teachers’ curriculum planning was represented by one of the two triangles. The preservice teachers’ curriculum planning involved mobilizing their espoused inquiry frameworks (tools/instruments) and existing science curriculum materials to construct revised instructional plans (object) in light of culturally-mediating elements of their curriculum planning contexts (rules, community, division of labor). The curriculum planning activity triangle is presented here again in Figure 5.2.

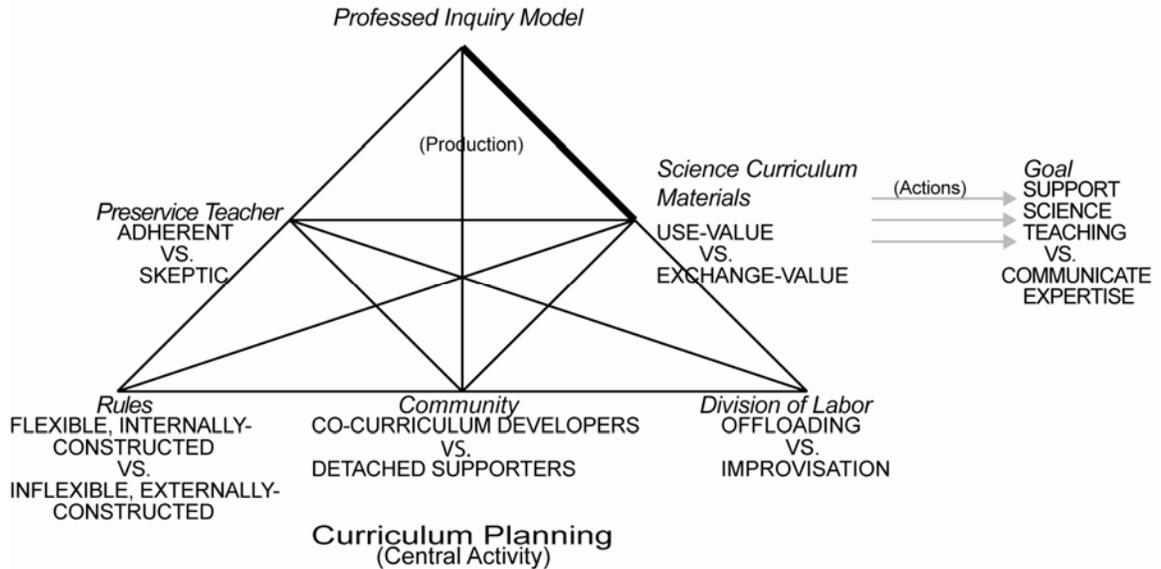


Figure 5.2. CHAT-based Model of Curriculum Planning for Inquiry

Recall that the production triangle, or top triangle in the curriculum planning activity, involves the preservice teacher (subject) using his or her espoused inquiry model (instrument) to adapt existing curriculum materials (object). Here, the unique ways in which the preservice teachers prioritized and visualized the various dimensions of inquiry influenced how and to what extent they drew upon their espoused inquiry frameworks as instruments in the production of instructional plans for science. First and foremost, the main contradiction driving their adaptations was a secondary contradiction between their espoused inquiry frameworks and features of the curriculum materials they used to plan their lessons (illustrated by the red line in Figure 5.2). To alleviate this contradiction, they adapted their lessons to make them more inquiry-oriented. As such, this secondary contradiction served as a positive force through which they were able to accomplish their goals as well as develop more effective, inquiry-based lessons. However, in adapting their lessons in this way, the preservice teachers had to negotiate various rules, community members, and divisions of labor inherent to their curriculum design contexts. In the end, these culturally-mediating elements more often helped explain adaptations the preservice teachers *did not* make than those they did.

In the results that follow, I discuss the preservice teachers' curriculum planning in two ways. First, I focus on the top triangle in Figure 5.2 (the production triangle) in

discussing the preservice teachers' inquiry frameworks and how they employed their inquiry frameworks to adapt existing science curriculum materials. I describe the preservice teachers' early inquiry models and how they employed their early inquiry models to plan their first science lessons. Next, I focus on the rapid evolution of their inquiry models between their first and second science lessons during the methods semester and the impact of the methods course on their inquiry models. I discuss how the preservice teachers continued to employ their inquiry models over the remainder of the study, emphasizing the unique inquiry practices that the preservice teachers emphasized. Finally, to illustrate how the preservice teachers' curriculum design decision-making was also shaped by context, I focus on the culturally-mediating elements of the triangle (rules/norms, community, and division of labor).

Planning for First Science Lessons

Even though they lacked significant teaching experience of their own to draw upon, the preservice teachers espoused existing ideas about effective science teaching at the beginning of the study, in large part drawn from their own experiences as students in science. In many ways, their early inquiry models, which were relatively vague and ill-defined, represented their attempts to reconcile existing conceptions of science teaching practice with features of inquiry promoted in the methods course. As I show in the sections that follow, their relatively limited models of inquiry were evident in their first attempts at curriculum design for inquiry. However, through their work in the methods course, the preservice teachers were able to begin articulating more robust, practice-specific inquiry models that would support their curriculum design efforts throughout the remainder of the study.

Instrument articulation - preservice teachers' early inquiry models. In the beginning of the methods semester, Mike, Kelly, and Lauren's models of inquiry were in their early stages of development. Each noted that they had heard references made to 'inquiry' at various points in their teacher education program but that the science methods course was the first experience they had with inquiry as a construct unique to the teaching and learning of science. At this point in the year, they had just begun to reconcile and incorporate criteria for various inquiry practices into their existing conceptions of effective science teaching. In contrast, Aliza's espoused inquiry model

was more articulated than those of the other three preservice teachers early in the year. She was able to articulate specific inquiry practices from early in the study, often using her experience in the plant laboratory as a referent.

Consistent with their early goals of making science fun and engaging for students, the four preservice teachers initially described effective science teaching as active, hands-on, and student-driven. Mike, for example, highlighted keeping students active by describing an effective science classroom, writing, “science should not be taught with students sitting at their desks, but with students roaming around the classroom with observation notebooks” and “a science class should do experiments, not sit at desks looking at scientific diagrams” (Journal, 9/10/07). They also described inquiry as highly student-driven. For example, Lauren wrote that, in general, “inquiry-oriented science teaching entails letting the students arrive at their own answers” (Journal, 9/11/07), “it’s good to have the whole inquiry-based learning and let kids figure things out for themselves” (FI1), and it “allows you to gauge what students already know and then base your teaching upon that” (FI1). In articulating these themes, the preservice teachers often referenced their own particularly memorable teachers they had embodied these traits. They also contrasted the form of effective science teaching and learning with secondary and post-secondary level science courses they felt had exhibited the opposite characteristics.

The preservice teachers initially articulated inquiry loosely in terms of asking questions using a particular set of practices to seek answers to those questions. Mike noted that questions were “the launching point for getting students to think about science” (FI1) and that “asking questions is a good way to orient inquiry into science: it’s challenging students and breeds exploration” (Journal, 9/10/07). Kelly described inquiry as a question- and explanation-driven practice through which student learning can be effectively promoted, writing, “students must be able to ask effective questions through inquiry and pursue explanations to those questions in scientifically-sound ways” (Journal, 9/10/07). Similarly, Lauren wrote that “typically, a question or topic is posed for discussion [and] the teacher allows the students to discuss their ideas and possibly form a hypothesis to prove/disprove” (Journal, 9/11/07). As evidenced in Lauren’s journal,

vestiges of more traditional notions of the scientific method were often apparent in the preservice teachers' early espoused inquiry frameworks.

However, the preservice teachers rarely articulated specific features of the epistemological practices they felt should be used to address these questions, instead only acknowledging that these practices exist, help answer scientific questions, and are accepted within the community. When asked explicitly about the various inquiry practices they had been introduced to, the preservice teachers often struggled to articulate substantive descriptions of these practices and the teachers' role in supporting them. For example, when asked about supporting students' collection and organization of data and evidence, Mike said, "I think that's important [but] I don't know how I'd do it yet, so it's difficult to speak on" (FI1). At this point in the semester, then, the preservice teachers were still largely working to articulate specific inquiry-oriented science teaching and learning practices in which they sought to engage.

Unlike Kelly, Mike, and Lauren, however, Aliza articulated a fairly robust inquiry model early in the semester. She described inquiry early in the semester as "questioning, evidence and explaining, communicating and justifying" and stated that "I know what the steps are" (FI1). She noted that "I think my ideas about science are pretty similar to the inquiry model and most of everything that we've been talking about [in class]" (RT2). As she had throughout the semester, Aliza described the inquiry practices emphasized in the methods course, writing, "includes the ability to develop an investigating question, design an experiment, collect and analyze data, and communicate and justify the results to themselves and to each other" (Journal, 12/4/07). Aliza said that she did not feel as though her conception of inquiry had evolved over the course of the semester, saying, "I don't know that they've really changed that much" (RT2). Aliza largely attributed this to her experience in the plant lab, saying, "I mean the whole inquiry process, that's what we do in the lab so maybe I was thinking that way before" (RT2). In this way, Aliza contrasted with the other three preservice teachers.

Mobilizing inquiry models in curriculum planning - preservice teachers' first curriculum design cycle. In their first reflective teaching assignment (RT1) during the methods semester, the preservice teachers were afforded their first opportunity to use their espoused inquiry frameworks to plan a science lesson as illustrated in Figure 5.2.

By the time the preservice teachers were working on their RT1 science lessons, they had been provided opportunities in the methods course to discuss various models of inquiry-based teaching and learning, as well as engage in experiences in which they applied these models the critique of existing lesson plans and video cases of teaching.

As shown in the previous section, Kelly, Mike, and Lauren's espoused inquiry frameworks as this point in the study were general and representative of their existing ideas about effective science teaching. Not surprisingly, these themes were prominent in their first science lessons (RT1), as was their goal of making science fun and engaging. The adaptations these three preservice teachers made to their RT1 lessons largely reflected their emphasis on making science more engaging through more student-driven, hands-on experiences. They also reflected the generality of their espoused inquiry frameworks and relative lack of specification for inquiry practices.

Kelly, Mike, and Lauren taught highly discussion-based lessons. Kelly, for example, taught a lesson in which students discussed waste in the environment, were shown a series of overhead transparencies that highlighted insect decomposers, and then, again as a whole class, discussed the role these organisms play in decomposition. Kelly noted she "tried to include what I could where I could, as far as allowing students to have more input themselves and thinking about how they might investigate decomposition" (Pre-Enactment Interview 1). For example, Kelly added a Know-Want to Know-Learned (KWL) activity to the introduction of her lesson, in which students recorded their existing ideas and what they hoped to learn about decomposers. Kelly suggested this would "stir the students' brains more right away and open the lesson in an interactive manner" (RT1). Kelly also embedded a series of discussion question to ask students during the presentation of the slides, arguing that it was important "just to keep them engaged, otherwise it will just be like me lecturing to them" (RT1).

Similar to Kelly, Mike's first lesson involved students brainstorming a list of items to take on a hypothetical trip to Mars. The purpose of this lesson was to promote students' learning about human survival needs and characteristics of Earth and Mars. The existing lesson plan Mike used involved a highly teacher-directed discussion. Mike chose, instead, to incorporate more small-group work into the lesson, writing that he "made this change to increase the inquiry of the lesson" (RT1) and that his "lesson is

inquiry-oriented because I have ample opportunities to let students share ideas and discuss” (RT1). Specifically, Mike wanted “students to bounce ideas off of one another before I got up and started to write them down” and to make it more engaging for students by “working in small groups [and getting] different points of view” (RT1).

However, neither Mike, Kelly, nor Lauren felt as though the lesson plans they used were very inquiry-oriented. Because these lessons did not include typical features the preservice teachers attributed to effective science (i.e., experiments), they each reported struggling to apply their inquiry models to the task of planning their lessons. Kelly noted that she “was trying to include things that we’ve read about in our book that are more project-based science” (Post-Enactment Interview 1). However, she also said her science lesson was not very inquiry-oriented and “was probably not the best choice for forming an inquiry-based lesson” (RT1) because “you can only use so much inquiry when teaching about a new idea (the function of beetles)” (RT1). Even after teaching, Kelly struggled to visualize how she might make this particular lesson more inquiry oriented, saying, “I don’t know how I would change it to be an investigation in this case” (Post-Enactment Interview 1). Similarly, Lauren was highly critical of her lesson, writing, “the lesson did not give students the opportunity to formulate their own ideas or questions about habitats. They did not have a problem/questions to investigate; therefore, they did not solve anything. I felt this was more of a lecture than anything experimental” (RT1). While reporting her addition of leaf-rubs made her lesson more hands-on, Lauren also acknowledged that, “I don’t think it affected the [lesson’s] inquiry-based orientation” (RT1). And even though Mike felt that his revised lesson was more inquiry-oriented, he also acknowledged that “lessons without experiments are harder to make inquiry-based” (RT1).

In contrast to the other three preservice teachers, Aliza’s first lesson was an investigation-based lesson in which students discussed the survival needs of plants and designed an experiment to test the effects of nutrient availability on plant growth. Like Kelly and Mike, Aliza believed her adaptations “[made] the lesson more student-oriented than teacher-oriented” (RT1). Aliza made three distinct adaptations, each of which targeted specific inquiry practices. First, she added an element to engage students in an introductory discussion to elicit their existing ideas about how plants grow. Second,

before students actually set up their experiments, Aliza modified her lesson to have students be more engaged in constructing an experimental design and discerning what data to collect. Aliza was particularly focused on “getting [students] thinking like little scientists” and said her lesson was “great so I can tell them, I work in a science lab and this is part of what we do...it’ll be just like what I do at work.” (Pre-Enactment Interview 1).

In summary, Kelly, Mike, and Lauren’s first efforts to apply their espoused inquiry frameworks to curriculum planning resulted in less strategic adaptations and lessons that were, for the most part, no more inquiry-based than those with which they began. In each case, they articulated inquiry models that emphasized student-directedness and hand-on experiences and did not draw upon specific inquiry criteria. For Kelly, Mike, and Lauren, this was exacerbated by the discussion-based, non-investigative lessons they had to work with. Aliza, however, began with a much more investigation-based lesson and, though she did not explicitly draw upon inquiry criteria to justify her changes, she did adapt the lesson in ways that addressed specific inquiry practices, as well as how student-oriented her lesson was.

Instrument-construction - preservice teachers’ evolving inquiry models. Recall that the preservice teachers’ inquiry models are situated as instruments in curriculum planning, as illustrated in Figure 5.2. In characterizing their espoused inquiry frameworks, evidence suggests that as the methods semester progressed, the preservice teachers continued to refine and elaborate upon their espoused inquiry frameworks, the crucial tools they employed in the production of planned science lessons in curriculum planning. For Kelly, Lauren, and Mike, the development of their inquiry models was markedly observable. Mike, for example, noted that “I didn’t understand [inquiry] at first but I’m really starting to grasp it” (FI2). Similarly, Lauren noted that earlier in the semester “I had no idea, I think I just thought it was like a general concept” but that by the end of the methods semester, “I know what inquiry means” (FI2). Each of them was actively aware of how their conceptions of inquiry had changed by this point in the semester through their work in the methods course and their first reflective teaching assignments.

This evolution was evident in a number of changes. First, the preservice teachers began to recognize that classroom inquiry did not need to be entirely student-driven, a major shift in their espoused inquiry frameworks. Mike said that at the beginning of the methods semester, “I really didn’t understand [inquiry] at first” and “was thinking inquiry was that students had to lead everything” (FI3). Similarly, Lauren noted that she had perceived inquiry as a set of practices in which “kids could generate questions that they wanted to know about and then you would base your lessons off of that to address their questions. So it’s like the kids are kind of setting the tone for what your unit was going to entail” (FI2). Over the semester, however, Kelly, Mike, and Lauren had instead begun to articulate inquiry models of inquiry in which classroom activity was more teacher-directed. In each case, this was an important transition that gave the preservice teachers confidence moving forward. Kelly, for example, said,

...if you let students ask their own questions and pursue those questions, it’s easier to do inquiry that way. But you can have it teacher-directed and still be inquiry-based...I guess it’s kind of a relief for me to know that you can still do inquiry that’s teacher-directed (RT2)

Second, in addition to recognizing that inquiry can be more teacher-directed, the preservice teachers also began to articulate and describe more robust constituent inquiry practices than they had earlier in the semester. Whereas they had espoused generalized and more global conceptions of inquiry earlier in the semester, they now discussed their inquiry models in detailed terms. For example, Lauren noted, “my idea of inquiry is a lot more structured than it was in the beginning” (FI2). In her final journal entry of the semester, she elaborated on this claim and described classroom inquiry, writing,

An investigation question is explicitly stated, and is what the students aim to answer by the end of the lesson. Students record their initial ideas/claims/predictions about the investigation question. Students then design an experiment or activity to solve the investigation question. They observe and collect evidence, then record their findings in some sort of organized manner (table, graph, etc.). Students then use the evidence to come to some sort of solution (answer to the investigation question) and explain their reasoning within their small group. The class can then convene for a class-wide discussion where the teacher can record each group's findings/explanation. This allows each group to communicate their ideas to the class. The collection of class wide data also shows trends or outliers in the data. Students (and teacher) can then tie their findings back

to the investigation question. They can revisit their initial ideas/predictions and revise them based on evidence if need be. Students can then answer and explain the investigation question, and from there form a new investigation question. (Journal, 12/11/07)

Lauren's quote illustrates a model of inquiry consistent with those articulated in the methods course and in science education reform.

This same trend was evident for Mike and Kelly. Kelly, for example, reiterated that "at the beginning [of the semester] I guess I just thought of [inquiry] as asking questions and discussing, and like building your lessons off of those questions" but acknowledged that she "learned that it's more than that...it has different parts to it, like the communication aspect, the predicting, and using evidence to back up your communication and explanations" (FI2). However, in addition to adding these dimensions to her inquiry model, Kelly also linked them directly to student learning, her consistent goal for curriculum enactment. She said,

I really liked putting a driving question on the board and, you know, just having effective discussions and making sure that they always link back what they discovered to their evidence, like their explanations to their evidence. I just keeping those few things clearly in mind throughout the lesson. I think in any subject you always need to back things up with evidence so I think it's really important to stress that. I know all the lessons are different but just really pushing them to communicate how they know what they are telling me, like the why. (FI2)

This quote illustrates how Kelly had begun to expand the utility of her inquiry model in relation to her goal of promoting student learning. In addition to having investigation questions to focus classroom activity, she began linking explanation-construction to these questions in inquiry-based sense-making.

Similarly, at the end of the methods semester, Mike argued characterized inquiry as "a science lesson where students not only predict and carry out an experiment, but also use analyze their information to make a supported conclusion" (Journal, 12/11/07). Mike reflected that in his earlier inquiry model, saying, "I was missing how to get students to use and analyze data, and then how to communicate it to their peers" (FI2). However, by the end of the semester, Mike had begun prioritizing the use of investigation questions, analyzing evidence, and making explanations, saying, "those are the 3 parts that I definitely focus on when I look at a lesson" (FI2).

In sum, Kelly, Mike, and Lauren experienced important shifts in their conceptions of inquiry during the methods semester. The evolution of their inquiry models largely took the form of increasing emphasis on teacher-directed inquiry and appropriation and articulation of specific features of classroom inquiry. Defining and explicating these inquiry models was an important step for the preservice teachers' curriculum design efforts. Aliza, in contrast, articulated a more robust inquiry model early on that did not drastically change during the methods semester.

Instrument-construction - influence of the methods course and elementary classrooms on preservice teachers' inquiry models. As shown in the previous section, the preservice teachers' espoused inquiry frameworks evolved substantially during the methods semester. This shift was driven largely by experiences in the methods course through which the preservice teachers articulated a quaternary contradiction between their existing inquiry models and those being promoted in the methods course. This relationship is shown in Figure 5.3.

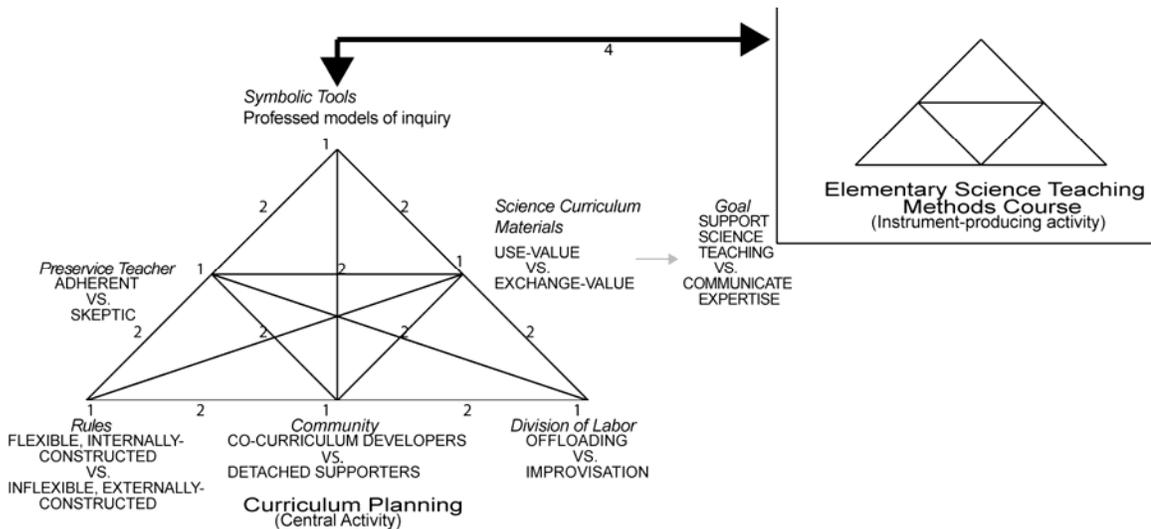


Figure 5.3. Influence of Elementary Science Methods Course as an Instrument-Producing Activity Supporting the Development of Preservice Elementary Teachers' Espoused Inquiry Frameworks

This contradiction served as a positive and productive tension the preservice teachers were forced to resolve. As shown in the previous section, they did so by reconciling their existing conceptions of science teaching with the reform-based inquiry frameworks

promoted in the methods course. In this sense, then, the methods course played an important role in supporting the preservice teachers to construct a more robust, articulated, and usable inquiry model than they espoused early on. In their reflections on the methods course, the preservice teachers highlighted specific learning activities that supported the development of their inquiry models. These activities fell into two sets: one that provided preservice teachers opportunities to explicate their inquiry models and another in which they applied them to professional tasks.

First, the preservice teachers highlighted opportunities they had to represent and negotiate their inquiry models. Two particularly critical turning points emerged in respect to these opportunities. The first was a whole-class discussion that occurred after the preservice teachers completed their first reflective teaching assignment. In this discussion, the class discussed both effective and less-effective examples of inquiry practices from their first reflective teaching lessons. As Mike suggested, “I think kind of your feedback on the first RT and then the class discussion when we talked about, I think those were the two major turning points [for me]” (FI2). Kelly elaborated on this experience, saying, “I think people just forgot the starting point, you know?...we’d been working with [inquiry] so much but where did it all begin? Like what was the origin, the first model that we were working from?” (FI2). The experiences that followed their first reflective teaching assignment, then, were important for revisiting and revising the preservice teachers’ espoused models of inquiry. The preservice teachers also highlighted an in-class activity around this time in which they worked in groups to actually produce representations of their inquiry models. Mike reflected that “the modeling...I learned a lot from that... it kind of clarified a lot of things for me” (FI2) and Lauren noted it was a critical learning event for her, saying, “I do credit that modeling thing because after making the model of it, that’s when I think I had an ‘oh, I get it’ sort of moment” (FI2).

Second, the preservice teachers emphasized the importance of opportunities they were afforded to interact with and use science curriculum materials. Specifically, they highlighted opportunities to apply their inquiry models to lesson planning in their reflective teaching assignments and lesson critique assignments. As Kelly said, for example, “I think just learning about what inquiry-based science is and having a concrete

idea then in your head, transferring that to when you're making the lesson. I think that's mainly what helped me" (FI2). Similarly, Lauren highlighted the value of the lesson critique assignments, in which the preservice teachers evaluated existing lesson plans using various criteria, saying, "I think all of the lesson analysis, those were helpful to look through a lesson and then try to decide how to make it more inquiry and modify it" (FI2). She also recalled that in the reflective teaching assignments, "The reflection was what I think was the most helpful, and the planning" (FI2). These experiences had direct impacts on the preservice teachers' lesson planning. Aliza said, for example, that the critique assignments were "really good practice for working on my own lesson plans...changing my own lesson plans to fit what I thought that my class needed and trying maybe to make it a little bit more inquiry-oriented" (FI2). Mike reiterated Aliza's comments, saying that even though "We're doing basically the same thing" in both assignments, "it was easier for me to see a different lesson plan for some reason than when I was trying to teach myself. I don't know why it was but I kind of saw inquiry better and knew what to look for me in the lesson critique assignments than I did in my own lesson plans" (FI2).

In sum, the preservice teachers described specific activities in the methods course that were important influences on the early development of their espoused models of inquiry. These opportunities for learning not only allowed them to explicate and negotiate what classroom inquiry was, but also valuable experiences using these tools in assignments that directly related to their curriculum design for inquiry. For Kelly, Mike, and Lauren, these experiences were particularly crucial in supporting them to develop less generalized and more practice-specific inquiry models like that which Aliza had articulated early in the year, thus allowing them to employ these instruments in their curriculum planning.

Summary. An important first phase in the preservice teachers' learning to engage in curriculum design for inquiry was focused on constructing and learning to employ a more robust, multifaceted model of inquiry. Not surprisingly, Kelly, Mike, and Lauren began the semester with conceptions of science teaching and learning that were highly student-directed, emphasized hands-on activities, and primarily concerned with promoting student fun. Their early inquiry models were very generalized and exhibited a

hybridization of, on the one hand, these characteristics of science teaching and learning and, on the other, specific inquiry practices they were being exposed to for the first time in the methods course. Their first planned science lessons reflected their relatively vague and ill-defined models of inquiry. In contrast, Aliza began the year with a more well-defined inquiry model and taught a more investigation-based lesson, thus facilitating more effective adaptations to her first lesson. The methods course provided all of the preservice teachers with important opportunities to further develop and refine their espoused models of inquiry. By the time the preservice teachers began planning their second reflective teaching assignments, their capacities to make more effective adaptations were enhanced by their more robust and more usable inquiry models.

Curriculum Planning – Planning for Subsequent Science Lessons

By their second reflective teaching assignments, the four preservice teachers began to engage in patterns of curriculum design for inquiry that would remain relatively stable throughout the year. This involved, first, beginning to employ their inquiry models as explicit frames through which they critiqued and adapted science lesson plans and other curriculum materials they used. Particularly for Kelly, Mike, and Lauren, this involved engaging in curriculum planning in a way that reflected their more articulated and practice-specific inquiry models, as described previously. In doing so, second, they all began to emphasize specific inquiry practices in their adaptations. This stands in contrast to their adaptations to their first science lessons, as discussed previously.

These results again are based in the production triangle of the preservice teachers' curriculum planning activities, as presented earlier in Figure 5.2. The adaptations the preservice teachers made in their curriculum planning were driven primarily by secondary contradictions between their inquiry models and features of the curriculum materials they used. In this section, I provide evidence for, first, how they employed their inquiry models to engage in curriculum design and, second, the specific inquiry practices they emphasized through their adaptations.

Inquiry became an explicit tool with which the preservice teachers evaluated and modified the science curriculum materials they used. In the CHAT-based model of curriculum planning shown in Figure 5.2, this interaction between the preservice teachers and the curriculum materials they used is illustrated by the uppermost triangle (the

production triangle) of the curriculum planning activity. Mike noted that as he began to employ a more robust inquiry model in curriculum planning, the process became easier, saying, “I started to see things differently...the concept of inquiry. Once I had that concrete in my head, it just clicked all the sudden” (FI2). He noted in his first lesson, for example, “I was trying to make everything student-directed [and] fun...the learning goal wasn’t the main priority for me at that point” (FI3). Mike said that, “Once I was familiar with [inquiry] and kind of understood that better, planning just seemed to come easier to me” (FI3). Mike again reported feeling as though inquiry was synonymous with effective science teaching. Similarly, when asked how successful she felt she had been at adapting her lessons to make them more inquiry-based, Lauren said, “the first one not really at all...but I think by the second one I had a stronger, more clarified grasp or idea of inquiry, so I felt like I was able to kind of tweak it and make adjustments to make it inquiry” (FI2). The preservice teachers were therefore aware of the new opportunities for curriculum design their evolved inquiry models afforded. Kelly, for example, reflected on her curriculum planning, saying, “learning about what inquiry-based science is and having a concrete idea then in your head, transferring that to when you’re making the lesson...just having those ideas in mind...that helped me form what I put into my lesson plans” (FI2). Kelly elaborated, saying, “I wouldn’t have used it as a framework had I not have taken this class” (FI2).

In employing their inquiry models to engage in curriculum planning, the four preservice teachers largely adopted a 3-part framework discussed in the methods course. This framework included three inquiry criteria: questioning and predicting (Q), making evidence-based explanations (E), and communicating and justifying findings (C). Kelly recalled, for example, “questioning, explanations, and communicating, yeah, just having those 3 in my mind and being able to draw upon those [in curriculum planning]” (FI2) while Mike said “those are the 3 parts that I definitely focus on when I look at a lesson, those are the 3 criteria I focus on” (FI2). Of the four preservice teachers, however, Lauren’s explicit use of her inquiry model was most substantial. Lauren described how she had begun using this inquiry framework as an explicit tool, saying, “I always print off the lesson plan and then I block off an area and say this is the Q, block off another area and say this is the E, and this is the C. And so when I’m doing that it allows me to see

like what places are missing something or, you know, that's just how I look at them" (FI1). Lauren said that "I honestly think that doing that little QEC thing is really helpful" (FI2), primarily because it helped her identify elements of existing lesson plans that aligned with her inquiry model. She said, "I just liked the QEC because it was just like a really easy way to look at an overwhelming lesson plan....you can break it down into segments" and "mark up the lessons, which is the Q, which is the E, which is the C, and if any substantial part is missing I can change and add in things" (FI2). After using this curriculum planning tool, she noted she "definitely feel less intimidated" by having to adapt lessons. Lauren's developing confidence in using the QEC inquiry framework as a tool was important since she believed "it is definitely crucial to make adaptations to science curriculum materials - if you never critique or question, you are not doing your job as a teacher" (Journal, 12/11/07).

Inquiry Practices Targeted through Post-RTI Curriculum Planning

As they began to employ their more robust and articulated inquiry models, the preservice teachers also began to emphasize specific inquiry practices that they had not, for the most part, emphasized in their first science lessons. However, they did so in unique ways and to varying extents, representative of their individual priorities and emphases for science teaching (curriculum enactment). In the sections that follow, I provide evidence for how the preservice teachers employed their espoused inquiry frameworks as instruments to adapt existing curriculum materials to address each of the five inquiry practices that comprise QEC and that were promoted in the methods course. These results provide a fine-grain examination of the production sub-process of curriculum planning for inquiry.

Engaging students in scientifically-oriented questions and questioning. In inquiry-based science, students engage in scientifically-oriented questions that they seek to answer to develop understandings of natural phenomena. Of the inquiry practices discussed in the methods course, engaging students in scientifically-oriented questions and questioning was the most readily observable in the preservice teachers' curriculum planning. As shown earlier in this chapter, the preservice teachers prioritized the use of questions and questioning in their initial conceptions of effective science teaching at the beginning of the methods semester. However, Mike, Lauren, and Aliza's focus on

engaging students in scientifically-oriented questions and questioning was sporadic over the course of the study. Though they had each articulated questions and questioning to be a crucial aspect of inquiry, this did not always emerge in their evaluation of the science curriculum materials they used. Across the science lessons they planned and taught throughout the year, these three preservice teachers used engaging students in scientifically-oriented questions and questioning as a criterion for evaluation and adaptation in seven of their 12 science lessons. In many of these instances, Mike, Lauren, and Aliza discussed engaging students in scientifically-oriented questions and questioning when the lesson plans they were using already included investigation questions (Mike RT1, Lesson 4; Lauren Lesson 3; Aliza RT1). These instances did not result in any adaptations related to questions and questioning.

However, more so than the other three preservice teachers, Kelly's curriculum planning was centrally-focused on engaging students in scientifically-oriented questions and questioning, particularly the use of investigation questions. Kelly used this inquiry criterion in all four lessons. In Kelly's first lesson, for example, she critiqued the existing lesson plan as effective in that it did include an investigation question. Following her first science lesson, Kelly noted that she hoped to do make engaging students in scientifically-oriented questions more student-directed, saying, "I want to prompt students to come up with good investigative questions, rather than myself...by giving them the prompt to create an investigation question and offering them scaffolding to do so, I would know if they could form effective scientific investigation questions on their own" (RT1).

In the other three science lessons Kelly taught over the course of the year, she made adaptations that engaged students in more student-directed questioning practices. Specifically, she had students co-construct lesson-specific investigation questions with her assistance during the lessons. For example, while Kelly said that her second lesson was inquiry-oriented because, as she wrote, "the meat of this lesson *is* an investigation" (RT2), she also said that it was not highly inquiry-oriented because, "students are not creating the investigation question themselves. Instead, the idea of the lesson is given to them" (RT2). To address this secondary contradiction between the lesson plan and her model of inquiry, Kelly added an investigation question to her second science lesson

(RT2) because “including an investigation question with the lesson helps keep students focused throughout their investigation on what they are trying to figure out”. As indicated in this quote, Kelly engages the students in formulating the investigation question that will guide their examination of evidence and sense-making. She said,

...this makes the lesson more inquiry-based because I allow students to help me form the question for our experiment. While the experiment is pre-planned, I am not telling them what we are investigating here, but allowing them to figure it out. Further, an investigation question includes many subquestions that students can seek the answer to themselves (RT2)

Following her lesson, Kelly suggested her addition of the investigation question was effective, saying, “it was good to have a question up on the board, just for them to look at and for me to refer to” (RT2). Kelly also said that “students had no trouble coming up with a question about how fungi survive or how they get their nutrients” (RT2) and indicated that she liked having students participate in developing an investigation question.

As with her second science lesson, Kelly continued to add investigation questions to her third and fourth lessons. In her third lesson, like her second, Kelly added an element to the lesson in which she supported students to come up with an investigation question rather than her simply providing them with one. She wrote that “this definitely creates a more inquiry-oriented investigation” and that the “investigative question will be helpful to refer back to throughout the experiment” (Lesson 3). In her fourth lesson, Kelly reintroduced the investigation question from her third lesson as a tool to support students’ interpretation of their graphs and support their formulation of evidence-based explanations. This trend was consistent for Kelly throughout the study and, as I show in later sections, engaging students in scientifically-oriented questions and questioning remained the linchpin of Kelly’s professed model of inquiry at the end of the year.

Supporting students gathering and organization of data and evidence. In inquiry-based science, students give priority to evidence, which allows them to develop and evaluate explanations that address scientifically-oriented questions. Throughout the study, the preservice teachers often referred to the importance of having students engage in the collection and organization of data and evidence. This was consistent with the early emphasis they placed on hands-on activities for science and their own experiences as science students. For example, as Kelly described in the middle of the study,

...you can't just have the question and just leave it...you need to gather evidence...and model it in a way by a table or whatever in a way to make sense of that evidence. If you just had an idea and just like, a lot of kids would just want to, you know, I think this is the answer because..., it's really important to have concrete supporting evidence and facts. You need to come up with your class about what constitutes good evidence, like valid evidence, otherwise your conclusion isn't supported. (FI2)

This criterion was used in seven of the of the preservice teachers' 16 lessons (Aliza, RT2; Lesson 3; Lauren, Lesson 4; Mike, RT1; RT2; Lesson 3; Lesson 4). Mike was the only preservice teacher who explicitly emphasized this inquiry practice in each of his four science lessons. The preservice teachers made few adaptations to their lessons that explicitly focused on better supporting students' collection and organization of data and evidence. For the most part, the preservice teachers were often satisfied with opportunities provided by their lessons to engage students with data and evidence. For example, like Kelly's third and fourth lessons described previously, many of the lessons the preservice teachers used included opportunities for students to record and graph data.

There were, however, a few examples of the preservice teachers' adaptations for collecting and organizing data and evidence. First, Aliza sought to adapt her first lesson to make existing opportunities to engage in data collection and organization more student-directed. In Aliza's first lesson, students set up an experiment to test plant growth under different conditions (organic vs. inorganic materials). Aliza had students discuss and negotiate, as a class, what specific variables they could and should measure as effective evidence of plant growth. This was part of a broader whole-class discussion that Aliza facilitated to support students to set up their plant experiments in the lesson. Aliza argued that "this makes the lesson more inquiry-oriented" because the lesson was "more student-oriented than teacher-oriented, elicits students' ideas instead of feeding them ideas, and engages them in scientifically-oriented questions" (RT1). She also suggested that "students will remember the [data] criteria we are looking to observe better if they come up with it themselves than if I just give it to them" (RT1). In making this adaptation, Aliza also expressed confidence in her students' ability to articulate data categories, writing, "my class is very smart" and in her ability to facilitate them doing so because "I've had experience in the lab that I work in, you know, it's a plant lab. I have grown my own flats of plants, kept track of all these qualities" (Pre-Enactment Interview

1). Aliza also noted this would be more engaging for students because “it’s great so I can tell them, I work in a science lab and this is part of what we do” (Pre-Enactment Interview 1). While this adaptation did not ultimately make the lesson more inquiry-oriented, it is evidence that Aliza was emphasizing students’ collection and organization of data and evidence in her curriculum planning. It also shows that in doing so, Aliza was not only working to promote student learning but make science engaging for students.

One instance in which one of the preservice teachers did make an adaptation to more effectively support students’ data collection and organization was Mike’s second science lesson. Mike’s second lesson involved students using various tools as models of bird beaks to explore adaptation. Mike wrote that his change involved “the addition of a data collection table” in which he had “each student write which tool they had and then record how much food they were able to gather at each station” (RT2). While Mike noted that there was a student journal page to go with the lesson, he felt as though it was not effective and students would “not collect any data to support their conclusions” (Pre-Enactment Interview 2). Mike felt as though his addition of this data collection table “definitely...made my lesson more inquiry-oriented” (Post-Enactment Interview 2). As Mike noted later,

I think the major thing is to have them practice gathering [data]...a lot of the lessons that I was doing...never had data collection tables or anything, [students] were just told to remember [data] in their head and recall or whatever. I felt it was important to get students to just collect data. In both of my lessons I created worksheets for them to fill in information just to get them in the habit of being able to gather information and we talked about analyzing. I think it’s important to start off right away in your science lessons either to create a science notebook or something for them to be able to record their own observations or data, even if you don’t specifically tell them to. (FI2)

This adaptation ultimately made Mike’s lesson more inquiry-oriented than the original lesson plan.

Formulating and communicating evidence-based explanations. In inquiry-based classrooms, students formulate, communicate, and justify explanations from evidence to address scientifically-oriented questions. As discussed earlier, the preservice teachers increasingly emphasized student learning as a goal for curriculum design over the course

of the study. Many of their adaptations were oriented towards student sense-making. In particular, they focused more, over time, on students' use of evidence to justify claims. This criterion was used in 10 of the of the preservice teachers' 16 lessons (Aliza, RT2; Lesson 4; Kelly, Lesson 3, Lesson 4; Lauren, Lesson 3; Lesson 4; Mike, RT1; RT2; Lesson 3; Lesson 4). As with engaging students in the collection and organization of data and evidence, Mike was the only preservice teacher who emphasized engaging students in formulating and communicating evidence-based explanations in each of his lessons. It is clear that the preservice teachers' use of this criterion became more frequent over time.

To report and discuss these results, I combine two of the inquiry criteria articulated in the five essential features of inquiry (NRC, 2000): formulating explanations from evidence and communicating and justifying explanations. I do so primarily because, for the preservice teachers, especially Kelly, Mike, and Aliza, these two criteria were largely inseparable, both in terms of their espoused inquiry frameworks, the adaptations they made to their lessons, and the classroom practices they sought to promote. Aliza perhaps best illustrated this issue. Aliza had trouble distinguishing between making evidence-based explanations and communicating and justifying explanations, saying, "any form of their expressing their thinking would be communicating and justifying, right? So I'm thinking I don't know where that explaining part really fits in then" (FI1). Aliza elaborated, saying,

...maybe it would be assumed that if a student can communicate whatever the results then they understand it themselves, I guess. It's just...the whole explaining, I don't know how you would really be able to separate that, I guess...cause to me explaining sounds like something that you would do to other people. (FI1)

Interestingly, Aliza's confusion about this distinction was related to her own experiences as a participant in scientific practices. She said,

The reason why it was sort of unclear to me is because I've done a lot of work in science and I guess the explaining, the way that you would explain would be...you know, you do an experiment, and then you keep track of everything, write down the results, that kind of is your explaining. If you publish a paper or something, that would be communicating to other people and you have your justification but it's still explaining (FI2)

This issue was similarly apparent with each of the other three preservice teachers.

In making adaptations to better support students' formulation and communication of explanations, the preservice teachers tended to make two types of adaptations. The first involved having students explicate and justify their existing explanations. Lauren was perhaps the best example of this, in large part because she had to find unique ways to support students' explanations given that three of her four lessons were introductory lessons that did not include substantial sense-making components. In Lauren's second lesson, for example, she had students provide evidence for the knowledge claims they contributed to the 'Know' column in the Know-Want to Know-Predict-Learned (KWPL) chart she had students construct. Specifically, had students provide the source of their ideas, which she recorded on the KWPL chart next to their claim. She argued that this change "helped limit their contributions to more legitimate statements. It also forced the students to back their claims" (RT2) and "they have to justify their knowledge but that they can't say that they just know, tell them you want something more" (Pre-Enactment Interview 2). With no post-investigation sense-making piece to the lesson, Lauren had applied her understanding of these inquiry practices to have students warrant their existing explanations as part of eliciting students' ideas.

Similarly, the preservice teachers often added elements to their lessons to have students make predictions about the phenomenon of interest. This was often a strategy through which to support students' comparisons of explanations, as I discuss more thoroughly in the next section. However, the preservice teachers typically did not distinguish between students' existing explanations and predictions since, for the latter to be justified, they would have to be based on the former. In Lauren's second lesson, she also made two changes focused on student sense-making. First, she eliminated the prediction column from the KWPL because she thought it was redundant. In effect, Lauren argued that students' predictions about the moon would essentially reflect their ideas already recorded in the know column of the KWPL chart, saying "I don't see how the predictions are any different from the know column in things that they would say" (Pre-Enactment Interview 2). She elaborated, saying,

...if someone said that the moon gives off light someone will say that because I know they think that – and then we debate about it and write it in the want to know, does the moon give off light? And then the predictions, if any anyone's going to predict anything, it'll be like the

moon does, the moon does not give off light. Especially if the know column isn't actually knowledge, it's predictions of what they think they know. (Pre-Enactment Interview 2)

In both her first and second reflective teaching assignments, Lauren's changes were therefore aimed at promoting student sense-making and the use of evidence to support explanations.

Kelly's increasing emphasis on supporting students' use of evidence to make claims was also evident in her other adaptations to her third and fourth lessons. Kelly inserted an element into her third lesson to have students make predictions about the conditions under which mold will grow the best, encouraging students to use their existing knowledge to make predictive claims. Kelly argued that the predictions "reinforce the investigation question and gets [students] asking questions in their own head and making predictions on what they already know and just reinforces what they're trying to discover" (Pre-Enactment Interview 3). Kelly specifically noted that she planned to support students to back up their predictions with evidence, saying she would, "ask them why, like what's their reasoning behind it and see if it's something they know from home or something we've learned in class. I definitely want to know why they were making the predictions" (Pre-Enactment Interview 3).

Second, through their adaptations, the preservice teachers also sought to support students' post-investigation formulation and communication of explanations, or sense-making after they had carried out new investigations and/or activities in the classroom. For example, in Lauren's first lesson, she struggled with adapting a conclusion to her lesson, saying, she "just [had] to figure out how I should end it" (Pre-Enactment Interview 1). As described earlier, this lesson had students use evidence from the text to accurately place various organisms in their habitats within a large tree displayed on the wall of the classroom. First, rather than having students merely place organisms on the tree, she wanted to have "each group place their organisms on the tree mural while explaining why they were placing them where they did" (RT1), using evidence from the text they read in the lesson. Lauren noted that she hoped to use students' explanations to have an end-of-lesson discussion in which they discussed "their strategies for placing the animals in particular spots (leaves/branches/bark/trunk)" (RT1). Lauren also added a journal entry to promote student sense-making but also as an informal assessment for her,

both of which were oriented toward her goal of promoting student learning of specified learning goals. Lauren said the journal entry “will allow me to see what the students have taken away from the lesson with reference to what makes an oak tree a habitat, and what organisms reside in it [and] assess each student's understanding” (RT1). Ultimately, she developed a journal entry in which students responded to the question “Why did you choose to place your organism where you placed it on the tree?” (RT1). These adaptations did make Lauren’s lesson more inquiry-based and provided students their only opportunities to formulate and communicate evidence-based explanations.

Similarly, Mike used the data collection table in his second lesson to have students make claims about the suitability for certain bird beak models for different food types. The students’ formulation of explanations was based entirely in a whole-class discussion that followed the modeling activity in which the students used the various tools to pick up items. This discussion was an element Mike added to afford students the opportunity to share their results, collaborate, and formulate explanations. To promote students’ explanations, he decided first to confirm students’ observational data by “ask[ing] for volunteers to help me fill out my overhead copy” (RT2). Mike noted that in the subsequent discussion, he would ask students “how do you know the nails are best for picking up the gummy worms?” and “will ask students to back up their results with some of the numbers in the tables” (RT2). Mike noted his “hope is students will refer back to their table to give me an answer dealing with the quantities of worms they picked up” (RT2). Ultimately, Mike’s intent with this adaptation was to support students to understand that different bird beaks are better suited for certain types of food, one of his explicit learning goals for the lesson.

Comparing explanations. In inquiry-based classrooms, students evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding. To promote student learning, the preservice teachers made many adaptations focused on students’ formulation and communication of explanations. Ultimately, these explanations must be evaluated summatively as evidence of student learning by comparing them to other explanations, particularly scientific explanations. Of the five inquiry practices promoted in the methods course, comparing explanations was the least often explicitly addressed by the preservice teachers. For example, in their

critiques of their lessons, not once was comparing explanations used as a critique criterion. However, the preservice teachers did adapt their lessons in ways that better supported students to compare explanations and ultimately made their lessons more inquiry-based.

One primary strategy they employed was having students revisit their own prior explanations after engaging in an investigation or activity. For example, in Lauren's third lesson, students were given time to explore light using flashlights and mirrors, share ideas about where light comes from, and then use their experiences to construct models of light. As with her first two science lessons, her third lesson was another introductory lesson that fell at the beginning of a science unit. Lauren decided to add an introductory discussion at the beginning of the lesson before students use flashlights and mirrors to explore light. She wrote,

I think it will help to get the students thinking about their current ideas about light...[and]... to look for justification of their explanations when investigating. It will also help them notice if their initial ideas are incorrect. Lastly, I feel that it will help foster a more productive discussion after investigating if we have something to compare our findings with. The discussion of initial thoughts will help make this more inquiry-oriented (Lesson 3).

As Lauren noted, the purpose of this discussion was to explicate students' existing ideas about light so that later, students can revisit these initial explanations in light of new evidence and explanations that they had since constructed. Even though her goal was to promote student learning of predetermined learning goals, she noted that students' explanations that were misconceptions at this point were acceptable because it was another introductory lesson. She said, "I'd rather kind of put pre-thoughts and their knowledge base as-is out on the table whether it be misconceptions or not so that they can investigate and see, 'ok, I was correct about this' or, 'ok, this was not how I thought about it'. I want them to have something to compare it to. So that's kind of why I decided to change that" (Pre-Enactment Interview 3).

Mike also made adaptations that supported students' comparisons of explanations. For example, in his second lesson, the changes discussed previously were also oriented toward allowing students to revisit their initial predictions. Mike noted the new predictions/conclusion worksheet he created was useful "so [students] can compare their

answers and see if they predicted right or got it wrong, and then we could talk about that”, specifically noting it, combined with the data tables, “allows for students to support their explanations with evidence” (RT2). In his third and fourth lessons, Mike added elements to the lesson to provide students opportunities to make predictions and revisit them at the end of the lesson as part of a whole-class discussion. In his third lesson, Mike had students make predictions at the beginning and then said, “I’m going to try to wrap it up by talking about the similarities and differences they noticed in the seeds,..then I’m going to ask about the predictions and whether they thought everything in that initial seed was going to be in the other ones” (Pre-Enactment Interview 3). In his fourth lesson, Mike also made a change to have students work in small groups because students are “going to have their one idea...if they have a different idea, see a different model, then they might start making some different assumptions about how it happens” (Post-Enactment Interview 4). Mike argued in his fourth lesson that he was “trying to make is a connection between, you know, you look up at the moon and you see it look like it does, why is that? And then that will lead into my activity. Oh, ok, that’s why the moon looks like it does. And then the follow-up discussion will really hammer that home” (Pre-Enactment Interview 4).

Finally, a critically important strategy for engaging students in comparing explanations involves having students compare their own explanations to scientific explanations. It is important to note that few of the preservice teachers’ adaptations focused explicitly on reconciling students’ explanations with the scientific explanations targeted in predetermined learning goals. In fact, this issue of supporting students to meet predetermined learning goals through inquiry became a primary contradiction within their inquiry models and, as I illustrate later, emerged as a tertiary contradiction in their lesson enactments. This contradiction largely centered around the need to, on one hand, engage students in inquiry practices that can lead to unpredictable evidence-based claims and, on the other, the need for students to achieve predetermined learning goals and make claims that are consistent with scientific explanations. The preservice teachers recognized that inquiry could be an inherently unpredictable process. Evidence-explanations constructed through inquiry might or might not be consistent with scientific explanations. In terms of inquiry, then, this contradiction specifically revolved around

how to engineer learning environments such that the explanations that students construct through inquiry are consistent with scientific explanations that constitute learning goals. I return to this contradiction, as well as ways in which it played out in the classroom, in Chapter 6.

Summary of Curriculum Planning

In this section I have discussed the preservice teachers' espoused inquiry frameworks and how they employed them in curriculum planning for inquiry. These results suggest that three of the four preservice teachers, Kelly, Mike, and Lauren, articulated somewhat vague and ill-defined inquiry models at the beginning of the semester, which was evident in their adaptations to their first science lessons. Aliza, on the other hand, espoused a more defined and articulated inquiry model. Kelly, Mike, and Lauren developed more articulated and robust inquiry models through their work in the methods course. In their second, third, and fourth science lessons, the preservice teachers began to employ their inquiry models as critical tools in their critique and adaptation of curriculum materials as part of curriculum planning. They adapted their lessons to more effectively engage students in scientifically-oriented questions and questioning, gathering and organizing data and evidence, formulating and communicating evidence-based explanations, and comparing their explanations to other explanations. While their adaptations addressed specific inquiry criteria, the preservice teachers also discussed a primary contradiction within their inquiry models that would have a crucial impact on their curriculum enactment, which I turn to later. Next, however, I discuss the cultural mediation of the preservice teachers' curriculum planning.

Cultural Mediation of Curriculum Planning

As shown in the previous sections, the four preservice teachers engaged in curriculum planning for inquiry to support their goals of making science engaging and promoting student learning. These results were largely restricted to the production triangle of the curriculum planning model in Figure 5.2, or the uppermost triangle that includes the preservice teacher (subject), his or her espoused inquiry framework (instrument), and the curriculum materials (object). However, production is culturally-mediated and another purpose of these qualitative analyses was to investigate the role features of the preservice teachers' curriculum planning contexts played in explaining

adaptations they made to their lessons. In this section, then, I focus on the other nodes of the curriculum planning triangle – norms, community, and division of labor – that ultimately serve as cultural-mediators in the production of lesson plans described thus far.

Surprisingly, rarely did culturally-mediating elements of the preservice teachers' curriculum planning contexts explain adaptations they did make. This suggests that in explaining underlying rationales for the adaptations described in the previous section, the cultural nodes of the curriculum planning activity (rules, community, and division of labor) were largely in alignment with the preservice teachers' goals of instantiating inquiry in their revised lessons. Or, in other words, the preservice teachers' curriculum planning contexts afforded them the capacity to make the adaptations they did which, as shown in the previous section, were driven by a secondary contradiction between the preservice teachers' inquiry models and the existing science curriculum materials they were using.

The issue of autonomy is important here, however. The preservice teachers were, not surprisingly, in no position to negotiate these culturally-mediating elements. As students in the teacher education program and student teachers in schools, they were subject to dominant norms and predefined roles. Therefore, when these culturally-mediating elements were not aligned with the preservice teachers' goals for curriculum planning, the preservice teachers had no real ability to affect them to bring them into alignment with their goals and desired actions (in this case, adaptations). In short, they were generally unable to reorient the culturally-mediating elements of their curriculum planning contexts in ways that better supported their attempts to instantiate inquiry in their revised lessons. As a result, these culturally-mediating elements more often helped explain why the preservice teachers *did not* make additional adaptations to their lessons that they often described.

In this way, culturally-mediating elements of the preservice teachers' curriculum planning contexts largely served as constraining forces in the preservice teachers' curriculum planning for inquiry. Secondary contradictions often emerged between the preservice teachers' goals of adapting their lessons to make them more inquiry-based and various culturally-mediating elements of their curriculum planning contexts. For example, as described previously, Lauren had students provide evidence for their existing

explanations for lunar phenomena in her second lesson. Lauren had originally wanted to add another column to the students' KWPL chart to record evidence for their claims. However, she was constrained in doing so, saying, "[students] have generated KWPLs or whatever before for other units...that's why I think [my mentor teacher] wants me to stick to this format because that's what the kids are familiar with" (Pre-Enactment Interview 2). Ultimately, Lauren's decision to have students justify their ideas without adding another column was a way to resolve this contradiction. She said,

I don't know that I necessarily have the leeway to add in an additional 'how' column but I could facilitate the discussion in a way that I say, you know, 'whatever you have' to say, 'I want you to give me an explanation or justify how you know that'.... I mean I can get them to justify it a little more that way but I don't know if she's going to want me to add in another column (Pre-Enactment Interview 2)

Second, Lauren was hesitant to make substantial adaptations to her first two lessons because her mentor teacher was "trying really hard to stick to this curriculum" (Pre-Enactment Interview 1). Ultimately, Lauren found a way to have students provide evidence for their claims, even though she did not add another column to the chart. In this case, the influence of culturally-mediating elements in her curriculum planning context, specifically her mentor teacher (community), norms associated with using the new science curriculum materials (rules), and Lauren's limited autonomy (division of labor), did not result in a less-inquiry based lesson.

In Mike's fourth lesson, students dropped marbles into pans of sand to model the cratering of the Moon's surface. As Mike described, the primary learning goal for this lesson was for students to understand that "craters on the moon's surface were caused by impacts of rocks from space" (Pre-Enactment Interview 4). Mike noted that one of the existing lesson plans he used to plan his lesson "had, which I really liked and wrote in the lesson plan, having different sized objects to drop into the pan to create different sized craters" (Post-Enactment Interview 4). Mike argues this change would afford a more accurate model of the moon, saying, "if they drop their marbles from the same height, all the craters are going to look almost identical...so their models won't look exactly like what's on the surface of the moon" (Post-Enactment Interview 4). Mike suggested this proposed adaptation was directly related to the learning goal of the lesson, saying, "I thought a better model would help students make that connection that there are different

size asteroids out there and the different size asteroids make different size craters” (Post-Enactment Interview 3). Mike said “I would like to do that change but don’t think I’m going to be able to [because] my [mentor teacher] is going to be gone tomorrow” and felt as though it would be overstepping his role in the classroom to make this change without consulting her. As with the example of Lauren previously, Mike’s mentor teacher (community) and limited autonomy (division of labor) ultimately dissuaded him from making this adaptation.

In other examples, however, the restrictive influence of culturally-mediating elements of the preservice teachers’ curriculum planning for inquiry did result in less inquiry-based lessons than they might have otherwise constructed. In Lauren’s fourth lesson, students were introduced to the terms translucent, transparent, and opaque and engaged in an investigation to apply those concepts to different materials. Lauren noted, however, that “students were not really required to justify or explain their answers, other than in a brief discussion” and, while they did make predictions at the beginning of the lesson, Lauren “wish[ed] there would have been a section to write about their findings and compare them to their initial predictions” (Lesson 4). Ultimately, this proposed adaptation would have afforded students better opportunities to formulate and communicate evidence-based explanations about light, thus making Lauren’s lesson more inquiry-based. However, Lauren noted that “it’s frowned upon to give them anything other than what’s in the curriculum” and that her mentor teacher “just said there’s already so much in there that it’s hard to find time” (Pre-Enactment Interview 4) for added lesson elements. Again, as with the previous two examples, there was at least an implicit norm to not make major changes to the lesson (rules), upheld by Lauren’s mentor teachers (community), and over which Lauren had little control (division of labor).

In sum, then, culturally-mediating elements of the preservice teachers’ curriculum planning contexts more often than not provided an explanation for changes they considered making to alleviate the secondary contradiction between their inquiry models and the curriculum materials they used (Figure 5.2), but ultimately did not make. While many of these proposed but ultimately unmade adaptations would not have made the preservice teachers’ lessons more inquiry-based, some of them would have. In this way, culturally-mediating elements of the preservice teachers’ curriculum planning contexts

served as either a neutral or constraining force on the preservice teachers' efforts to engage in curriculum planning for inquiry.

Summary

In this chapter, I have presented results that illustrate these four preservice teachers' initial espoused inquiry frameworks, how they evolved during the methods semester, how the preservice teachers' curriculum planning decisions were mediated by their espoused inquiry frameworks, and how this process was culturally-mediated by features of their curriculum planning contexts. These results show that the preservice teachers' initial inquiry models were vague and ill-defined, and that they struggled to effectively engage in curriculum planning to translate their inquiry models into their first lessons. Through the emergence of a quaternary contradiction between their existing conceptions of science teaching and inquiry frameworks promoted in the methods course, the preservice teachers rapidly articulated inquiry models that were increasingly practice-specific and consistent with those promoted in the course. They mobilized these evolving inquiry frameworks to evaluate the curriculum materials they used and, to resolve emergent secondary contradictions between their espoused inquiry frameworks and the curriculum materials, made adaptations that better represented their espoused inquiry frameworks. These findings build upon those presented in Chapter 4 to further illuminate the essential production sub-process of the curriculum planning activity.

However, while the preservice teachers' planned lessons were most often more inquiry-based than those with which they began, results suggest they equally as often did not ultimately reflect the totality of their espoused inquiry frameworks or their ability to translate them into lesson adaptations. Instead, features of their curriculum planning contexts limited them from making some of the changes they described which, if they had been realized, would have further increased the overall inquiry-orientation of many of their lessons. These factors, including expectations of using school-provided curriculum materials (rules), the preservice teachers' mentor teachers (community), and the ways in which roles and authority were distributed in curriculum planning (division of labor, often restricted the preservice teachers in making additional changes to their lessons that would have likely made them even more inquiry-based. These findings build upon those presented in Chapter 4 and earlier in Chapter 5 by showing how the

curriculum planning production sub-process was situated within broader cultural contexts that ultimately limited the effectiveness of the preservice teachers' planned science lessons.

These findings provide insight into dominant patterns in the preservice teachers' curriculum planning for inquiry. However, their enactment of these lessons also provided an important context for curriculum design, as well as an important vehicle for the preservice teachers' subsequent learning and development of pedagogical design capacity. Next, in Chapter 6, I focus on the preservice teachers' enacted lessons, as well as their further evolution of their inquiry models and curriculum design practices.

CHAPTER 6

CURRICULUM ENACTMENT AND THE EVOLUTION OF PRESERVICE TEACHERS' INQUIRY MODELS AND CURRICULUM PLANNING PRACTICES

In Chapter 5, I presented findings from the four preservice teachers focused primarily on their curriculum planning for inquiry (central activity) and the early evolution of their espoused inquiry frameworks and curriculum planning practices. In the CHAT-based model of curriculum design for inquiry (presented earlier in Figure 2.3), curriculum enactment is the object-activity in which curriculum materials, the object of the curriculum planning activity, become instruments that help shape and guide classroom practice. I now turn to the preservice teachers' lesson enactments and the ongoing evolution of their espoused inquiry frameworks and curriculum planning practices.

Overview of Findings

Current emphases on inquiry-oriented science teaching and learning are meant to serve as an alternative to traditional, didactic forms of classroom science that have been historically pervasive. To provide a starting-point for situating the preservice teachers' lesson enactments in this study's CHAT-based framework, as well as to use CHAT as an explanatory tool, I first present a CHAT-based model of more traditional, didactic science teaching and learning. This is illustrated in Figure 6.1 below.

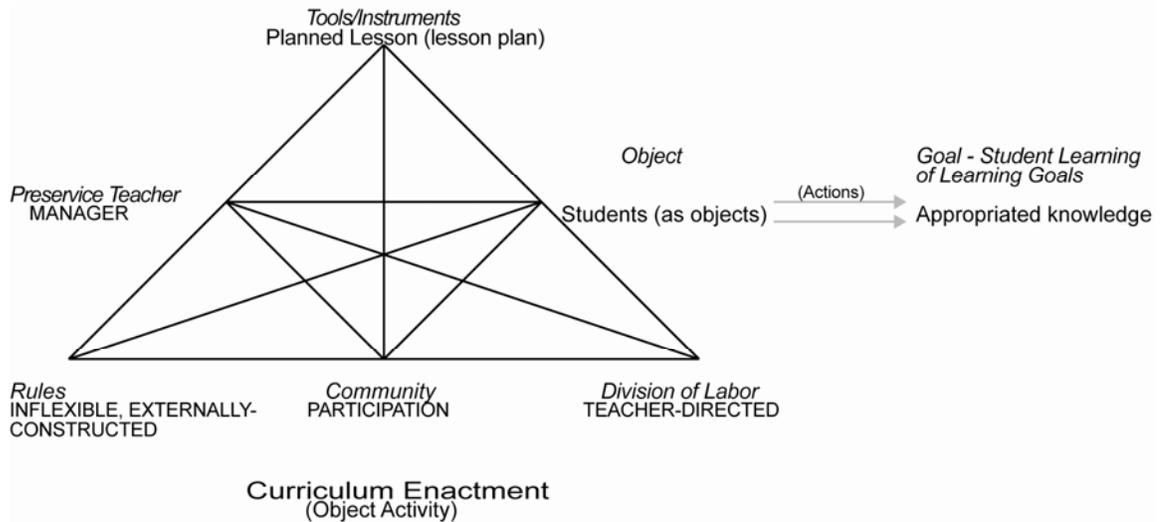


Figure 6.1. CHAT-based Model of Traditional, Didactic Science Teaching

In the form of science teaching and learning activity illustrated in Figure 6.1, students are the object of activity, or individuals to be acted upon and shaped by the teacher to promote student learning. In this context, teachers act as managers who enforce relevant rules and norms, engage in more teacher-directed instruction, and insure participation by any and all community members. The goal of such learning environments is students' reproduction of scientific explanations for phenomena (appropriated knowledge).

As shown in Chapters 4 and 5, while the curriculum materials the preservice teachers used to plan their lessons did afford some degree of inquiry practice, they were, on average, not particularly inquiry-oriented. The adaptations the preservice teacher made often served to better engage students in specific inquiry practices. However, each of the preservice teachers also sought to adapt their lessons in ways that not only emphasized these specific inquiry practices, but also to alter the nature of classroom activity more generally by repositioning students as community members rather than the objects of activity. This shift is shown in Figure 6.2 below.

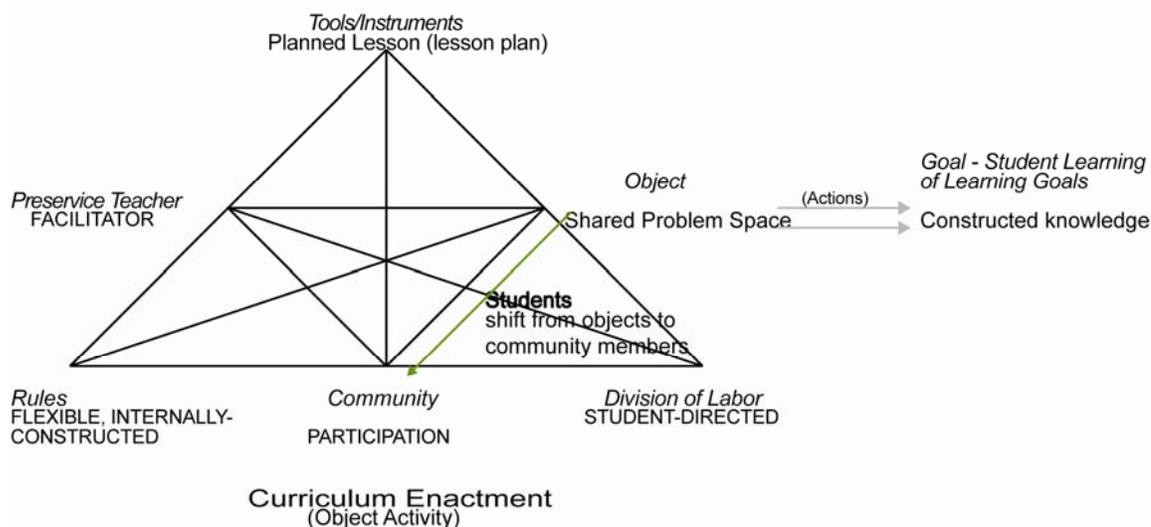


Figure 6.2. CHAT-based Model of Constructivist Science Teaching

This represents a fundamentally different activity system than the more traditional, default form of classroom practice shown earlier in Figure 6.1. With students as community members, the object of activity was no longer the students themselves, but rather lesson-specific shared problem-spaces that were jointly constructed by the teacher, now acting as more of a facilitator than manager, and the students. These lesson-specific problem spaces were defined by specific concepts, how they had been problematized, and relevant reifications of these concepts with which the teachers and students worked. In general, the form of science teaching and learning represented in Figure 6.2 is necessarily governed by more flexible, internally-constructed rules and norms and tended to be more student-directed. Whereas the goal of the more traditional form of activity (Figure 6.1) is students' appropriation and/or reproduction of scientific explanations, here, in the form of activity more often instantiated in the preservice teachers' revised lessons (Figure 6.2), the primary goal was the construction of new knowledge through collaborative sense-making.

As shown in the sections that follow, Lauren's lessons, unfortunately, did not afford her the opportunity to actually engage students in collective sense-making. While she believed she was adapting her lessons in ways that repositioned students as contributing community members, as shown in Figure 6.2, her enacted science lessons were more aptly characterized as more traditional science instruction, as shown in the

Figure 6.1. In contrast, Kelly, Mike, and Aliza were able to adapt their lessons in ways to better engage students in more constructivist science instruction shown in Figure 6.2.

However, Kelly, Mike, and Aliza’s enacted lessons often played out in ways that were inconsistent with their planned lessons. The repositioning of students from objects to contributing community members led to set of contradictions that emerged in the classroom. These contradictions are shown below in Figure 6.3.

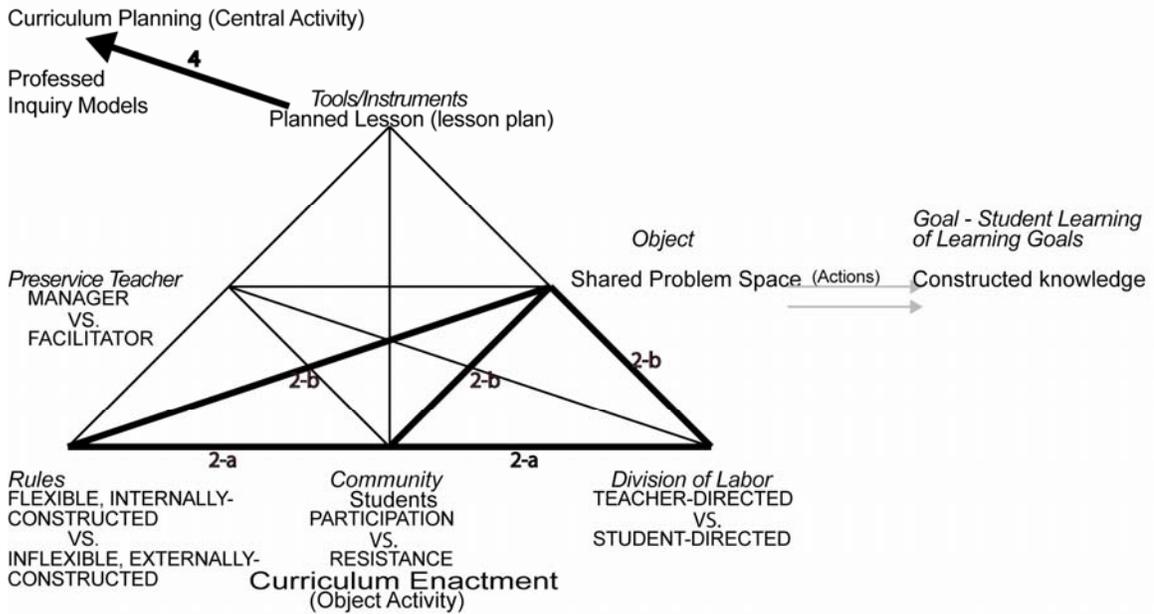


Figure 6.3. Emergent Contradictions in Preservice Elementary Teachers’ Constructivist Science Teaching

A cascading set of secondary contradictions were observed in Mike, Kelly, and Aliza’s enacted lessons. First, secondary contradictions emerged between, on one hand, students new role as community members and, on the other, divisions of labor and rules/norms that governed activity (labeled as ‘2-a’ in Figure 6.3). These two contradictions were evident in issues of classroom management often articulated by teachers who were primarily concerned with students adhering to rules/norms and assuming their expected roles. However, another set of secondary contradictions (labeled as ‘2-b’ in Figure 6.3), emerged between these culturally-mediating elements and the object of activity. These contradictions were evident in the challenges the various rules/norms, students as community members, and divisions of labor presented in co-constructing and working with lesson-specific shared problem spaces. In effect, these contradictions were not only concerned with students adhering to rules/norms and

assuming their roles, but accomplishing particular lesson-specific goals by doing so. As shown in the sections that follow, Kelly, Mike, and Aliza each confronted different combinations of these contradictions and worked to resolve them in various ways.

Lauren did not experience such contradictions enacting her lessons, in large part due to the specific lessons she taught and her own espoused inquiry framework. As a result, there was little observable development of either her curriculum planning or her professed model of inquiry after the methods course. However, because Kelly, Mike, and Aliza experienced these contradictions enacting their lessons, they also articulated quaternary contradictions between the curriculum enactment and curriculum planning activities, specifically between, on the one hand, the curriculum enactment activity and, on the other, the preservice teachers' curriculum planning and their espoused inquiry frameworks (illustrated in Figure 6.3 by the '4'). In an attempt to reconcile this quaternary contradiction Kelly, Mike, and Aliza learned to engage in modified forms of curriculum planning and continued to refine their espoused inquiry frameworks in unique ways as discussed in the sections that follow.

Ultimately, the preservice teachers' experiences enacting their lessons led to a tertiary contradiction between two objects and goals of curriculum enactment that should lead to student learning of predefined learning goals. This contradiction is illustrated in Figure 6.4 below.

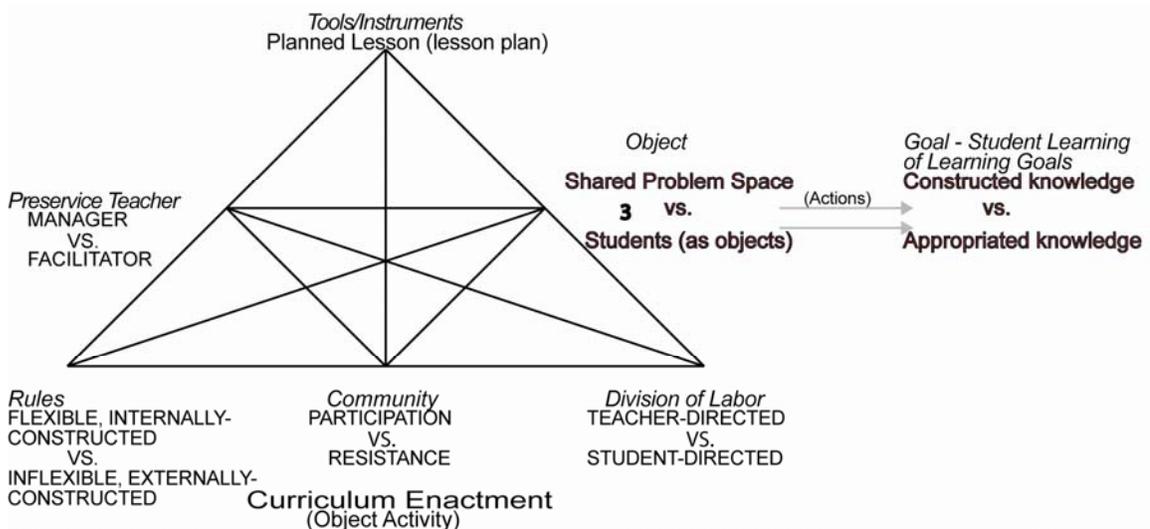


Figure 6.4. Tertiary Contradiction Between Traditional, Didactic and Constructivist Science Teaching

Ultimately, this contradiction revolved around the need for students to meet predetermined learning goals. On the one hand, classroom science could position students as objects of activity to appropriate these learning goals. While this perhaps afforded a greater degree of certainty that students could meet these learning goals, it also, to these preservice teachers, necessitated engaging in more teacher-directed instruction. On the other hand, students could be positioned as community members who, through the construction and shaping of shared problem spaces, could be provided the opportunity to construct scientific explanations. However, the preservice teachers perceived doing so as forgoing some of the certainty that students would construct the predetermined, scientific explanations which their lesson-specific learning goals emphasized. While there is evidence that some of the preservice teachers made progress in resolving this contradiction, all were still struggling to reconcile it at the end of the study.

In sum, there were three specific types of contradictions that emerged in the preservice teachers' curriculum enactment activities. These contradictions are summarized in Table 6.1 below.

Table 6.1

Emergent Contradictions in Preservice Teachers' Curriculum Enactment for Inquiry

Contradiction	Description
Secondary	Contradictions between nodes of the curriculum enactment activity (Figure 6.3). The specific number and types of secondary contradictions varied for each of the preservice teacher and are illustrated in subsequent sections.
Quaternary	Contradiction between the preservice teachers' enacted lessons (curriculum enactment) and their curriculum planning (Figure 6.3).
Tertiary	Contradiction between two competing object-goals for curriculum enactment (Figure 6.4). The two object-goals the preservice teachers articulated where shared problem spaces through which students construct explanations about phenomena versus students as objects who appropriate scientific explanations about phenomena.

To illustrate how the four preservice teachers negotiated these contradictions in their curriculum enactment for inquiry, as well as how their curriculum enactment experiences ultimately influenced the further development of their inquiry models and curriculum planning practices, I next turn to individual teacher cases. In these cases, I refer back to

the three contradictions described in Figures 6.1-6.4 and described in Table 6.1. The tertiary and quaternary contradictions described previously were the same for each of the preservice teachers. However, the secondary contradictions they described and experienced varied. As such, where pertinent, I provide detailed teacher-specific models to illustrate the specific secondary contradictions that emerged in their enacted lessons.

Teacher Cases

Lauren

Overview. Of the four preservice teachers, Lauren articulated the least student-directed inquiry model. While she adapted her lessons to more effectively promote students' formulation, communication, and comparison of explanations, she did so in a way that utilized highly teacher-directed inquiry as a means through which to illuminate and correct students' misconceptions about targeted science concepts. Lauren's enacted lessons were equally teacher-directed and yielded no contradictions because they were largely aligned with existing rules/norms and divisions of labor in her school and classroom. As a result, Lauren's curriculum planning and professed inquiry model remained stable over most of the year. At the end of the year, Lauren largely retained her emphasis on students' appropriation of knowledge through more teacher-directed inquiry.

Articulating a fundamental contradiction. Unlike the other three preservice teachers, Lauren articulated the tertiary contradiction at the beginning of the year between, on one hand, her goal of having students construct understanding through participation in inquiry and, on the other, having them achieve predetermined learning goals (shown in Figure 6.4). This contradiction emerged in response to a videocase of inquiry-based science teaching used in the methods course. She wrote that her "only concern [with inquiry] is that the teachers may rest too much responsibility in the hands of the students, and possibly frustrate them" (Journal, 9/11/07). She also said that inquiry must eventually lead students to predetermined learning goals, saying, "it doesn't really seem beneficial at the end if you just let the kids go away with their own ideas...you have to know that your students have grasped a concept before you can move on" (FI1). She recalled a video of inquiry-based science teaching from the methods course, saying,

I was so confused after watching the video and how [the teacher] never really wrapped it up...if you're going to dedicate 3 days or however much time to getting students to wrap their heads around this certain idea you

have to at some point give them some sort of resolution and say this is what you're supposed to take out of it. (FI1)

Lauren tied this issue to a science lesson she observed her cooperating teacher teach early in the methods semester. This lesson involved asking students to experiment with common classroom materials (e.g., crayons, paper, etc.) in order to introduce them to an investigation framework specific to the science curriculum (Journal, 9/11/07). However, Lauren came away from the observation confused because she felt the lesson had no resolution. She noted that "I think the kids really did understand the whole process of thinking like scientists and using the correct terminology... but they were really confused about what was supposed to happen with the crayons" (FI1). She observed at the end of the lesson students "were like 'ok, so nothing was supposed to happen with the crayons, what was the point?' you know and, so that kind of caused the explanation to be lost" (FI1). In this way, Lauren was concerned, at least early in the study, that it would be particularly difficult to support students to achieve predetermined learning goals through engagement in inquiry.

Lauren's lesson adaptations and enactments. As discussed in previous sections, Lauren's curriculum design efforts throughout the year largely focused on sense-making dimensions of inquiry (i.e., formulating, communicating, and comparing explanations). However, while this trend was consistent to varying extents for the other three preservice teachers as well, Lauren assumed a highly teacher-directed perspective on students' sense-making. Lauren's emphasis on these inquiry practices was strongly focused on identifying students' misconceptions, engaging students in more teacher-directed inquiry to help them correct those misconceptions, and, if unable to accomplish this goal through inquiry in the allotted time, engage in direct instruction of the targeted concepts.

Lauren's first three lessons were introductory lessons without traditional experiments or investigations. However, she was able to make adaptations to her lessons that better promoted students' formulation, communication, and comparisons of explanations. For example, as described earlier, Lauren added opportunities for her students to communicate and provide evidence for their explanations in her first lesson. Similarly, in both her second and third lessons, she made changes to provide students opportunities to communicate and provide evidence for their existing explanations, as well as revisit and compare their initial explanations based on their experience in the

lesson. The focus of these changes was to illuminate students' existing explanations and revise them through inquiry. Lauren noted about her third lesson, for example, that "these questions will give us something to refer back to at the end of the unit for revision; this will help to ensure the unit/lesson is more inquiry-oriented" (Lesson 3).

More so than the other three preservice teachers, Lauren's enacted lessons went smoothly and tended not to produce any secondary contradictions between, on the one hand, her goal to promote student learning and, on the other, culturally-mediating elements of the curriculum enactment activity (rules, community, and division of labor). For example, after her fourth lesson, Lauren wrote that "I really cannot think of anything that went differently when enacted than when planned...it did not seem as though I strayed from the lesson plan" (Lesson 4). This was consistent across Lauren's four lessons and suggests that Lauren's enacted lessons were no more or less inquiry-oriented than the lessons she had planned (Lesson [1, 2, 3, and 4] Enactments).

Evidence suggests, however, that Lauren did not address the tertiary contradiction she articulated at the beginning of the year. This contradiction revolved around, on hand, the objectification of students and promotion of knowledge appropriation through more traditional, didactic instruction and, on the other, supporting students' collaborative sense-making and construction of knowledge through inquiry. Rather, the existing lesson plans Lauren used, in conjunction with her more teacher-directed inquiry model and emphasis on students' misconceptions, largely engaged students in confirmatory activities through which they were expected to appropriate scientific explanations for phenomena. Her lesson enactments were more consistent with more traditional, didactic science instruction shown in Figure 6.1. Specifically, none of her lessons afforded students opportunities to construct knowledge through collaborative sense-making, as shown in Figure 6.2. Lauren's first three lessons primarily provided opportunities for students to share their existing explanations and, even with adaptations she made to them, did not provide students opportunities to engage in direct experiences with phenomena or work collaboratively to construct new knowledge from those experiences. Lauren recognized the absence of substantial sense-making elements in these lessons, writing in her third lesson, for example, "if this were not an introductory lesson, I would have had to consider how to correct misconceptions" (Lesson 3). In fact, the lack of opportunities

for students to construct new knowledge in her first three lessons was a major source of frustration for Lauren.

In her fourth lesson, however, Lauren did have an opportunity to engage her students in the post-investigation formulation, communication, and comparison of explanations in the form of a whole-class discussion. In this lesson, to which Lauren *did not* make any substantial changes, students investigated properties of light by shining light through a host of different materials. Before doing so, they made predictions about how much light would be visible through each material and then recorded their findings. This lesson, however, while it did include an investigation and post-investigation sense-making component, was largely confirmatory in nature, in that students were first introduced to three scientific concepts and terms (translucent, transparent, and opaque) and were then asked to investigate and rank different materials using these terms. This contrasts, for example, with an alternative approach in which students might engage with phenomena first, construct explanations and categories from their investigation, then connect those explanations to scientific explanations and terms. The end-of-lesson whole-class discussion that emerged in Lauren's lesson was highly teacher-directed and, after Lauren reviewed the definitions of translucent, transparent, and opaque with students, mostly involved students sharing their findings and categorizing the various materials. For example, the following segment from the discussion illustrates how Lauren facilitated her students' communication of explanations

[Lauren] Great, so you had foil and cardboard as opaque. Plastic square? Raise your hand and tell me what you had it as. [Student 1]?

[Student 1] Um, opaque?

[Lauren] Opaque? Opaque means no light got through. No light got through this?

[Student 1] Which one?

[Lauren] This, plastic square. Can you see me through this [Student 1]?

[Student 1] Um, most...

[Lauren] Most light through...what's that called? Transparent. Raise your hand if you had this as something other than transparent. No one? Good, we're all on the same page [Lesson 4 Enactment, 49:40-50:16]

This discussion continued similarly for some time but rather than being provided an opportunity to construct knowledge collaboratively, students were limited in the

discussion to categorizing objects as translucent, transparent, or opaque. Lauren noted afterward that she “tried to get [students] to explain their findings...they didn’t necessarily have to compare theirs to anyone else’s or justify why they did something” (Post-Enactment Interview 4). Ultimately, Lauren was unhappy with the discussion and the fact that the existing lesson and student worksheet did not provide students an opportunity to formulate and compare explanations. She wrote, “I wish there would have been a section to write about their findings and compare them to their initial predictions. I think those elements are important to understanding why we do certain things, and correct previous misconceptions” (Lesson 4).

Lauren’s revised inquiry model. As discussed earlier, Lauren’s approach to planning shifted as she began to explicitly employ her QEC inquiry model to evaluate and adapt her lessons. However, her planning remained fairly stable from there on. At the end of the year, Lauren’s professed model of inquiry remained relatively consistent with that she had articulated over the course of the year. She said that, “when I think of inquiry, I think of like the model of inquiry that we drew in [methods] and of the QEC that I use while I’m teaching science” (Post-Enactment Interview 4). Her end of the year model of inquiry is shown in Figure 6.5.

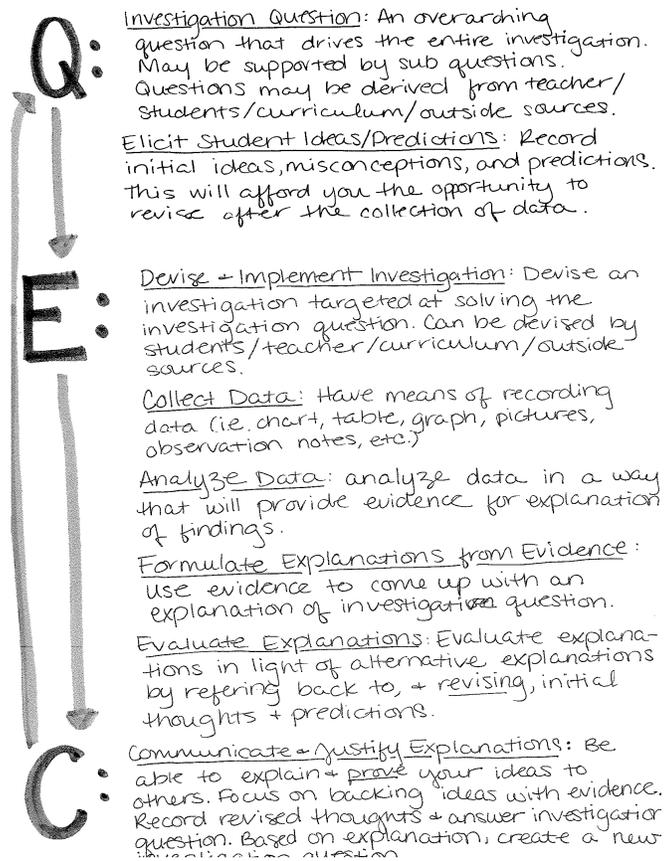


Figure 6.5. Lauren's End-of-the-Year Professed Model of Inquiry

As shown in her inquiry model, Lauren had appropriated the various features of inquiry discussed in the methods course. For her, these were subsumed under the three dominant inquiry categories questioning and predicting (Q), making evidence-based explanations (E), and communicating and justifying findings (C). As she discussed throughout the second half of the year, her QEC inquiry model served as a crucial tool in her planning for inquiry (FI3).

Lauren's primary emphasis was on the 'E' portion of her model, or collecting and analyzing data and evidence, and formulating and evaluating evidence-based explanations. She said, "then I try to make it so that the E is like the biggest portion 'cause that's what I usually spend the majority of the lesson doing...I spend the most part on the evidence and explanations" (FI3). She argued that "for science that's crucial" because "with science you go in with these preconceived notions or initial ideas..., and then you're supposed to investigate something, collect evidence, and draw on the

evidence to make some sort of conclusion and then revise your initial thoughts... the whole cycle needs to be completed in order to gain some sort of substantial knowledge about something” (Post-Enactment Interview 2). She also noted that “having the kids refer back to predictions, noting what they’ve learned, it allowed them to address any misconceptions” (FI3). Here, then, is evidence of Lauren’s specific emphasis on correcting misconceptions through evidence-based explanation-construction.

Lauren also reinforced the importance of students’ conclusions being in line with specified learning goals for the lesson. If, through inquiry, students make explanations that are not consistent with scientific explanations, Lauren noted that the role of the teacher is to facilitate exploration of these differences. However, her goal was to “ultimately settle on an agreement, like class-wide. That should through teacher facilitation lead them to a final, correct something, you know what I mean?...I think there has to be some sort of whole class communal discussion at the end where everybody leaves on the same page...I think it’s kind of crucial that everybody leave on the same page” (Post-Enactment Interview 2). In the end, Lauren summed up her inquiry model, saying, “as long as I have like a major question and the kids are actively involved in solving that question, and then come out with some sort of evidence and explanation of that in the end and then can readdress any you know misconceptions or initial thoughts that need to be addressed, then that to me seems like a successful inquiry-based lesson” (FI3).

Lauren’s perceived resolution to the tertiary contradiction. As discussed previously, Lauren had, throughout the year, articulated a fundamental tertiary contradiction between various elements of inquiry practice and her goal of promoting student learning of predefined learning goals rather than supporting misconceptions. Lauren recalled a lack of emphasis on explanations in her model of inquiry from the beginning of the year. Again, she recalled the video from class, saying, “the videos, it went on and on forever, just kept fueling misconceptions, that one, with that woman, but going on and on and on”. (FI3). Lauren noted that in her own teaching, she didn’t “want to step in and say, ok, this is the right answer, this is what you were supposed to have taken out of it” but, simultaneously, “was also nervous about letting it go on and on and on” (FI3). She wrote,

I've learned, through my several attempts at inquiry-oriented science teaching, that patience is necessary. It is so difficult to bite my tongue and avoid jumping in and saying, "No, this is how you're supposed to do it," or, "This is what you're supposed to be getting out of this." It's really a struggle to remove myself from the activity and really just serve the purpose of facilitating. I often get frustrated watching students do something incorrectly, or not get at the aim of the lesson... It makes me realize that I need to watch myself; there is a difference between "teaching" and "telling." (Lesson 4)

Lauren had come to appreciate the challenges of facilitating inquiry in the classroom.

Ultimately, Lauren noted she "consider[ed] inquiry to be more student-led than teacher-led but, at the same time, I don't consider it to be totally student-led" (FI3). She said that while it was still difficult to put more autonomy in the hands of students, she had begun to better assume the role of facilitator in the classroom. However, Lauren also stated this was an area for further development. While Lauren said she was not entirely comfortable facilitating students' construction of knowledge through inquiry, she did believe, "there's a way to guide it enough to where students are going to come out with the same ideas but not guide it so much that they're still having the majority of the involvement" (FI3). Here again is evidence of Lauren's emphasis on students' attainment of predetermined learning goals. Similarly, in reference to her fourth lesson, she noted "once [students] were given the opportunity to investigate, they found the correct answers on their own" (Lesson 4). Lauren's assessment of artifacts her students produced in her fourth lesson may have provided evidence of learning. However, as mentioned before, this lesson did not allow students to truly construct understanding from their experiences – rather, it afforded them the opportunity to confirm existing scientific explanations. While Lauren emphasized her recognition that some balance existed between supporting students in more open-ended inquiry and insuring they attain predetermined learning goals, her emphasis on correcting students' misconceptions as a form of explanation-construction caused her to perceive students' confirmation and appropriation of scientific explanations in her fourth lesson as the construction evidence-based explanations. In short, largely because of the particular lessons she taught, Lauren had little opportunity to truly engage her students in collaborative sense-making through inquiry. As a result, by the end of the year, she had not resolved the tertiary contradiction between, on the one hand, students' construction of knowledge through the articulation of shared problem-

spaces and, on the other, acting *on* students as objects in curriculum enactment to support their appropriation of scientific explanations.

Summary. Throughout the year, Lauren had engaged in curriculum design to support students' formulation, communication, and comparison of explanations. More so than the other three preservice teachers, however, Lauren articulated a more teacher-directed model of inquiry focused on addressing students' misconceptions. She experienced no real contradictions between her goals and culturally-mediating elements of her curriculum enactment context because she engaged in largely teacher-directed science teaching practice. While Lauren felt as though she had alleviated this contradiction by the end of the year, particularly in light of her fourth lesson, a more likely explanation is that the specific lessons she taught did not afford her the opportunity to engage students as collaborative, co-contributors in defining and shaping shared problem-spaces of classroom science. While Lauren believed she had made strides in alleviating this contradiction in her own teaching practice, her curriculum planning practice, science teaching practice, and model of inquiry remained fairly stable over most of the year.

Mike

Overview. As shown in Chapter 5, Mike's adaptations over the course of the year largely focused on engaging students in the collection and organization of data and evidence and formulating, communicating, and comparing explanations. However, across these specific inquiry practices and unlike Lauren, Mike sought to make changes to his lessons that better enabled students to be active participants in the science lessons he taught. This involved, primarily, increasing opportunities for students to collaborate, engage in discourse, and construct shared understandings of the concepts of interest, thus positioning students as community members. However, in enacting his lessons, Mike struggled to reconcile contradictions that emerged between, on the one hand, his goal of having students construct knowledge through collaboration and, on the other, positioning students as community members who shared the same object and goal. In response to the challenges he faced in enacting his lessons, Mike articulated a quaternary contradiction between curriculum planning and curriculum enactment and, in response, developed a new approach to curriculum planning. Mike's new curriculum planning approach not

only helped alleviate this contradiction, enabling him to better position students as community members in inquiry, but also helped him further develop his model of inquiry by the end of the year. However, it also brought to light the tertiary contradiction articulated by all of the preservice teachers between, on one hand, his goal of having students construct understanding through participation in inquiry as community members and, on the other, having them appropriate predetermined learning goals.

Mike's adaptations. A consistent theme across Mike's adaptations was the incorporation of elements that provided students more substantial opportunities to collaborate and engage in discourse through inquiry. For example, as described earlier, Mike's first lesson involved students using their knowledge of survival needs and the characteristics of Mars and Earth to make claims about items they would take on a hypothetical trip to Mars. Mike made a number of changes to the lesson to increase the amount of small-group work because he felt this would ultimately better support students to make relevant claims in the lesson.

This trend was consistent in Mike's second and third lessons as well. Mike's second lesson involved students modeling bird feeding using various tools and items meant to represent bird beaks and food. Rather than have the teacher demonstrate the bird beaks (as the original lesson suggested), Mike instead wanted his students to engage in the activity and collaborating while doing so. First, then, he decided to have groups of students demonstrate each bird beak model for the rest of the class. Second, Mike added a whole-class discussion at the end during which students reexamined their initial predictions in light of the data they collected and then completed a student worksheet as a class rather than individually. Mike noted his goal with the concluding discussion was to "try to connect [the models] to adaptations...so I could pick it up [in the next lesson] and connect everything together..., to talk about like how the different beaks served different purposes and because they served different purposes birds live in different places" (Post-Enactment Interview 2).

Mike's third lesson involved having students dissect and observe various seeds to learn that there are parts of a seed consistent across plant species. Again, as with his first two lessons, Mike made a number of changes to have students work in groups and "talk among themselves...about what's going on" (Post-Enactment Interview 3). Mike noted

that “I think it allows students to kind of discuss with each other more” and that “it makes the lesson more inquiry-oriented because it allows students more opportunity to verbalize what they’re seeing and analyze...data” (Post-Enactment Interview 3). Mike argued these changes were ultimately oriented toward sense-making, saying, it was “a good way to analyze the data, looking at their drawings, looking at their peas,...making connections between all of them, no matter what size or shape, they all have those 3 parts to it” (Post-Enactment Interview 3).

Mike’s first three enacted lessons. While Mike generally felt as though his first three enacted lessons were successful, he also struggled to effectively engage students as contributing community members in his lessons. Mike had adapted his lessons to reposition students from objects of classroom instruction (as shown in Figure 6.1) to co-contributing community members (as shown in Figure 6.2). However, the students’ new roles resulted in a series of contradictions that ultimately led to in situ adaptations that made Mike’s first three lessons less inquiry-based. These contradictions are illustrated in Figure 6.6.

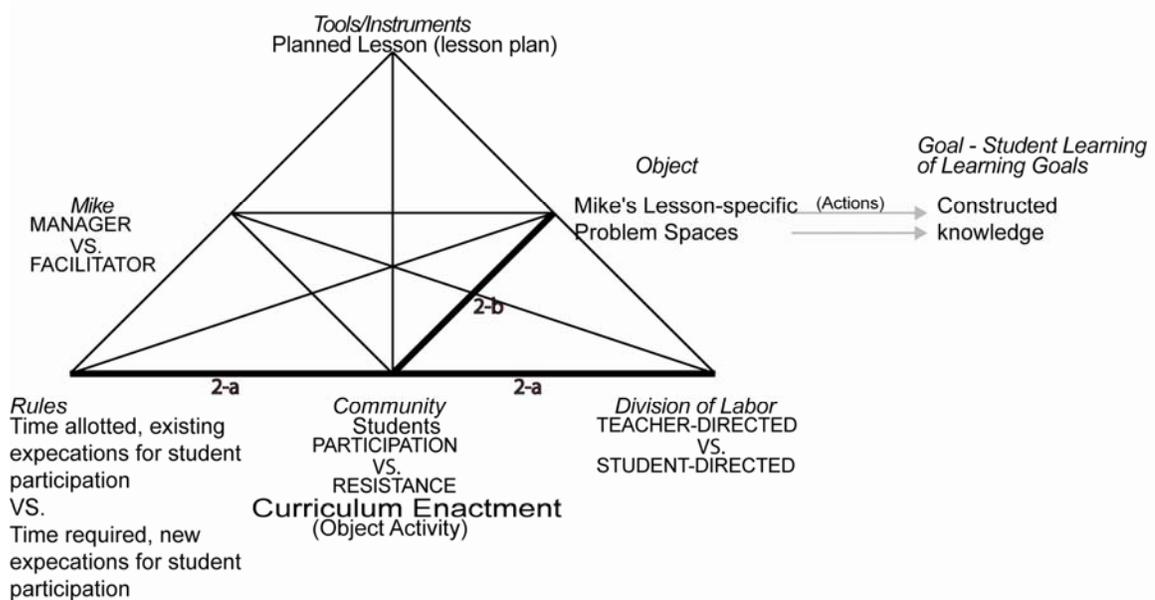


Figure 6.6. Secondary Contradictions in Mike’s First Three Enacted Lessons

First, secondary contradictions emerged between, on one hand, the students in their new roles as community members and, on the other, both existing rules/norms governing time and expectations for students’ participation in the classroom and students assuming a

more active, participatory, student-directed role in the classroom (division of labor). These contradictions are labeled '2-a' in Figure 6.6. Ultimately, these contradictions led to another secondary contradiction (labeled '2-b') between students and the construction of lesson-specific problem-spaces Mike had planned. In effect, Mike struggled to facilitate students' engagement with lesson-specific problem spaces in their new collaborative roles. These problem-spaces, which were ultimately focused on discourse-based explanation-construction in Mike's second and third planned lessons, ended up being cut from his lessons due to the emergent contradictions shown in Figure 6.6.

In his first lesson, for example, Mike attributed the emergence of these management-related contradictions to the number of transitions between whole-class and small-group discussions in his lesson due to the addition of the student group-work. However, Mike indicated he still believed engaging kids in collaborative inquiry practices was important, saying, "even though I had management issues...I still think it was beneficial for students to work together" (RT1). In his second lesson, however, these classroom management issues ultimately made his lesson less inquiry-oriented than he had planned. Because the modeling activity took longer than anticipated, Mike ran out of time to have his students return to their predictions from the beginning of the lesson and to make claims about the bird beak models using evidence they collected and recorded during the lesson.

These classroom management issues led to a turning point in Mike's third lesson. Mike described his third lesson as "a total failure" (Lesson 3). During his lesson enactment, Mike essentially forgot to enact early parts of the lesson. For example, he noted that "I was going to have them make predictions...but I don't think I actually did that. I think I just kind of labeled right away for them, so I think I kind of totally defeated that purpose." (Post-Enactment Interview 3). At that point, Mike began to flounder and noted that "once I lost my confidence, [my lesson] went downhill" (FI3). As the lesson continued, Mike reflected on how "management and modeling went poorly and my control over the students was eventually lost" (Lesson 3). As a result, Mike was unable to enact any of the adaptations he had made to make his lesson more inquiry-oriented. Mike recalled that, "where I had built in all those opportunities to speak and to talk and talk with their group members and analyze their data, I think I lost all of that" (Post-

Enactment Interview 3) and “I didn’t do my end of the lesson discussion” (Post-Enactment Interview 3). In short, Mike noted “I thought I had planned a good lesson, but my execution was below par” (Lesson 3). As a result, his third lesson was far less inquiry-oriented than he had originally planned.

Mike’s revised approach to curriculum planning. In direct response to his third lesson, as well as to the classroom management issues he had confronted over the course of his first three lessons, Mike articulated a quaternary contradiction between his curriculum planning and curriculum enactment (see Figure 6.3). Essentially, Mike began to express frustration at the difficulties he had continued to experience enacting his planned lessons, saying,

I think I do a fairly good job of planning my lessons and kind of making them inquiry-oriented...I have a good plan when I go in but it’s my execution I think that’s lacking. Cause I think when I plan I plan everything, I have all my [inquiry] criteria, but then when I actually do it, it doesn’t happen. (Post-Enactment Interview 3)

At this point, Mike developed a new approach to curriculum planning that better enabled him to consider management issues along with inquiry and to better internalize his lesson plans before enacting them. First, Mike described a need to consider how to establish rules and norms to promote classroom management concerns first. He recalled about his third lesson, “next time I’ll do management first. I kind of did it backwards this time” (Post-Enactment Interview 3). Mike noted that if “I know how I’m going to handle each of my management things before I plan inquiry,...it’ll be easier to plan [for inquiry] and then I’ll just have to adjust [my lesson] right there at the end” (Post-Enactment Interview 3). Second, Mike noted that he would now “read through the lesson plan,...write down detailed like step by step what I want to do, ...then I turn that into something just like an outline of the major things I want to point on” (Pre-Enactment Interview 4). Mike described rehearsing his lessons before teaching and which he said “worked out really well for me” (Pre-Enactment Interview 4). In effect, then, Mike had begun to account for culturally-mediating elements of the enactment context in his curriculum planning for inquiry and to better internalize his planned lessons prior to enacting them.

Mike’s fourth enacted lesson. Mike used his new curriculum planning strategy to plan for his fourth science lesson, which involved the students dropping marbles into pans filled with sand to model the formation of the moon’s surface. Mike’s new

approach to planning supported him to enact his lesson much more effectively than before, thus alleviating the quaternary contradiction between curriculum planning and curriculum enactment he had articulated after his third lesson. He reflected that “the lesson went just like I had planned it” (Lesson 4) and that using his new approach to planning in this lesson ultimately resulted in a more productive enactment, saying, “planning more makes me feel more comfortable [and] I think being more comfortable I make better decisions on the fly” (Post-Enactment Interview 4). Mike recalled not experiencing any classroom management issues and felt as though he had been more successful and engaging students. He had, therefore, also alleviated the secondary contradictions related to classroom management shown discussed and illustrated previously in Figure 6.6.

By resolving these various contradictions, Mike was able to focus more on supporting students’ inquiry in his fourth lesson by engaging his students as community members in a whole-class discussion in which they constructed and communicated explanations for why the moon’s surface appears as it does based on the results of their modeling activity. Afterwards, Mike said he “thought students really understood what the model represented and were really able to draw some good conclusions from it” (Post-Enactment Interview 4). Because his enacted lesson was more effective than his previous ones had been, Mike was able to engage students in the concluding discussion he had planned (for the first time in his four lessons), thus making the lesson more inquiry-based due to his adaptations. Mike highlighted an interaction he had with one student during the discussion, saying,

I felt like right there, that’s inquiry, like right there. Now I need to transfer that into the rest, make sure I have that throughout my whole lesson. ‘Cause as soon as I got done, I was like, [...] that was, you know, when I was even talking to him, I was like this is inquiry, so. Now it’s just a challenge of getting that through the whole lesson and specifically maybe even just transferring that more into the conclusion at the end, you know. Having students using their drawings to explain to me and to prove or disprove their theory. (Post-Enactment Interview 4)

This experience was an important one for Mike in terms of his developing inquiry model. In each of his previous three lessons, he had struggled to engage students in substantive sense-making discussions, often because he spent most of the lessons trying to address issues of classroom management that resulted from his efforts to position students as

contributing community members. Mike’s new approach to planning had enabled him to effectively address management issues and, in doing so, Mike was able to focus on engaging students in inquiry to promote student learning, his primary goal.

Mike’s professed model of inquiry. At the end of the year, Mike’s professed model of inquiry retained important features that he had articulated after the methods semester. As he had earlier in the year, Mike continued to emphasize the importance of engaging students in questions, gathering and analyzing data, and communicating and justifying explanations. In particular, Mike continued to focus on having students make predictions and share their initial explanations, saying, “that’s where you start getting the kids thinking about what’s going on, making predictions...I think that’s important” and that students should “go back to your predictions and talk about your predictions and why they would or wouldn’t work” (FI3). Mike’s professed inquiry model from the end of the study is shown in Figure 6.7.



Figure 6.7. Mike’s End-of-the-Year Professed Model of Inquiry

First and foremost, Mike began to describe a more student-centered approach to inquiry that was consistent with the more constructivist-based model of science teaching presented in Figure 6.2. He described his earlier inquiry model and how it had evolved, saying, “[inquiry]’s not black and white, there are so many grey areas. I was thinking like oh, this criteria, this criteria, this criteria, it’s inquiry or it’s not inquiry...you just follow the steps” (FI3). This was evidenced in Mike’s evolving focus on what he described as more “free exploration” (Post-Enactment Interview 3, FI3) for students. Specifically, what Mike was referring to was variability that can occur when students are provided opportunities to collect data and use that evidence to make explanations. Mike began to describe a more student-directed approach to data collection. As shown in Figure 6.7, Mike included multiple places for gathering/analyzing data. Mike elaborated on this change, saying, “this is new, I have like three places for gathering and analyzing data because everybody’s different, like I noticed that in my last science lesson, everybody had different data, different results” (FI3). Mike contrasted this with “a cookie-cutter experiment where everybody gets the same results” (FI3). In his earlier lessons, the purpose of more controlled investigations had been to provide evidence that would support the construction of explanations that contrasted with their initial ideas and predictions.

Ultimately, Mike believed that giving students more freedom to collect divergent data better supported students’ explanation-construction and learning than did more teacher-directed inquiry. Mike noted that in “This [new model] you talk about different things, you’re able to show them what you have, and then you’re able to like communicate that with others, and you know, make sense of that. You can see different ways of doing it. I think that’s important” (FI3). Mike noted that with his new approach, “they’re not just filling out a worksheet and being done. They’re actually using words and what they created to explain to me what that crater is and what their model represents...being able to justify that or using that information, I think it makes deeper understanding” (FI3). Again, discourse was at the heart of this process for Mike, who said,

...that leads directly into the using data to justify their meaning because once they have that, they’ve been talking and have all these ideas, then you bring them in, you set them down, and you go over that. You ask them to

use what they've created in their gathering and analyzing data to justify what's going on...and then once you have that I think you could also go back to your predictions and talk about your predictions and why they would or wouldn't work (FI3)

As shown in these quotes, a fundamental dimension of Mike's inquiry model was the role discourse played in negotiating shared meaning in the classroom, in this case through the use of authentic evidence collected by students through inquiry.

As discussed thus far, Mike's new approach to curriculum planning had helped him overcome the secondary contradictions he was experiencing in the classroom between, on the one hand, his goal of having students construct meaning through collaboration and, on the other, positioning students as community members who shared the same object and goal. Ultimately, his new approach to curriculum planning also helped him better engage his students in inquiry in his fourth lesson and the ongoing development of his own inquiry model.

However, this new approach to curriculum planning brought to light the fundamental tertiary contradiction in curriculum enactment discussed earlier and shown in Figure 6.4. As Mike had stated, his new curriculum planning strategy involved scripting out his lessons, thus helping him better internalize the lesson prior to enacting it. While this helped insure Mike did not forget parts of his lesson and supported better classroom management practices, it also conflicted with Mike's developing orientation toward more student-directed inquiry practices. This contradiction developed because of the inherent difficulty of helping students achieve predefined learning goals by scripting out and heavily planning lessons in which Mike sought to draw so heavily on students' predictions and student-directed data collection and evidence-based explanations. Mike still argued that the purpose of concluding discussions was to "verify and then explain what's going on...all the students are on the same page but we still have a chance to explain what they're talking about and what their results were" (FI3). However, based on his experiences enacting his lessons throughout the year, Mike noted that "with teaching science so far as inquiry-based, being able to plan the conclusion part, I think it's difficult" (FI3). Mike elaborated, saying,

You can plan up through predictions but once you get your predictions, that's when the lesson kind of goes its own way... I got up to the prediction point real well I think but after that point I'm still trying to...it's

more challenging for me to plan beyond that point...cause I have the learning goals I want [students] to achieve and I'm going to try to achieve them but I'm not going to not take [students'] ideas and predictions. (Post-Enactment Interview 4)

Here, Mike notes the fundamental tension between achieving predefined learning goals while still positioning students as contributing community members in the classroom through the explication of their ideas and questions. Mike noted he still need to learn how to support students to make goal explanations, thus achieving his goal of promoting student learning, while also allowing them to engage in more student-directed inquiry, saying, "I'm still working on making those decisions at the end and deciding what questions to ask and how to do that" (FI3). This tension, or the tertiary contradiction shown in Figure 6.4, represented for a Mike a core area for future professional growth.

Summary. Through his curriculum design efforts, Mike sought to enable his students to be active, contributing participants in the science lessons he taught, particularly through opportunities for collaborative discourse. However, in enacting his first three lessons, Mike struggled to reconcile a secondary contradiction that emerged between, on the one hand, his goal of having students construct meaning through collaborative discourse and, on the other, positioning students as community members who shared the same object and goal. After his third lesson, Mike developed a new approach to curriculum planning that, in his fourth lesson, helped him better support students as co-constructors of explanations about the surface of the moon. This experience also served as an experience through which Mike expanded his inquiry model. However, it also brought to light the tertiary contradiction articulated by all the preservice teachers between, on one hand, his goal of having students construct understanding through participation in inquiry as community members and, on the other, having them appropriate predetermined learning goals.

Kelly

Overview. As shown in previous sections, Kelly adapted her science lessons over the course of the year to engage students in inquiry practices, particularly asking and answering scientific questions. However, like Mike, Kelly sought to make changes to her lessons that better enabled students to be active participants in the science lessons she taught. For most of the year, this involved positioning students as co-constructors of

investigation questions and investigations, positioning them as contributing community members in these inquiry practices. However, as Kelly came to increasingly prioritize students' formulation, communication, and comparison of evidence-based explanations, she began to engage in curriculum design to engage in student-centered inquiry. However, despite her perceived success in facilitating students' construction of investigation questions, Kelly struggled to support students to engage in sense-making discourse. Kelly ultimately drew upon her emphasis on investigation questions to partially alleviate the tertiary contradiction she articulated between, on one hand, her goal of having students construct understanding through participation in inquiry as community members and, on the other, having them appropriate predetermined learning goals. At the end of the study, evidence suggests Kelly was engaging in new forms of curriculum planning and leveraging her perceived capacity to support students' construction of investigation questions to make strides in better supporting their formulation, communication, and comparison of evidence-based explanations through discourse.

Kelly's adaptations. As discussed previously, Kelly adapted her first two lessons in ways to make them more engaging for students. For example, in her first lesson, Kelly added a set of discussion questions as well as a KWL to her lesson, both of which were designed to provide students more opportunities to contribute to the discussion about insect decomposers. Similarly, in her second lesson, Kelly added a discussion through which she supported students to formulate an investigation question rather than simply provide them with one.

Kelly's third and fourth lessons, which she taught during student teaching, involved setting up an experiment to test the growth of mold on bread, collecting and graphing data, and using that data to make claims about conditions that effect mold growth. As with her second lesson, Kelly again adapted her third lesson to involve students in a discussion to co-construct an investigation question rather than simply giving them one. Additionally, Kelly adapted her third lesson to have students play an active role in deciding what variables to test in their investigation and how to design it.

Finally, unlike in her first three lessons, Kelly adapted the concluding whole-class discussion of her fourth lesson to have students engage in more substantive conversation and sense-making about their results. She argued that as written, the lesson only

emphasized students' sharing of results, not their engagement in collective sense-making. In light of this, Kelly reorganized the concluding discussion in the lesson because she wanted students to engage with and provide feedback on others' findings. She said that "it's a whole other level to push students to hear what their peers are saying and then like make sense of that too" and that "I hope they do evaluate one another's results" (Pre-Enactment Interview 4). Overall, Kelly argued that such communicating also promotes sense-making, saying, "being able to understand what someone else is saying about their data and to interpret it will help them just have a deeper understanding on the whole about what they're doing" (Pre-Enactment Interview 4).

Kelly's enacted lessons. Kelly perceived her enactments of her first, second, and third lessons as reasonably successful and did not articulate any contradictions. In particular, she felt that she successfully supported students to co-construct lesson-specific investigation questions. For example, in Kelly's third lesson, for which the primary learning goal was to "identify the conditions that encourage bread mold growth" (Lesson 3), the students first discussed a multitude of factors that might or might not affect bread mold growth. Before turning to actually setting up their investigations, Kelly supported students to develop an investigation to guide their inquiry. In the discussion, Kelly drew on a number of students' ideas to make explicit the primary question they were addressing:

[Kelly] Alright, so we've come up with some ideas about what might affect bread mold growth. What are we trying to figure out today when we set up a fair test with our bread mold? What are we trying to discover today? What 's the one thing we're trying to find out with our bread mold? [Student 1]?

[Student 1] How long, how long it might take for the bread to mold?

[Kelly] Yep, and more specifically we're looking at all these variables. What are we trying to figure out about these variables? [Student 2]?

[Student 2] The [inaudible]...

[Kelly] You're along the right lines. I'm just trying to figure out...we're going to be setting up a fair test today where we're changing only one variable. So what are we trying to discover today? What's the main thing that's guiding us? What are we looking for? [Student 3]?

[Student 3] How mold grows.

[Kelly] That's one good question. 'How mold grows' [talking while writing].
[Student 4], did you have another question that we're trying to discover today? What do you think?

[Student 4] Um, yeah, what conditions, how different conditions will affect how mold grows.

[Kelly] Did everybody hear [Student 4]? Say that one more time really loudly.

[Student 4] How different conditions will change how mold grows.

[Kelly] So 'how do different conditions...How do different conditions affect mold growth?' [reading while writing on overhead]. So look down to page 32 and we're going to fill out this table together... [Lesson 3 Enactment, 13:39-15:58]

This episode illustrates Kelly's attempt to engage her students to co-construct an investigation question that directly addresses the lesson's learning goal. Following her lesson, Kelly also said that "students had no trouble coming up with a question about how fungi survive or how they get their nutrients" (Lesson 3) and indicated that she liked having students participate in developing an investigation question. For Kelly, then, facilitating the articulation of a shared problem-space through the construction of an investigation question had emerged an effective means through which to position students as co-contributors.

Over the course of the year, Kelly also articulated the same tertiary contradiction as the other three preservice teachers between, on the one hand, engaging students as co-contributing community members to construct knowledge through inquiry and, on the other, positioning students as the objects of the teachers' activity for whom knowledge needs to be appropriated (Figure 6.4). For example, though Kelly had felt increasingly comfortable engaging her students in the co-construction of investigation questions, she was critical of how she supported her students to do so in her second lesson. She said that she "felt like it was a little contrived just because I was like, 'so what kind of question would you ask if you wanted to know how fungus survives?'," I was like saying the question when I was asking them that" (Post-Enactment Interview 2). Kelly discussed how she might have scaffolded students more effectively to produce an investigation question, saying, "I could have left it a little bit more open, like 'what type of question could we ask to drive this investigation?'," but then I didn't know if they'd get to that point" (Post-Enactment Interview 2). By suggesting a more open-ended approach

to supporting students' development of an investigation question, Kelly acknowledged that she would have relinquished some control over her ability to emphasize an investigation question that highlighted her predetermined learning goals. Similarly, after enacting her third lesson, Kelly described the biggest challenge she faced, which was to harness students' existing ideas to steer them back toward her predetermined learning goal and investigation question. She said,

...just knowing how to use their questions and ideas to relate them back to the main idea for our lesson... staying on track. Not being too thrown off or getting off topic. Making sure it stays focused and trying to answer the investigation question and what we're doing. (Post-Enactment Interview 3)

Kelly noted that accounting for students' ideas and contributions while still addressing predetermined concepts and learning goals "is still an area in which I am struggling to find the right balance" (RT2).

There is evidence that over time, Kelly did find a balance that worked for her. For example, Kelly highlighted the discussion in her third lesson in which students came up with variables they would test in their mold experiments. Kelly wrote that she wanted students "to come up with most of the ideas (about variables affecting mold growth, etc) themselves" (Lesson 3), again positioning students as co-contributors to the investigation. However, she also acknowledged that her role in this discussion was also to draw students back towards the specific variables the lesson provides as options for their investigations, saying, "there were also points that I felt it necessary that I tell them the variables that we would be working with" (Lesson 3). Negotiating a balance between students' contributions and Kelly's predetermined variables was facilitated by what Kelly described as congruence between the two. Kelly said that "I did have a list of variables that I wanted to list on the board eventually but they came up with them themselves across the board" (Post-Enactment Interview 3). In effect, Kelly's students articulated the same variables as she had hoped, thereby easing the emergence of a tertiary contradiction between predetermined objectives and those constructed by the students.

Unlike her first three lessons, however, Kelly's attempt to enact her adaptations in her fourth lesson proved problematic due to contradictions that emerged. These are shown in Figure 6.8 below.

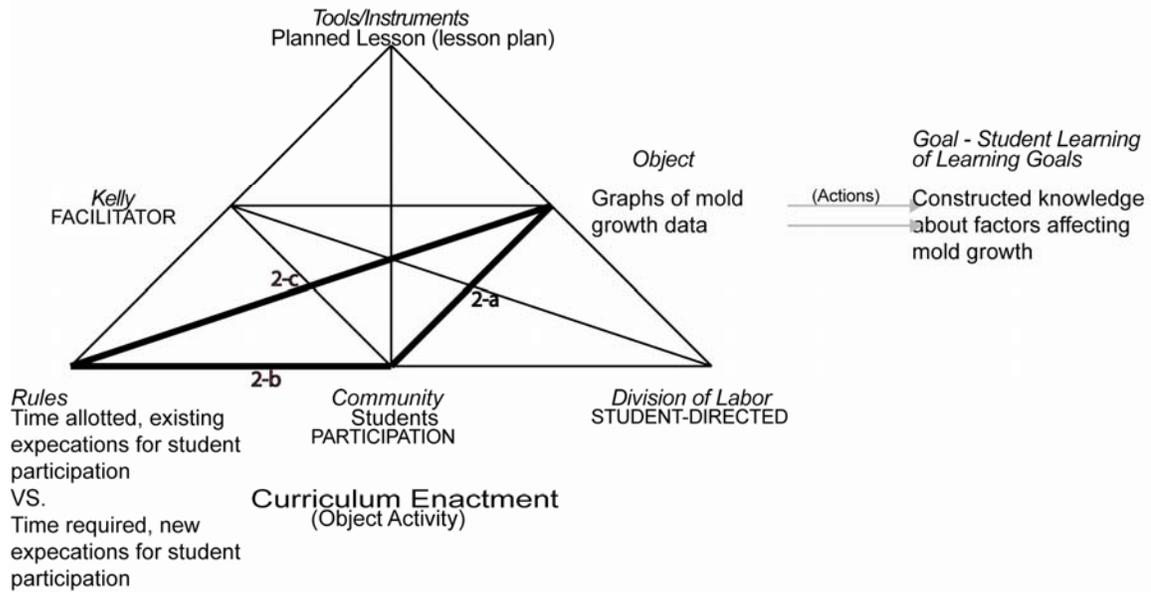


Figure 6.8. Emergent Contradictions in Kelly's Fourth Enacted Lesson

Kelly struggled to keep students engaged during the part of her fourth lesson in which they graphed their results, in large part due to students' lack of familiarity with the rules/norms governing the construction of graphs. Kelly noted that "once I let them go and start graphing, a lot of people were like, 'I don't get this', 'I don't know what I'm doing' [which] was frustrating because I'd just explained it" (Post-Enactment Interview 4). This resulted in a secondary contradiction between Kelly's students and the object of the lesson (labeled as '2-a'). In part because of Kelly's struggles to keep students engaged in constructing their graphs, another secondary contradiction emerged between students (community) and the rules governing time (labeled '2-b'). Finally, time became a mediating factor in having students actually make evidence-based explanations, evidenced in yet a third secondary contradiction between rules governing time and the shared problem-space of their graphs (labeled '2-c').

Kelly acknowledged that her modified whole-class discussion was "more difficult than I thought to try" (Post-Enactment Interview 4). In the end, to alleviate the contradictions that emerged in her lesson (shown in Figure 6.8), Kelly shifted her role from facilitator to manager, taking control of the discussion and essentially telling students what they should have found. In effect, in that in situ instruction decision, she shifted students from their role as collaborating community members back into the role of

objects so as to cover the lesson objectives within her allotted time. This is shown in Figure 6.9.

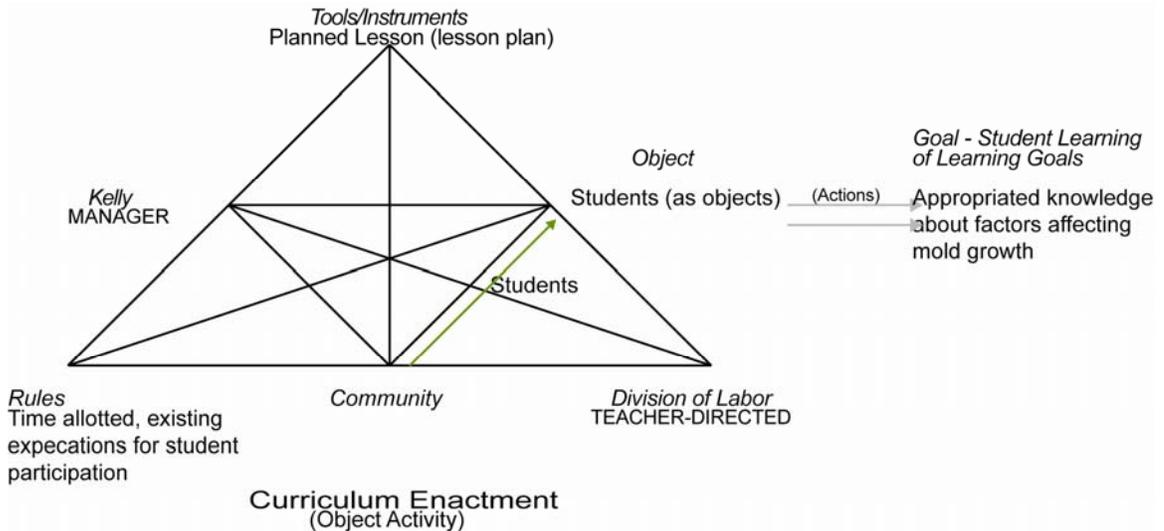


Figure 6.9. Resolution of Contradictions in Kelly's Fourth Enacted Lesson

She recalled after her lesson, "I just didn't leave enough time and I think it seemed like pushed or contrived because I was trying to connect ideas really quickly but we didn't have much time to talk about what happened" (Post-Enactment Interview 4). As a result, Kelly's fourth lesson ended up being less inquiry-oriented than that which she had planned.

After her lesson, Kelly concluded that most students were able to produce graphs that accurately reflected the mold growth data from their investigation. However, she noted that without the substantive discussion she had planned, "it's hard to know if [students] really understood, you know, ok, what can you see from this data now? Like what does this tell you?" (Post-Enactment Interview 4). Kelly noted her disappointment, saying, "I wanted to leave more time so that I could make it apparent that the reason we're making these graphs is so we can see trends and assess predictions, that we can see what's going on with our data and what it tells us. I think I did mention that a little bit but we didn't get to conclude with that thought as I'd hoped" (Post-Enactment Interview 4). In the end, Kelly was unsure of whether or not her students had met the learning goals she had set for them and, because the discussion she planned went largely

unaddressed, her enacted fourth lesson was less inquiry-oriented than that which she had planned.

Kelly's professed model of inquiry. At the end of the year, Kelly's professed inquiry model was consistent with that she had articulated throughout the year. Kelly summarized her professed model of inquiry, saying, "I think the importance of having a strong driving idea or question to your lesson and making sure that students support their conclusions with concrete evidence. I think those are the two things I've really taken away" (FI3). Kelly's inquiry model is shown in Figure 6.10.

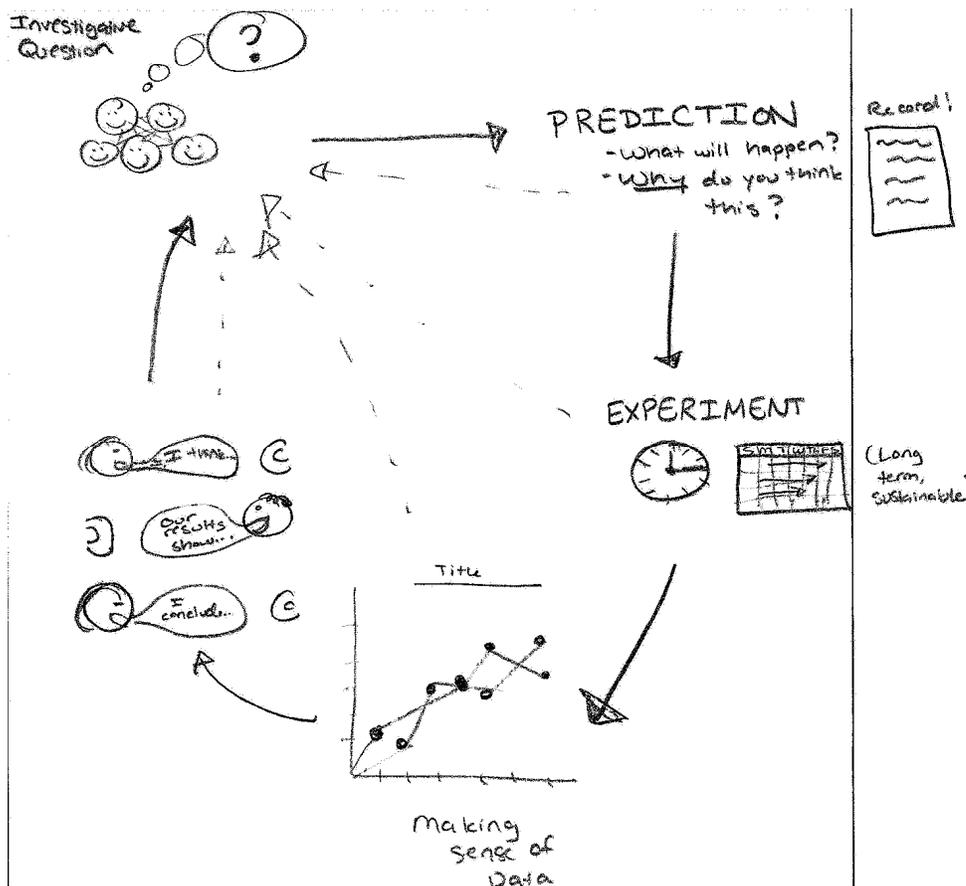


Figure 6.10. Kelly's End-of-the-Year Professed Model of Inquiry

As evidenced in her inquiry model, Kelly continued to prioritize the use of investigation questions, saying,

I think each piece is important but I think each piece comes back to the investigation question. That needs to be at the center. But I think all parts need to be included. I don't think you should cut out any of those parts but

I think they all should relate to the driving question. (FI3)

Consistent with her previous statement, Kelly had all other elements of inquiry linked back to the investigation question in her inquiry model. In describing her model, she said,

...all the arrows come back to [the investigation question] at all points. I mean at every part of the lesson, whether it was making sense of our data through a data table or a graph, or communicating about our conclusions at the end, like no matter what, I thought it was important to bring it back to what we were trying to be discovering in the first place so kids don't lose that and so I don't lose that, like focus. So that was the thing that really, really helped me as far as applying what we learned about inquiry in the classroom was the driving questions and forming that with your students and always coming back to it. (FI3)

Kelly recalled that over the year, she used an investigation question in each of her lessons and found that helpful. She also acknowledged that engaging students in more student-directed inquiry by having them come up with investigation question was effective. She said that students "had a lot of questions and were good about helping me come up with a whole investigation question" (FI3).

More specifically, these investigation questions served as instantiations of the shared problem-spaces Kelly and her students co-constructed. The investigation questions became important tools for Kelly to balance the need to address predetermined objectives while still allowing for students' contributions, the key tertiary contradiction discussed by Kelly and the other preservice teachers (Figure 6.4). Because the investigation questions had been co-constructed, Kelly felt comfortable using them in other parts of the lesson to steer students back to the purpose of the lesson. She said, for example, "it was very helpful to have a driving question written on the board - without referring back to this, students (and I) might lose the main focus of the lesson - what are we really trying to discover?" (Lesson 3). Specifically, in reference to her fourth lesson, she noted the importance of the investigation question to make the object of activity, in this case the students' graphs, meaningful, saying, "[it] kind of reminds them of the purpose of making graphs. It's just kind of making sense of our data implied in that question...it's important for them to know why we're using the graphs in the first place" (Post-Enactment Interview 4). In this way, the investigation questions Kelly and her students co-constructed could serve as meaningful guides for learning while not

objectifying students to do so. In this way, the collaborative work inherent to the more constructivist inquiry practices (Figure 6.2) could be internally-regulating and orienting.

Kelly's revised approach to curriculum planning. Kelly acknowledged after her fourth lesson that she needed to continue to develop her ability to facilitate students' formulation, communication, and comparisons of explanations, particularly through classroom discourse. However, as a first step, Kelly recognized that she would need to engage in curriculum planning so as to insure that culturally-mediating elements of the curriculum enactment context were aligned with her goal of promoting students' participating in collaborative discourse and sense-making. This represented an emerging quaternary contradiction between her curriculum planning and curriculum enactment activities, as shown earlier in Figure 6.3. First, she noted that she would need to emphasize engaging students, saying, "a lot of that's management too. If you don't have good management the kids aren't going to get much from your lesson" (Post-Enactment Interview 4).

Second, Kelly noted that she needed to engage in curriculum planning to better account for the pacing of her lessons, saying, "[I] just need to realize how much time it takes to have a worthwhile synthesizing discussion". She specifically noted that learning to do so was crucial to promoting student learning, saying, "if you just ask them a few questions last minute about their data and what happened, it won't stick with them. I think to really leave 10 to 15 minutes at the end to just ask them questions that really get them thinking and having them communicate their ideas with one another...it's definitely worth it" (FI3). Moving forward, Kelly acknowledged this would be an important challenge for her, saying, "that's the main struggle for me, just making sure that I leave enough time to have a culminating conclusion at the end of the lesson" (FI3). She noted that having substantive collaborative discourse as a part of inquiry was time consuming. She said that "I think you need to leave more time than you think for that communication of results, and conclusions, because it just takes time to connect ideas in like a dialogue...The part that was difficult was the communicating at the end and connecting ideas and one another's explanations. Like I said, I usually ran out of time for that, and need more time for it" (FI3). However, Kelly expressed confidence in her capacity to revise her approach to curriculum planning to better support students' knowledge

construction through inquiry, saying,

I think now that I've had more experience and know how kids' minds work better and like how to set up an experiment better, I am able to add a lot more management ideas and also like better help them form knowledge using inquiry. I think it's just more clear-cut for me now.

Kelly had therefore drawn upon her curriculum enactment experiences over the course of the year to help develop a more robust approach to curriculum planning for inquiry.

Summary. Like the other three preservice teachers, Kelly engaged in curriculum enactment for inquiry and, in doing so, articulated a tertiary contradiction between, on one hand, her goal of having students construct understanding through participation in inquiry as community members and, on the other, having them appropriate predetermined learning goals. For Kelly, this issue did not result in secondary contradictions within her enacted lessons until her fourth lesson when she attempted to engage students in collaborative discourse about their explanations. This experience not only led Kelly to revise her approach to curriculum planning, but also to leverage her existing prioritization of engaging students in scientifically-oriented questions and questioning to position students as valid, contributing community members in shared sense-making. While she had not resolved this tertiary contradiction entirely, these strategies had helped her begin to address it and target it as an area for ongoing professional growth.

Aliza

Overview. Aliza's focal point for curriculum planning in her science lessons, particularly her first two science lessons, was engaging students as community members with whom, through collaborative discourse, she could facilitate shared sense-making. However, in attempting to accomplish this in her lesson enactments and like Kelly and Mike, Aliza struggled to reconcile secondary contradictions that emerged between, on the one hand, her goal of having students construct meaning through collaborative discourse and, on the other, rules and norms regarding the management of time. While Aliza did, like the other three preservice teachers, articulate promoting student learning as a goal for curriculum enactment, over time she shifted towards a more teacher-centered approach to science teaching in which students were less community members but rather objects of enactment themselves. While Aliza's commitment to student learning as a goal of curriculum design was evident in her end-of-the-year inquiry model, she continued to

wrestle with a tertiary contradiction between two possible versions of curriculum enactment, how to engage students in inquiry in light of affordances and constraints of her context.

Aliza's enacted lessons. Aliza's focus on collaboration and discourse was most evident in her first three lessons. As discussed in a previous section, Aliza's adaptations in her first lesson focused on having students develop their plant experiments and determine which variables they would focus on for their data collection. This occurred in a student-centered whole-class discussion that Aliza facilitated. For example, after students had offered up and described an experimental design, Aliza facilitated a discussion in which they agreed upon a number of variables upon which to focus their data collection.

[Student 1] ...and see which one grows better, which one's more healthy.

[Aliza] I really like that idea. Do people agree that that would be a good experiment?

[All] yeah, um-hmm

[Aliza] Ok, so that sounds like a good idea, I think we can do that, but then as we're growing our plants, how can we tell which one's growing better? Yes?

[Student 2] Look at which one's green and grows a lot?

[Aliza] Right, so all of those would be qualities of the plant that we'd be observing, right? And if we were watching our plants grow, we could write down our data, right, our information about the different qualities of plants? So [student 2] just said the color, right, if it's green, if it's tall, so it's size [writing on board]. And what else did you say?

[Student 2] If it's not decomposing

[Aliza] If it's not decomposing, right, how it's growing. So do you have some other ideas?

[Student 3] This was something to add. Since plants need worms in the soil, you could take a couple of redworms out and put them in so the worms can help them decompose.

[Aliza] That is a good idea. Our pots aren't going to be very big so I don't know if that would be good for the worms. But we could take some of the worm castings, right, because that's really rich nutrients and we could add that to our organic pot so it could grow better. So those are really great ideas, I think we should try that. (Lesson 1 Enactment, 34:22-37:02)

This collaborative discourse was an important element in her lesson in which the students participated as community members, jointly-constructed the problem of designing their plant experiments to answer their investigation question. In the end, Aliza supported students to articulate variables that would ultimately support their sense-making about their results.

Aliza’s second lesson was actually a follow-up lesson to her first in which students examined their results and made claims about the effect of organic materials on plant growth. After her lesson, Aliza reported feeling as though her students had achieved the learning goal she had emphasized in her lesson, writing,

During our class discussion and also in their final conclusions, it is clear that students recognize that nutrients promote plant growth, and that is why our plants in organic material grew healthier, because they had more nutrients from the decomposing organic material in the soil, specifically worm castings. Students wrote things like, “The plants in organic material grew better because they had more nutrients in the soil” and “The worm castings helped the organic plants grow bigger.” (RT2)

These were the primary goals for student learning Aliza articulated for her first and second science lessons.

However, a secondary contradiction emerged between Aliza’s goal of co-constructing a shared problem-space with students and the rules governing the time that she was allotted to do so. This is illustrated in Figure 6.11 below.

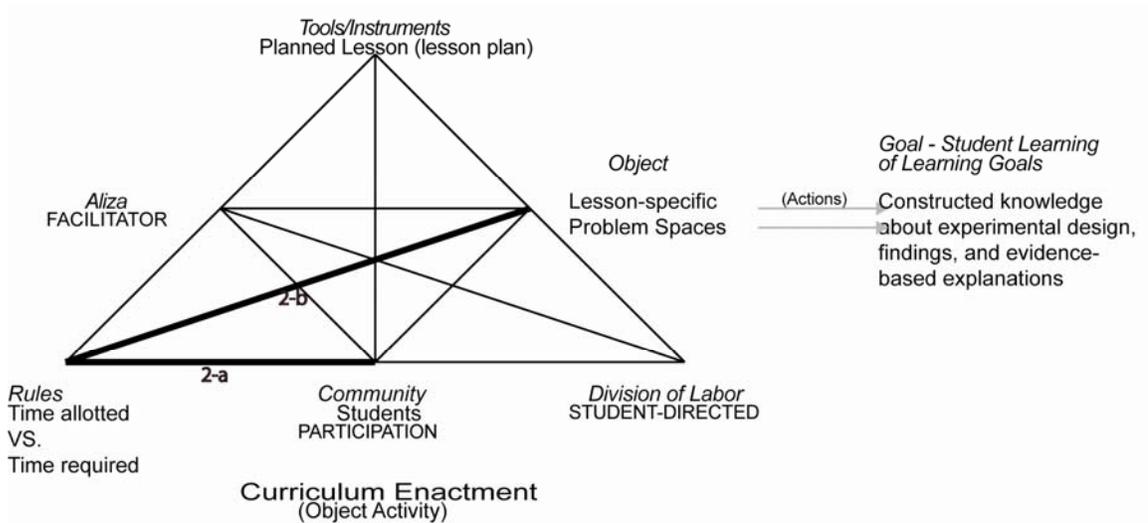


Figure 6.11. Secondary Contradictions in Aliza’s First Three Lessons

Aliza noted that because of the lengthy discussion she facilitated during her first lesson, she “ran out of time at the end” and, as a result, “was unable to do a wrap-up to the lesson” (RT1). Similarly, in her second lesson, Aliza ran out of time to have her students write their explanations in their journals, the final element in her planned lesson. After teaching her first two lessons, Aliza noted that accounting for time in her enacted lessons was an area for future growth, writing, for example, that she “need to work on time management” (RT1). In some ways, Aliza was confused by her apparent inability to conclude her lessons in the time she was allotted to teach science, saying, “It’s so weird because I have taught other lessons [and] I feel like the timing has usually worked out before in the other [subjects]” (Post-Enactment Interview 2). In this sense, then, this an issue that was, for Aliza, unique to her curriculum design for science. She began to prioritize the need to complete her lessons on time, saying after her second lesson that “even if I run out of time, I need to leave some time to do some closure” (Post-Enactment Interview 2).

Aliza’s enactment experiences ultimately resulted in the tertiary contradiction between two possible forms of curriculum enactment discussed by all of the preservice teachers. Aliza wrestled with how to engage students in discourse as community members, as she had done in her first two lessons, while still insuring that the discussions were time-efficient and supported students to make explanations she wanted them to make. Form the beginning of the study, Aliza had emphasized students’ engagement in science as an important goal and this was evident in her desire to try to base her science teaching around their existing ideas and questions. Aliza recalled how she had approach previous lessons she had taught similarly and how her science lesson “was the same thing. Just having them think about it, letting the discussion go on, asking questions” (Post-Enactment Interview 2). She said after her first lesson that “what’s hard for me I guess is when the kids have legitimate science questions...I need to work on finding a time to cut them off and not take any more questions, because I feel bad doing that” (Post-Enactment Interview 1). This issue was still apparent halfway through the year. Aliza said,

I talked about sort of time management issues for me, and somehow get things to fit into the time that they’re supposed to. And I don’t know, I think it’s still, it’s a delicate balance between letting the students share

their thoughts and ideas and questions and moving on in a sense, like having time to do everything that you need to do in the lesson. (FI2)

This trend continued in Aliza's third lesson, which was an introductory lesson to minerals in which students made observations of various minerals, recorded their properties, and looked for patterns in these properties. One of Aliza's adaptations to the lesson was to have students collaborate in small groups to record observations and then have a whole-class discussion to discuss similarities and differences. Aliza argued this was "a good way to close a lesson is to have students talk about what they've learned as opposed to just writing it down" because "when they're talking about it... it's more inquiry-oriented...it's like extending the thinking process... like the next step in inquiry" (Pre-Enactment Interview 3). However, during the lesson, and like her first two lessons, Aliza began to run short of time. Unlike her first two lessons, however, in which Aliza continued to attempt to enact her lesson as planned, in her third lesson she made additional in situ changes to her lesson. Aliza recalled,

...there was a point where, you know, there was a lot of discussion in inquiry-based learning and especially when they're observing something and making notes about it. But I realize and probably also because of the materials issue that there was a lot of talking and maybe not so much of writing things down. So that was when I sort of just stepped in and was like, 'ok', and I took each mineral and held it up and said, 'ok, what did we learn about this mineral?' or 'what did we discover about it?' and had some student give examples. Then I said 'ok, if you haven't written anything down about this mineral, those would be some good things to write down'. So we did that for the minerals (Post-Enactment Interview 3)

Due to the limited amount of time she had remaining, Aliza stepped in and focused the students on the observations she wanted them to make in light of predetermined learning goals she had articulated for the lesson. This is illustrated in Figure 6.12 below.

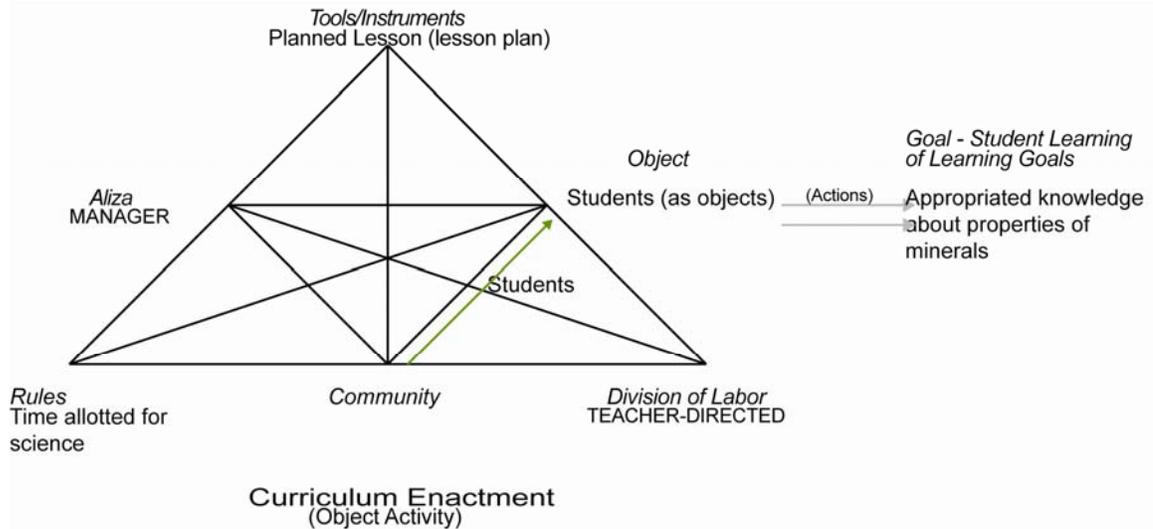


Figure 6.12. Resolution of Contradictions in Aliza’s Third Enacted Lesson

This instructional decision resulted from the same secondary contradiction between Aliza’s goal of having students’ collaboratively construct evidence-based explanation and the rules governing time for her to enact her lesson. This in situ adaptation essentially repositioned students as objects of the activity themselves, while also removing their opportunities to construct explanations about their minerals, thus making Aliza’s lesson less inquiry-oriented than she had originally planned.

Aliza’s professed model of inquiry. Aliza’s experiences enacting her lessons did not fundamentally influence the ways in which she engaged in curriculum planning over the course of the year. However, important shifts were visible in her model of inquiry by the end of the year that helped explain how she was attempting to resolve this tertiary contradiction in curriculum enactment. Most importantly, Aliza described prioritizing first and foremost student learning in her revised model of inquiry, which is shown in Figure 6.13.

anyone had an idea, they were sort of bouncing it off someone else and sharing it with someone else so you could have that for any of those” (FI3).

However, as before, Aliza reiterated the tertiary contradiction she experienced in her lesson enactments. She reiterated that “it seems like one of the main purposes of inquiry is having the students be the ones kind of exploring things on their own...student-oriented experiments” (Post-Enactment Interview 3). However, as had been evident in her third lesson, Aliza recalled the tension between more student-directed inquiry and predefined learning goals, saying, “I think it’s the same problem in the videos we were watching in your class really, where they were doing those experiments about, what was it, water and condensation. It was just like days and days of the students trying to figure things out on their own and just not really getting [it]” (Post-Enactment Interview 3). This represented a fundamental shift in Aliza’s conception of what ‘student learning’ meant. Whereas earlier in the semester she had focused much more on students’ collaborative construction of knowledge, she seemed to be focusing more now on predetermined learning goals. She reiterated that “I think that the goal was always student learning definitely” but said that “maybe I was like more aware of that towards the end” (FI3). Aliza recalled making on the spot changes to her lessons, saying, “as I would be running out of time for things, I would sort of like make those split-second decisions to focus on what was most important to you know, have student achievement of those objectives that I had for that lesson from the beginning. And while I mean I think that was the goal from the beginning, I probably improved on actually being able to do that, maybe towards the end” (FI3). She contrasted this approach, which had been increasingly evident by her third lesson, to her facilitation of more student-directed discourse in her first two lessons, saying, “like earlier, and, again, not that this is necessarily bad, but we would have really long discussions and I realized that you do really need to, I mean it’s great to have these discussions but you also need to be moving on to like the more concrete parts of the student learning also” (FI3).

Ultimately, then, Aliza articulated a vision for inquiry-based science teaching that represented a compromise between her own goals for student learning and the affordances and constraints of curriculum enactment contexts. Consistent with her renewed emphasis on student learning as the goal of inquiry, Aliza began prioritizing

eliciting students' existing explanations as a means through which to make inquiry more student-centered, though perhaps not student-directed. By preassessing what students already know, Aliza felt she could better engineer her lessons to insure that students achieve predefined learning goals through participation in inquiry practices. This is evident in her emphasis on students' existing ideas and preassessment (FI3). Also, again, Aliza recalled the video case from class, saying,

...you know how when we were in class and we were watching those videos where they were trying to let the kids figure out for themselves about, what was it, perspiration on a bottle when it's hot outside? And it was taking them forever to get there. I don't know, I kind of feel like maybe if the teacher somehow tried to sort of set up the experiment in a way where it would like address their particular misconceptions, maybe it would have cleared them up more quickly. (FI3)

In this way, then, Aliza's developing model of inquiry represented a way to prioritize discourse while still accomplishing pre-determined learning goals in a more time-efficient manner.

Summary. Aliza, unlike the other three preservice teachers, articulated a relatively robust inquiry model at the beginning of the year and taught two science lessons during the methods semester that were investigation-based. Aliza's emphasis on positioning students as contributing community members in inquiry was evident from the beginning. However, in trying to enact these lessons, Aliza experienced a secondary contradiction between her goal of co-constructing shared problem-spaces and promoting students' construction of knowledge and the rules and norms structuring how much time she had to teach her lessons. To alleviate this contradiction, Aliza began engaging in more teacher-directed inquiry in the classroom and moved away from promoting discourse as she had in her first two lessons. However, Aliza continued to emphasize the importance of both addressing predefined learning goals and positioning students as co-contributing community members in inquiry, thus articulating the same tertiary contradiction as the other three preservice teachers. To begin to address this contradiction, Aliza shifted her inquiry model to centralize student learning and focused on eliciting students' ideas as a way to align students' 'need to know' with the learning goals she established for her lessons.

Summary of Preservice Teachers' Curriculum Enactments

Consistent with the CHAT-based model in which this work is grounded, classroom teaching, or curriculum enactment, represents the object-activity for the preservice teachers' curriculum planning for inquiry. As such, it serves as the crucial site for the implementation and use of the instructional plans produced through curriculum planning (central activity), through which the preservice teachers here attempted to translate hypothetical, imagined practice into actual classroom practice. Like any activity, however, the process of enacting these planned lessons is culturally-mediated by rules, community members, and divisions of labor.

As shown in the individual teacher cases, the preservice teachers attempted to adapt their lessons in ways that better positioned students as community members who contributed to the articulation and formulation of problem-spaces. Through collective action, the preservice teachers sought to facilitate the students' construction of knowledge through engagement in inquiry practices. However, their attempts to shape the curriculum enactment context to support this form of science teaching and learning activity often resulted in emergent secondary contradictions between, on the one hand, the formulation of shared problem-spaces and their goal of promoting student learning and, on the other, culturally-mediating elements of the activity settings, particularly rules and norms. Because the preservice teachers had limited autonomy to alter these culturally-mediating elements, they alleviated these contradictions by making in situ adaptations during enactment. These changes tended to engage students in more teacher-directed practices, put the teacher in the role of manager, and, perhaps most importantly, shifted students from community members to the objects of curriculum enactment, simultaneously shifting the goal from constructed knowledge to more appropriated knowledge. In many cases, these in-situ changes also made their lessons less inquiry-oriented. Ultimately, this led to a tertiary contradiction between these two possible forms of curriculum enactment (Figure 6.4) that the preservice teachers were still struggling to reconcile at the end of the study.

However, the emergence of this tertiary contradiction in curriculum enactment led to quaternary contradictions between classroom teaching (curriculum enactment) and both the preservice teachers' curriculum planning activity and their espoused inquiry frameworks. In their curriculum planning, the preservice teachers began to account for

culturally-mediating elements of the curriculum enactment context (rules, community, division of labor) alongside their inquiry models in curriculum planning. Kelly and Aliza explicitly began planning to leave time for students' sense-making while Mike began to consider rules and norms that would better position students in the role of community member rather than the object of activity itself. Similarly, with the exception of Lauren, the preservice teachers' espoused inquiry frameworks evolved largely in conjunction with their curriculum design practice.

Summary of Case Study Findings

In Chapters 5 and 6, I have presented findings from the case studies of four preservice elementary teachers studied in-depth throughout the year. These findings address research question 2, in which I ask, "why do preservice elementary teachers mobilize and adapt science curriculum materials in ways that they do, particularly in light of their espoused inquiry frameworks?", and research question 3, in which I ask, "how do preservice elementary teachers' espoused inquiry frameworks and curriculum design practices for inquiry-oriented science teaching evolve over time?". Using cultural-historical activity theory as an explicit analytical framework, I have provided evidence that illustrates why these four preservice teachers engaged in curriculum design for inquiry in the ways that they did.

First, the preservice teachers articulated two goals for curriculum design. Early in the year, they emphasized planning and enacting science lessons that were fun and engaging for students. They also prioritized promoting student learning, though initially less so. Over time, however, the preservice teachers began to more heavily emphasize promoting student learning through curriculum design for inquiry and came to view making science fun and engaging as a prerequisite to meeting that goal.

Second, to accomplish their goals, the preservice teachers began mobilizing their espoused inquiry frameworks to evaluate and adapt existing science curriculum materials. Early on, Kelly, Mike, and Lauren's inquiry models were relatively vague and ill-defined and their attempts to instantiate their inquiry models in their first lessons were not overly effective. Aliza, on the other hand, articulated a more practice-specific inquiry model early in the study and made changes to her first lesson that reflected this. However, due to the preservice teachers' work in the methods course, they relatively quickly elaborated

upon their early inquiry models, particularly Kelly, Mike, and Lauren. Their evolving inquiry models were much more consistent with those promoted in the methods course and, as a result, they were able to adapt their subsequent lessons to make them more inquiry-oriented.

Third, culturally-mediating elements of the preservice teachers' curriculum planning contexts (rules, community, division of labor) did not help provide an explanatory basis for adaptations the preservice teachers made to their lessons in their curriculum planning activity. When preservice teachers did make adaptations, it was not due to contradictions between their goals and these culturally-mediating features. Rather, the cultural mediation of the preservice teachers' curriculum planning helped explain adaptations they sought to make but did not. These did represent secondary contradictions between their goals and culturally-mediating elements of curriculum planning. Because the preservice teachers did not have the autonomy (division of labor) to modify or influence many of the rules and community members influencing their curriculum design decisions, the only way to alleviate these contradictions was to *not* make those adaptations. Ultimately, evidence suggests many of the adaptations that they wanted to make but did not would have ultimately made the preservice teachers' lessons more inquiry-oriented. In this way, the culturally-mediating elements of the preservice teachers' curriculum planning contexts were a constraining influence on their curriculum planning for inquiry.

Fourth, an aggregate effect of the preservice teachers' adaptations was to engineer classroom learning environments so as to position students as collaborators and authentic contributors in collective sense-making. In essence, this was an attempt by the preservice teachers to facilitate more student-directed inquiry practices through which students would construct understanding of various natural phenomena. Unlike their curriculum planning, however, culturally-mediating elements of the preservice teachers' curriculum enactment contexts proved highly influential. In attempting to enact their lessons, Kelly, Mike, and Aliza experienced secondary contradictions between their goals and culturally-mediating elements of their enactment contexts, particularly rules and norms over which they had little influence. The emergence of these secondary contradictions in practice often led to additional in-situ adaptations which, in most cases, made the preservice

teachers' lessons less inquiry-based. They also caused quaternary contradictions between, on the one hand, curriculum enactment and, on the other, curriculum planning and the preservice teachers' models of inquiry. Ultimately, the preservice teachers each articulated a tertiary contradiction between more student-centered and more teacher-centered inquiry and, though each preservice teachers' curriculum planning and/or inquiry models evolved over time in light of this contradiction, each was still working to resolve it at the end of the study.

CHAPTER 7

DISCUSSION AND IMPLICATIONS

Teachers need to engage students in inquiry-oriented science. However, to do so, they need to learn to effectively use curriculum materials in particular professional contexts to accomplish certain goals, or develop pedagogical design capacity for inquiry. Findings from this study broadly inform existing research science teacher learning and expertise (Abell, 2007; Magnusson, Krajcik, & Borko, 1999) and practicing science teachers' use of science curriculum materials (Barab & Luehmann, 2003; Pintó, 2004; Schneider, Krajcik, & Blumenfeld, 2005). They also contribute directly to an emerging body of research focused on preservice elementary teachers' critique and adaptation of science curriculum materials (Beyer, 2009; Davis, 2006; Dietz & Davis, in press; Forbes & Davis, 2008; Schwarz et al., 2008). Finally, they inform theoretical perspectives on the teacher-curriculum relationship (Brown, 2009; Remillard, 2005) and CHAT-based research on teachers and teacher learning (Grossman, Smagorinsky, & Valencia, 1999; Roth & Lee, 2007).

In this study, I use cultural-historical activity theory as a holistic theoretical and analytical framework for investigating preservice elementary teachers' development of pedagogical design capacity for inquiry. In Chapter 2, I presented a CHAT-based model designed to represent the preservice teachers' curriculum design for inquiry (Figure 2.3). Data collection and analyses (Chapter 3) were explicitly aligned with and designed to illuminate elements of the model in Figure 2.3. In my presentation of results (Chapters 4, 5, and 6), I returned to components of the model and used them as explanatory frameworks for specific dimensions of the preservice teachers' curriculum planning and enactment activities.

These findings, embedded within this CHAT framework, elaborate upon the notion of pedagogical design capacity (Brown, 2009) by highlighting its systemic rather than individualistic nature, illustrating its causal influence on teachers' professional

decisions and actions, as well as mapping its evolution over time. Using CHAT, I have explored the essential elements of pedagogical design capacity, which include instructional goals, teachers' and their espoused knowledge, beliefs, and other 'teacher characteristics', the curriculum materials teachers use, and the contexts of professional practice to understand specific actions that constitute activity, the outcomes of those actions, as well as the broader activities that constitute curriculum design for inquiry. In the sections that follow, I discuss these findings and their implications, again using my CHAT-based model of curriculum design for inquiry as an organizing framework.

A small but growing body of research focused on preservice elementary teachers and curriculum materials has made important contributions to the field's understanding of how preservice elementary teachers evaluate existing science curriculum materials (Beyer, 2009; Davis, 2006; Dietz & Davis, in press; Forbes & Davis, 2008; Schwarz et al., 2008). However, the process by which preservice teachers adapt and use their curriculum materials based on these critiques remains unexplored. Findings from this study extend and complement previous research by illustrating preservice elementary teachers' curriculum design decision-making that both precedes and follows their critique of science curriculum materials, specifically the types and frequencies of curriculum materials preservice teachers use, as well as the adaptations they make in their curriculum design for inquiry.

In discussing my findings here, I turn again to my CHAT-based model as an organizing framework. This model represents not only the preservice teachers' curriculum design actions and outcomes of those actions, but also elements of pedagogical design capacity emphasized in this study - the preservice teachers' espoused inquiry models, the curriculum materials they used, and features of their curriculum design contexts - that provide explanations for those actions and outcomes. First, I focus on results from the preservice teachers' mobilization and adaptation of curriculum materials, as well as how inquiry-based they were. These findings, which are largely drawn from Chapter 4 but also from Chapters 5 and 6, illustrate the production sub-process of the curriculum planning activity. This sub-process 'working sphere' of curriculum planning for inquiry, illustrated by the uppermost triangle in the curriculum planning activity model, includes the actions and outcomes of the preservice teachers'

curriculum planning, as well as how the preservice teachers' mobilized their espoused inquiry frameworks to make these curriculum design decisions. Second, I discuss the context of the preservice teachers' curriculum design activities, largely drawn from the cases studies presented in Chapters 5 and 6, particularly the culturally-mediating elements (rules, community, divisions of labor) that also shaped their curriculum design decision-making.

Curriculum Planning Sub-Processes

Curriculum Planning Sub-Processes: Preservice Teachers' Curriculum Design Actions and Outcomes

As noted above, I first focus on the production sub-process of curriculum planning first illustrated in Figure 5.2. The curriculum planning activity triangle is presented here again in Figure 7.1, with the triangle representing the production sub-process emphasized.

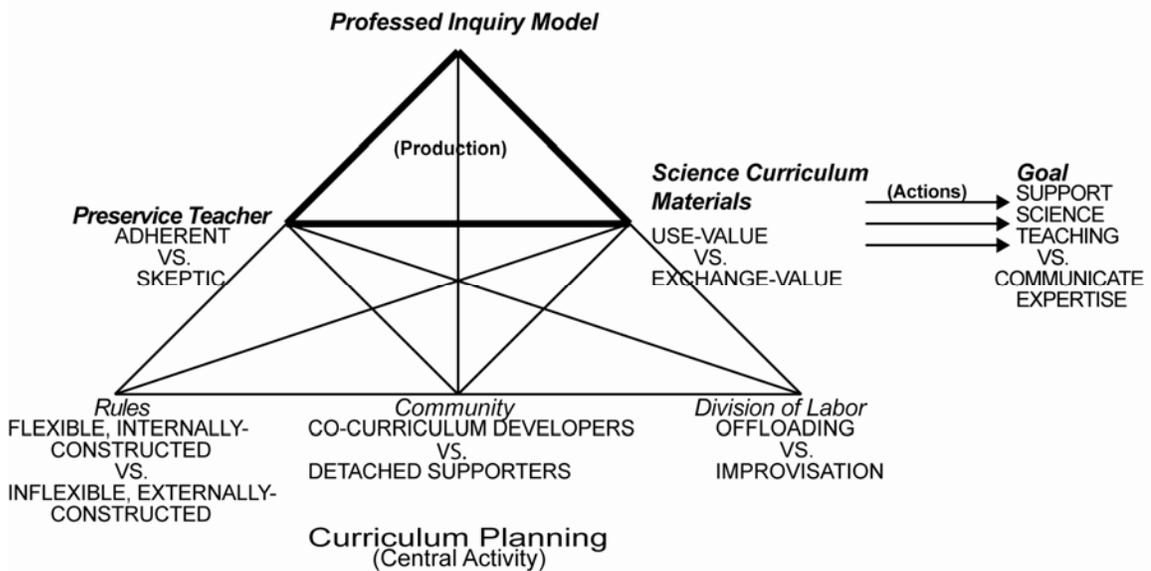


Figure 7.1. Production Sub-Process of Curriculum Planning for Inquiry

In the sections that follow, I discuss the preservice teachers' curriculum design decisions (actions) and the outcomes of their curriculum design decisions, and situate these findings within existing teacher-curriculum research (Brown, 2009; Remillard, 2005).

Curriculum design actions. An important element of the preservice teachers' lesson plan production were their curriculum design decisions (actions). As shown in the

results, the preservice teachers studied here primarily used existing lesson plans and student worksheets to engage in curriculum planning for inquiry. The preservice teachers most often tended not to construct instructional plans from a variety of curricular resources. These preservice teachers, like beginning elementary teachers, tended to use existing curriculum materials, particularly existing lesson plans and associated documents, rather than engaging in all-out curriculum design (Forbes & Davis, 2007; Grossman & Thompson, 2004; Kauffman et al., 2002). This finding not only illustrates the process by which preservice elementary teachers adapt science curriculum materials, but specifically that the curriculum materials they use play a critical role in defining the working space within which teachers evaluate and adapt them in light of their ideas about inquiry.

Even though the preservice teachers tended to rely on existing lesson plans rather than mobilizing a wide variety of curriculum materials in each of their lessons, they still adapted these existing curriculum materials in most cases. The preservice teachers largely added, deleted, or substituted elements in the lesson plans and curriculum materials they used. They did not tend to rearrange existing lesson elements (i.e. they rarely made relocations, translocations, or inversions). Also, some preservice teachers tended to consistently make more adaptations than others. Recall that there were moderate to strong, statistically-significant correlations between the types and frequencies of preservice teachers' adaptations across the two reflective teaching assignments. This suggests that preservice teachers who tended to make more adaptations in their first reflective teaching assignment also tended to do so in their second, and vice versa. Trends in the preservice teachers' adaptations, then, were more consistent across the two reflective teaching assignments, unlike their curriculum materials mobilization.

Outcomes of preservice teachers' curriculum design actions. The outcome of preservice teachers' curriculum design that was of interest in this study was the inquiry-orientation of their planned lessons. Previous research has shown that teachers, including preservice elementary teachers, may or may not make productive adaptations to the curriculum materials they use (e.g., Collopy, 2003; Davis, 2006; Pintó, 2004; Remillard, 1999; Schneider, Krajcik, & Blumenfeld, 2005; Schwarz et al., 2008). However, as

shown in the results here, the preservice teachers were successful at adapting existing curriculum materials to develop lesson plans that were more inquiry-oriented than those with which they began. This is an important finding that complements existing research by showing preservice elementary teachers can effectively adapt existing curriculum materials.

Despite the increasing emphasis on the role teachers play in critiquing and adapting curriculum materials, however, a tension still exists between teachers' curricular decision-making and intentions of the curriculum developers. As discussed previously, some research has found teachers to adapt curriculum materials in ways that contradict the intentions of the curriculum developers. As discussed in Chapter 2, past curriculum development efforts have sought to minimize the influence of the 'teacher effect' on curriculum enactment, instead promoting enactment with fidelity (Nye, Hedges, & Konstantopoulos, 2004). It is important to note that here, in only three out of the 93 lessons analyzed in this study did the preservice teachers' adaptations actually make their lessons *less* inquiry-oriented than those with which they began. In some ways, this finding contrasts with a reasonable assumption that preservice teachers, due to their lack of expertise, might be most likely to unintentionally develop lessons that are less effective than those with which they started. Rather, as shown in the results from the regression model, the inquiry scores of the curriculum materials they used was the biggest influence on the inquiry score of the preservice teachers' revised lessons. In sum, the preservice teachers were highly unlikely to decrease the effectiveness of existing science lessons through their curriculum design decisions.

Characterizing the curriculum planning sub-process. Based on these findings, a generalized picture of the preservice teachers' curriculum planning production sub-process begins to emerge. The preservice teachers predominantly used curriculum materials to which they had ready access rather than mobilizing a variety of curriculum materials. Because the preservice teachers did adapt the curriculum materials they used, the process of curriculum design observed in this study is indicative of *invention* (Remillard, 1999) or *adaptation* and *improvisation* (Brown, 2002). These two findings, to draw on the model of teachers' curriculum materials use from Figure 2.4, show that the preservice teachers' curriculum design actions lie primarily in the *curriculum adaptation*

domain and illustrate a curriculum design pattern characterized by *focused improvisation*. This is shown in Figure 7.2 below.

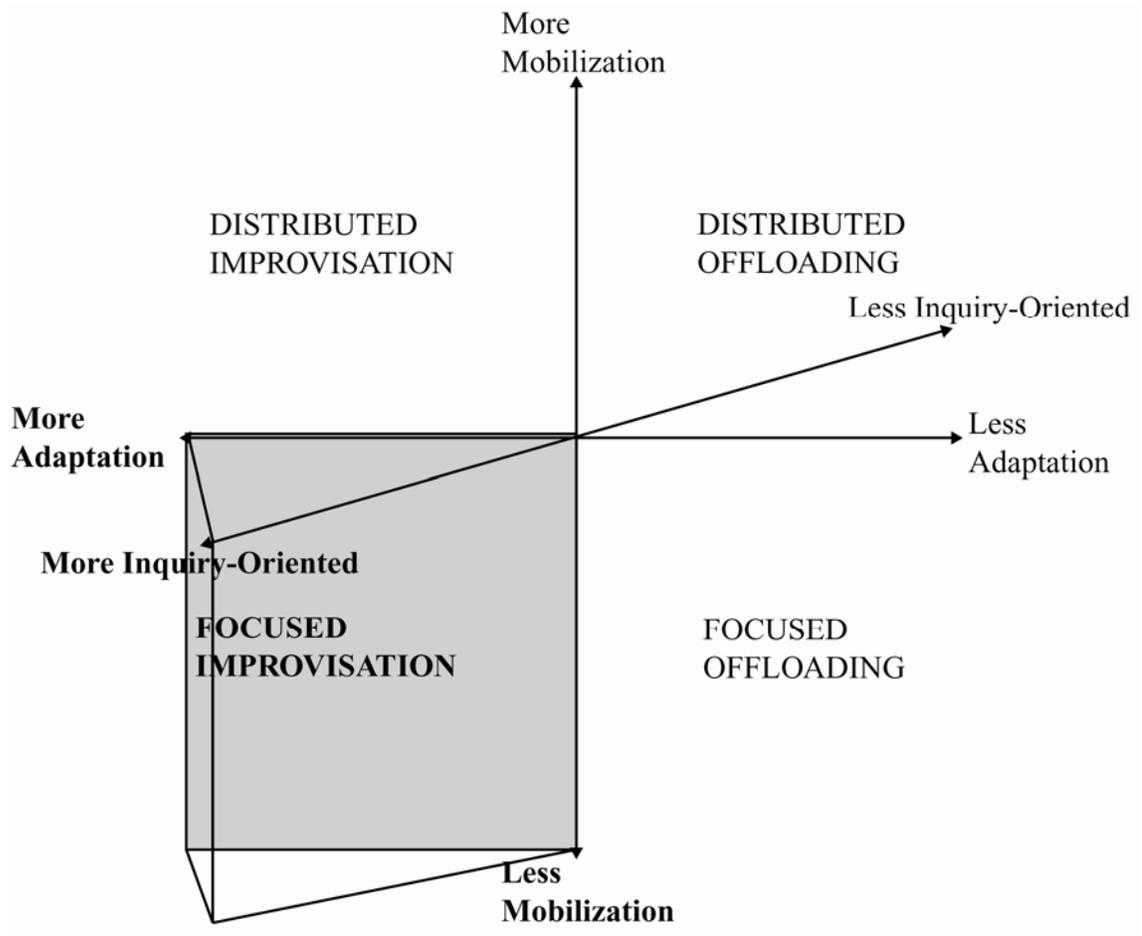


Figure 7.2. 3-Dimensional Model of Preservice Elementary Teachers' Curriculum Design for Inquiry

Consistent with Engeström's (2008) notion of 'working spheres' of activity, Figure 7.1 illustrates the multi-dimensional process characterizing the production of instructional artifacts. By engaging in focused improvisation, which was characterized by the adaptation of existing, easily-accessible curriculum materials, the preservice teachers were able to make revised planned lessons that were more inquiry-based. In this sense, the preservice teachers were successful in their production sub-process of curriculum planning at achieving the goal of developing more inquiry-based lesson plans.

Curriculum Planning Sub-Processes: The Influence of Preservice Teachers' Espoused Inquiry Frameworks on Curriculum Design Actions and Outcomes

As shown in the previous section, the preservice teachers' curriculum mobilization was highly lesson-dependent. More specifically, the curriculum materials the preservice teachers used (typically existing lesson plans) drove their planned instruction. The inquiry-orientation of the preservice teachers' planned lessons was largely determined by the curriculum materials they used. On the other hand, the curriculum materials they used provided the preservice teachers with a bounded working space for within which they employed their inquiry frameworks as tools to make their lessons even more inquiry-based. Having outlined the preservice teachers' curriculum design decisions (actions) and the outcomes of those actions (how inquiry-based their planned lessons were) in the previous section, it is important to discuss the influence of the preservice teachers' espoused inquiry models on those actions and outcomes.

Preservice teachers often articulate conceptions of inquiry and inquiry-based teaching and learning that are often inconsistent with those advocated in science education reform (Abell, 2007; Bryan, 2003; Gess-Newsome, 2002; Howes, 2002; Windschitl, 2003, 2004). In the current study, at least early in the year, the preservice teachers struggled to articulate specified, criterion-based models of inquiry. Rather, consistent with previous research (Abell, Bryan, & Anderson, 1998), they emphasized student-led, hands-on science activities that were enjoyable for students. However, the preservice teachers were able to rapidly expand and elaborate upon their espoused inquiry frameworks during the methods semester. First, as shown in Chapter 4, the preservice teachers were able to accurately assess how inquiry-based their lesson plans were in both reflective teaching assignments. This finding suggests that, at least at a general level, the preservice teachers' conceptions of inquiry were largely consistent with the inquiry frameworks promoted in the methods course. Case-based data from the focal preservice teachers also illustrates how they articulated inquiry models over time that were more aligned with specific features of inquiry articulated in science education reform (AAAS, 1993; NRC, 1996, 2000).

Preservice teachers often struggle to translate their ideas into science teaching practice (Bryan & Abell, 1999; Crawford, 1999; Southerland & Gess-Newsome, 1999; Zembal-Saul, Blumenfeld, & Krajcik, 2000). However, as shown in the results of this study, the preservice teachers were able to adapt their lessons in to make them more

inquiry-based. For example, in both reflective teaching assignments, the preservice teachers developed lesson plans that were significantly more inquiry-oriented than were the original lesson plans they used. Thus, the preservice teachers were able to engage in curriculum design practices to better support inquiry-based science instruction, reinforcing findings from other studies (Schwarz et al., 2008). These results also support those from a few other studies that suggest preservice teachers can learn to engage in more inquiry-based science teaching practices more generally (Crawford, 1999, 2007).

Summary of Curriculum Planning Sub-Processes

In this section, I have focused on the production sub-process of the preservice teachers' curriculum planning as shown in Figure 7.1. The preservice teachers in this study were able to develop more articulated, robust, practice-specific inquiry frameworks (instruments) and, when allowed to employ them, were able to do so to adapt (actions) curriculum materials (object) and make them more inquiry-oriented (outcome). In effect, then, the preservice teachers were able to develop more robust pedagogical design capacity for inquiry, or at least the portion of it evidenced in the interactions between, on one hand, the teachers and their inquiry frameworks and, on the other, the curriculum materials they used (the production sub-process of curriculum planning). However, as discussed in Chapter 2, pedagogical design capacity is also defined by the contexts in which these interactions occur. I next turn to a discussion of the influence of the preservice teachers' professional contexts on their curriculum design for inquiry.

Cultural-Mediation of Curriculum Design Decisions and Outcomes

In the previous section I discussed the production sub-process of the preservice teachers' curriculum planning for inquiry. This essential relationship between the teacher and the curriculum materials, which is foregrounded as the crucial working space within which decisions are made that ultimately impact classroom practice, has largely been the focus of existing research on teachers and curriculum materials (e.g., Remillard, 2005). However, consistent with notions of pedagogical design capacity and the CHAT framework for curriculum design presented here, the contexts within which these teacher-curriculum interactions are based also have a crucial role to play. This is evidenced by the culturally-mediating elements (norms, community, divisions of labor) in the CHAT-based model used in this study.

The case studies of the four preservice teachers, the results of which were presented in Chapters 5 and 6, were critical for illuminating how culturally-mediating elements of their professional contexts influenced the preservice teachers' curriculum design decision-making. As these findings illustrated, the preservice teachers' curriculum design decisions, and ultimately their capacities for pedagogical design, were fundamentally shaped by their curriculum planning and enactment contexts. The net effect of these culturally-mediating factors in both the curriculum planning and curriculum enactment contexts was to constrain the preservice teachers' abilities to plan and enact more inquiry-based science.

As discussed in previous sections, evidence from the methods course and the case studies show that the preservice teachers were able to make adaptations to their lessons that made them more inquiry-based. These typically targeted specific inquiry practices promoted in the methods course and consistent with science education reform (AAAS, 1993; NRC, 1996, 2000). However, the case studies of the four preservice teachers also show that they adapted and attempted to enact their lessons in ways that would fundamentally reconfigure their classroom learning environments. To accomplish this, as discussed primarily in Chapter 6, the preservice teachers attempted to assume the role of facilitator to engage students as meaningful participants in the shared construction of lesson-specific problem-spaces. This generally involved affording students a more active role in classroom inquiry and relying on internally-constructed standards of practice. This shift is shown again here in Figure 7.3.

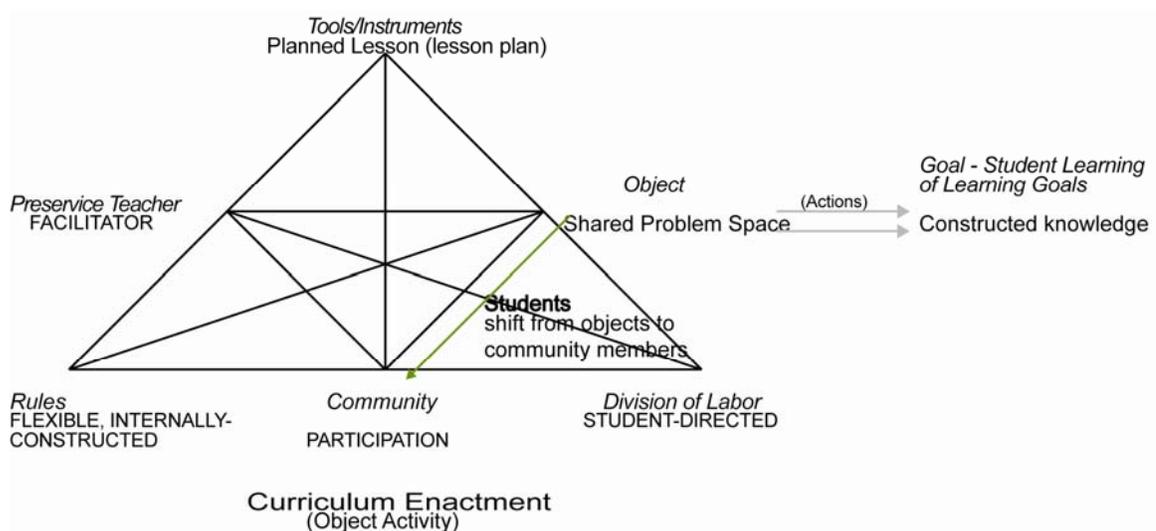


Figure 7.3. CHAT-based Model of Constructivist Science Teaching

In attempting to reconfigure classroom contexts in this way, the preservice teachers were doing more than engaging students in particular inquiry practices – they were taking steps to create a culture of inquiry in the classroom (Llewellyn, 2007).

In this way, the preservice teachers' curriculum design efforts worked to establish more constructivist, collaborative, inquiry-based learning environments focused on shared sense-making through inquiry. This contrasts starkly with more traditional, didactic instruction which has too often characterized school science and to which contemporary, reform-based models of science teaching and learning represent alternatives. The distinction between these two forms of science teaching and learning are consistent with a distinction Engeström (1987) makes between 'learning actions' and 'learning activity'. Learning actions, a less advanced form of learning, are indicative of the sort of rote memorization and recitation inherent to the many traditional school-based practices. Such learning actions are concerned primarily with the reproduction of text (or other representations of knowledge) which serve as the objects of activity rather than serving as tools or instruments in activity. In essence, Engeström argues that formal schooling has not yet transformed to enable true learning activity.

Why? A primary reason schools have not achieved this is because the dominant cultural dimensions of formal schooling still largely support the reproduction of text, or reproduction of knowledge, rather than knowledge-construction and shared sense-making. As shown in the results of this study, the preservice teachers' efforts to reconfigure their classroom learning environments to promote inquiry resulted in contradictions with pre-existing classroom practices and their underlying cultural dimensions. Emergent demands of their classroom-based inquiry practices often conflicted with externally-imposed, institutionally-derived rules, norms, and expectations. What emerged in the preservice teachers' instruction, then, were *hybrid inquiry practices*. These practices were evidence of a negotiated application of inquiry given, on one hand, the preservice teachers' espoused inquiry frameworks and curriculum materials and, on the other, their unique professional contexts that often served to constrain implementation of their lesson plans. These dominant forms of schooling, as

well as the norms through which they are reinforced, have a strong socializing influence that is difficult for novice teachers to overcome (Lortie, 1975). It should come as no surprise, then, that consistent with previous research (Appleton, 2003; Appleton & Kindt, 2002; Crawford, 1999, 2007; Enyedy & Goldberg, 2004; Haefner & Zembal-Saul, 2004; Songer, Lee, & Kam, 2002), the preservice teachers here experienced numerous barriers to engaging students in more inquiry-based science teaching and learning.

While the four preservice teachers in the focal group struggled with various challenges, none was more pressing than that of time, the rules and norms for which were pre-established in their schools. Invariably, their efforts to enact their planned lessons conflicted with the time they were allotted to teach their lessons. It is important to highlight that these norms governing time were institutional in nature and largely beyond the scope of the preservice teachers' individual classrooms. Their immediate curriculum enactment contexts (object-activity), like those of all teachers, are embedded within the broader cultural contexts of the institutions in which they reside (Lemke, 2000; Roth, Tobin, & Ritchie, 2008). As such, they are subject to its norms and structure. Here, the emergent demands of classroom inquiry contradicted with norms of time imposed by their institutions.

Past research has shown that for students to develop a rich understanding of scientific explanations, it is crucial that they have sufficient time to question, investigate, and construct explanations about those phenomena (Clark & Linn, 2003). Yet, as language arts and mathematics have enjoyed ascendant positions within the elementary school curriculum in recent years, science has become increasingly deprioritized (Marx & Harris, 2006; Spillane et al., 2001). Recently published data from the Schools and Staffing Survey (SASS - Morton & Dalton, 2007), for example, show that in grades 1-4, students receive an average of 3 hours per week of science instruction and that as a subject, science is afforded less than half of the instructional time as mathematics and less than one-fifth of the instructional time as language arts. With such a limited amount of time available for science teaching, it is no wonder that elementary teachers, including the preservice teachers studied here, struggle to engage their students in often time-consuming inquiry practices.

Evidence from this study also provides insight into what specific practices are being lost in science instruction due to these constraints. As shown in these results, when contradictions emerged in the classroom, the preservice teachers often shifted themselves back into the role of manager and engaged in more teacher-directed instruction in an effort to economize time. Once the structure of activity changed, so too did the ways in which the preservice teachers engaged students in discourse. This is consistent with existing research that shows how discursive patterns serve as cultural tools and are inexorably tied to the nature of classroom activity (Lemke, 1990; Polman, 2004; Reiser, 2004; Tabak, 2004; van Zee & Minstrell, 1997; Wells & Arauz, 2006). In the end, it was most often the collaborative, discourse-based elements of the preservice teachers' lessons that were minimized or eliminated in response to the contradictions they articulated. This, unfortunately, conflicts what previous research suggests about the important role of classroom discourse in the context of inquiry-based science teaching and learning. Negotiatory, dialogic patterns of discourse are defining characteristics of inquiry-oriented science teaching and learning in elementary and secondary classrooms (Reiser, 2004; Tabak, 2004; van Zee & Minstrell, 1997; Wells & Arauz, 2006).

In the absence of such collaborative, dialogic discourse, however, classroom science is ultimately less inquiry-based. This is because student sense-making and explanation-construction are linked explicitly to discourse that arises from inquiry practices (Krajcik & Blumenfeld, 2006; Krajcik & Mamlok-Naaman, 2006; Sandoval & Reiser, 2004). It is also the formulation and communication of explanations, or the generative process of shared meaning-making more generally, that constitutes 'learning activity' (Engeström, 1987). Recall that the preservice teachers in this study did not draw strong distinctions between the formulation and communication of explanations as inquiry practices. As such, to them, the collaborative discourse in which they sought to engage students was a critical element not only of communicating explanations, but also constructing them. However, in making in-situ changes to their lessons to address emergent contradictions in the classroom, the preservice teachers most often ended up deemphasizing this discourse. The preservice teachers were aware of this inherent tension, each articulating the essential tertiary contradiction first described in Chapter 6 (Figure 6.4) and shown here again in Figure 7.5.

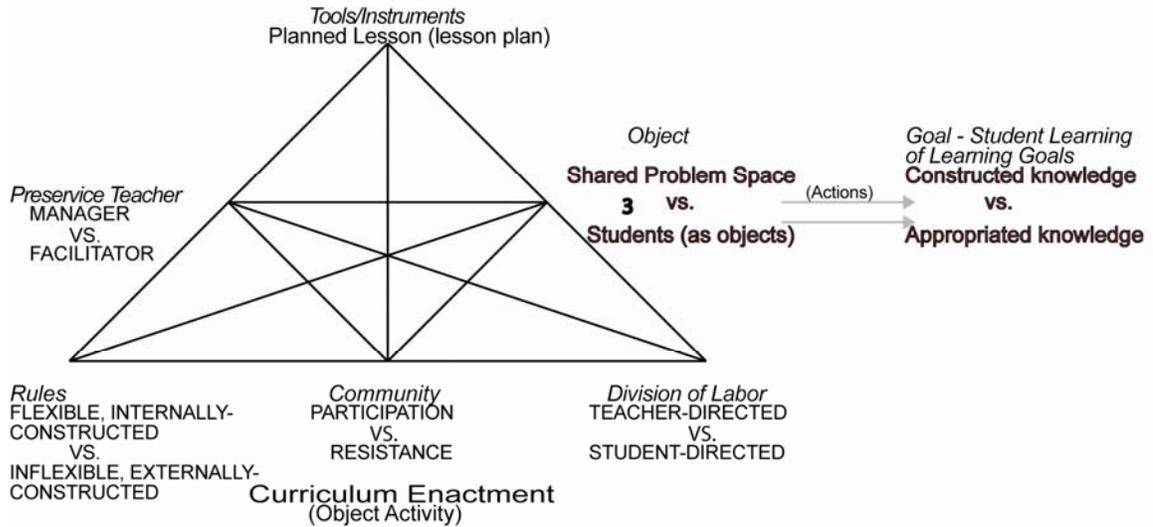


Figure 7.5. Tertiary Contradiction Between Traditional, Didactic and Constructivist Science Teaching

This contradiction, ultimately based on the conflict between emergent practices and the institutional features of schools largely resulted in lessons that were less inquiry-based, specifically in regard to sense-making and explanation-construction. When this shared sense-making is absent, classroom practice is indeed reduced to a series of ‘learning actions’, as Engeström (1987) argues.

Implications for Enhancing Teachers’ Pedagogical Design Capacity for Inquiry

The discussion in the previous section suggests that as a crucial component of teachers’ pedagogical design capacity for inquiry, the institutional features of their professional contexts ultimately caused their planned and enacted science lessons to be less inquiry-based. However, while these findings are troubling, the pedagogical design capacity of a particular system can be enhanced and improved by addressing its constituent components, particularly teachers’ personal characteristics (knowledge, beliefs, and identities), the curriculum materials they use, and their professional contexts, each of which was foregrounded in the CHAT-based framework used in this study. To enhance the pedagogical design capacity for inquiry of elementary classroom systems, elementary teachers, particularly preservice teachers, need to develop robust, usable inquiry frameworks, have access to effective, inquiry-based curriculum materials, and engage in curriculum design in institutional contexts that support and cultivate the autonomy of teachers and students to co-construct explanations about natural phenomena through

inquiry. Findings from this research have important implications for teachers' development of pedagogical design capacity for inquiry. In the sections that follow, I discuss implications of these findings and for science curriculum development, teacher education, and schools as institutions and how each can enhance the pedagogical design capacity afforded by school science systems.

Implications for Science Curriculum Development

Findings from this study illustrate the need for curriculum developers to continue to develop inquiry-based curriculum materials. Unfortunately, many science curricula used by teachers, particularly at the middle and secondary level, are not consistent with tenets of effective science teaching and learning (Kesidou & Roseman, 2002). In this study, as shown in Chapter 4, the more inquiry-based existing science curriculum materials were, the more likely the preservice teachers' planned and enacted lessons were to be equally or more inquiry-based. If inquiry-based teaching and learning is to be emphasized in teacher education (and professional development), it stands to reason that it should be instantiated in the curricular tools teachers use to engage in teaching practice. Ongoing curriculum development and research efforts should continue to explore how various inquiry frameworks can be effectively represented in the design of science curriculum materials (Barab & Roth, 2006; Brown & Edelson, 2003; Krajcik, McNeill, & Reiser, 2007; Linn, Clark, & Slotta, 2003; Songer, Lee, & Kam, 2002).

Aside from providing students with experiences that engage them in inquiry practices, curriculum materials can directly support the interaction between the teacher, employing his or her model of inquiry, and the curriculum materials themselves. These teacher-curriculum interactions can be supported through features of curriculum materials that are intended to be educative and flexibly-adaptive for teachers (Ball & Cohen, 1996; Davis & Krajcik, 2005; Fishman & Krajcik, 2003; Schwartz et al., 1999). These features could serve to support teachers' learning about inquiry teaching and learning, as well as specific scientific content. However, they can also scaffold teachers' curriculum design decision-making about when and how to adapt the curriculum materials to the needs of their students. The results from this study, for example, suggest educative features of curriculum materials could conceivably support teachers to reconcile time constraints with the emergent demands of inquiry practices.

Of course, to develop such powerful curriculum materials, curriculum developers need a thorough understanding of those to whom such materials are meant to be educative for and by whom they are meant to be adapted. However, there is still little research that informs our understanding of how teachers use these educative features of curriculum materials (Davis & Krajcik, 2005; Dietz & Davis, in press; Schneider & Krajcik, 2002). By better understanding how preservice elementary teachers mobilize, adapt, and enact science curriculum materials in light of their espoused inquiry frameworks, these materials can be better designed to simultaneously support their use and teacher learning.

Implications for Teacher Education

The findings from this study help science teacher educators better understand the needs of their students and have implications for promoting preservice elementary teachers' developing pedagogical design capacities for inquiry. First, they reinforce the need to emphasize the teaching and learning of science as inquiry in formal teacher education (NRC, 1996; NSTA, 2003), as many science teacher educators already do (e.g., Davis & Smithey, in press; Gess-Newsome, 2002; Schwarz et al., 2008; Windschitl, 2004). As shown throughout the results, evidence here suggests that while preservice elementary teachers may initially hold ill-defined, vague, and perhaps somewhat simplistic ideas about inquiry-based teaching and learning, they are able to develop, through their work in elementary science methods courses and elementary classrooms, more robust and practice-specific inquiry models that are better aligned with models of effective science teaching promoted in contemporary science education reform.

While these findings are encouraging, they also point to specific dimensions of inquiry that science teacher educators may emphasize in teacher education. For example, one consistent finding here was that the preservice teachers did not explicitly address the inquiry practice of comparing explanations, particularly when it came to reconciling students' explanations with scientific explanations for phenomena that constituted content-focused learning goals for their lessons. This is critically important not only because it's a fundamental component of sense-making more generally (NRC, 2000, 2007), but also because it was at the heart of the essential tertiary contradiction the four preservice teachers articulated between collaborative construction of knowledge and

having students appropriate pre-defined learning goals. Preservice teachers need to learn to support students to not only reconcile newly-constructed explanations with their existing ideas, but also with those of others, including the scientific community.

Even if preservice teachers articulate substantive inquiry frameworks and have access to high-quality, inquiry-based curriculum materials that include educative features, however, they still need opportunities to learn to employ their inquiry frameworks to use curriculum materials effectively. Existing research has shown that beginning teachers rely heavily on curriculum materials (Forbes & Davis, 2007; Grossman & Thompson, 2004; Kauffman et al., 2002). Beginning teachers should not expect to begin their teaching careers with no experience using curriculum materials to engage in inquiry-based science, especially given the other demands placed upon them (Davis, Petish, & Smithey, 2006). Rather, teacher education should help ensure beginning teachers are indeed well-started beginners in this regard by providing them opportunities to learn how to mobilize and adapt science curriculum materials to better promote inquiry in the classroom. This is especially important since previous research suggests preservice elementary teachers often do not independently emphasize inquiry in their critique of science curriculum materials (Beyer, 2009; Dietz & Davis, in press; Schwarz et al., 2008).

Focusing on teachers' use of curriculum materials is one way to emphasize teacher learning in and from practice in teacher education. Historically, university-based teacher education has been far removed from school classrooms, a problem that has contributed to their lack of impact on teachers' practice, and there are growing calls for an increased emphasis on professional practice in teacher education (Grossman, McDonald, Hammerness, & Ronfeldt, 2008; Richardson, 1996). Teacher education, specifically methods courses, must become more oriented toward classroom practice and features of teacher education programs must be aligned to support this focus. Preservice teachers, while inexperienced, can participate in professional communities focused on problems of professional practice (Sim, 2006). The emphasis on curriculum materials use in the methods course, and the preservice teachers' curriculum design activity in this study, is just one example of how preservice teachers can be engaged in authentic professional practices. Through such experiences, the divide between theory and practice

can be bridged when preservice teachers are provided opportunities to apply theory *to* practice and derive theory *from* practice.

These findings also provide some insight into how preservice teachers might be better supported to learn to engage with curriculum materials in teacher education. For example, for Lauren, repeatedly teaching introductory science lessons that did not involve any investigations or experiences with phenomena was a limiting influence on her developing pedagogical design capacity for inquiry over the course of the year. It is important that preservice teachers have opportunities to plan and teach many types of lessons that are based around many types of activities so as to experience engaging students in inquiry practices in unique ways. However, in all cases, preservice teachers need to learn to emphasize inquiry practices that are most relevant to goals for particular lessons. A consistent finding across all four of the case study teachers was that they struggled to enact their lessons within the time allotted. Science teacher educators must better support preservice teachers to account for time in their use of curriculum materials.

The recommendations for science teacher education forwarded thus far in this section need to be supported with empirical evidence for specific methods and strategies through which to promote preservice teachers' learning in methods courses and science teacher education. The lack of strong, empirical evidence for the impact of teacher education has been at the root of calls for reforming teacher education and teacher education research more broadly (Clift & Brady, 2005; Cochran-Smith & Fries, 2005) and may help explain why existing science methods courses tend to vary greatly in their goals and structure (Smith & Gess-Newsome, 2004). For example, there is still little research, as Davis and colleagues (2006) note, that has actually explored preservice teachers' conceptions of inquiry in terms of the five essential inquiry practices articulated in *Inquiry and the National Science Education Standards* (NRC, 2000). Similarly, there is a need for more research that investigates the impact of particular features of methods courses on preservice teachers' espoused inquiry frameworks, teaching practices, and student learning. The further development of these research bases is essential to inform science teacher education reform efforts.

Implications for the Institutional Culture of Schools

Finally, this study has important implications the design of professional environments that support preservice teachers' development of pedagogical design capacity for inquiry. Perhaps most importantly, findings from this study provide further evidence that reform is needed for the institutional culture of schools to fully support inquiry-oriented science teaching and learning at the classroom level.

Reforming school science. For over 20 years, the teaching and learning of science as inquiry has been a foundational element of constructivist, standards-based science education reform efforts (AAAS, 1993; NRC, 1996, 2000, 2007). Yet, as described earlier, the sought-after widespread reform of school science has yet to be realized (Duschl, 1994; Grandy & Duschl, 2007). As science education research continues to provide evidence for institutional barriers to inquiry-based teaching and learning, significant questions have to be addressed. As Grandy and Duschl (2007) state,

...the institutional culture of public education is severely constrained by economical, ideological and pedagogical conditions. Such constraints have the effect of promoting certain forms of curriculum, instruction, and assessment practices while denying others on the basis of cost effectiveness; e.g., professional development for K-12 teachers. On the other hand, research on learning and research on science learning are contributing to a richer understanding of the classroom contexts and conditions that promote scientific reasoning and understanding. Do we fit the research on learning into the instructional culture of schools or do we change the culture of schools to accommodate the learning research? There are significant policy and practice issues that come to the table. (pg. 158)

As seen in this study, many of these questions lie outside teachers' spheres of influence. To promote teachers' and students' abilities to engage in inquiry practices in the classroom, policymakers, administrators, and others must work to reform schools as institutions.

The lingering question, however, is what kind of reform is required to bring about conditions under which collaborative sense-making through inquiry, or Engeström's (1987) 'learning activity', can occur in the classroom? A reasonable response, supported by both empirical results of this study and theoretical assumptions of cultural-historical activity theory, is that those who actually engage in the activity (i.e., teachers and students) must have a significant hand in shaping the activity itself. Engeström observes that the essential contradiction between activity and the economization of time results in, "an objective pressure, manifesting itself in various forms, toward *taking over the*

mastery of the whole work activity into the hands of the people who participate in that activity” (1987, pg. 82 [emphasis in original]). This means that the tools and instruments, rules and norms, and divisions of labor of a particular activity must, to some significant extent, be constructed and negotiated from within a given activity, not imposed entirely from without. To accomplish collaborative sense-making through classroom inquiry, teachers and students must be empowered to mobilize appropriate instruments and tools, as well as establish appropriate expectations and roles, that support inquiry practices and the development of a classroom culture of inquiry.

What exactly does this mean? Inquiry-based science teaching and learning demands a certain degree of flexibility that it is typically not afforded in schools. For example, the average elementary school day is highly-structured, with time periods blocked off for subject-specific instruction and other activities. As a practice focused on knowledge-construction, inquiry often demands more time than science is allotted, thus creating the tensions with the temporal dimensions of the school day pervasive in this study. Students also need to learn to assume different roles than those with which they are most often familiar. The kind of collaborative sense-making sought-after by the preservice teachers and occasionally observed in this study requires students to be active, engaged, and contribute substantively to the shaping of shared problem spaces through which new understandings are constructed. As such, teachers and students engaged in inquiry also need to be able to negotiate and establish rules and norms that govern their inquiry practices.

Some previous research has shown that the sort of internally-driven forms of classroom-based inquiry practice described thus far can be effective, self-regulating, and self-sustaining. Inquiry, broadly defined, is a coherent, epistemic practice focused on knowledge-construction, and others have explored the possibility that teachers and students can function as communities of learners engaged in inquiry practices (e.g., Brown & Campione, 1994). Particularly in the context of more project-based science learning environments, there are examples that illustrate how the barriers between school and life outside school can be mitigated (Crawford, 2000; Krajcik & Blumenfeld, 2006; Metz, 2000; Petrosino, 2004). By engaging students in real-world problems that require scientific understanding, school science can reposition text, or representations of existing

knowledge, from the object of activity to essential instruments that support the investigation of specific phenomena-related problems and issues. For teachers this involves, among other things, engaging students as community members in articulating, investigating, and explaining particular phenomena, as the preservice in this study sought to do. This is a powerful vision for how school science can become true learning activity rather than disconnected sets of learning actions.

However, the results presented here illustrate another related but distinct tension that was consistent in the preservice teachers' curriculum design for inquiry. As an epistemic practice, inquiry is fundamentally a process of knowledge-construction. However, from a theoretical standpoint, as well as from the practical standpoint of the preservice teachers in this study, there exists an inherent contradiction between, on one hand, engaging in open-ended epistemic practices such as inquiry and, on the other, setting predefined goals for what new knowledge will be constructed through engagement in such practices. To insure that students arrive at *existing* scientific explanations for phenomena, classroom inquiry must be engineered in a way that the process itself is not entirely open-ended. This assumption is encapsulated in notions of the inquiry continuum (NRC, 1996, 2000, 2007), or inquiry practices that run the gamut from more teacher-directed to more student-directed. However, again, as shown in these results, the more tightly-controlled the learning environment becomes, the more likely it is that classroom practice will shift towards traditional, didactic teaching and learning practices that objectify students and promote the appropriation rather than construction of knowledge. There appears to exist a very fine line before more teacher-directed inquiry and traditional, didactic science teaching. Some workable balance must be found between these two visions of science teaching and learning.

Where is such a balance to be found? Clearly science teaching and learning must shift away from traditional, didactic methods which have not remedied U.S. students' comparatively poor performance on standardized science assessments (e.g., Baldi, Jin, Skemer, Green, & Herget, 2007; Gonzales, Williams, Jocelyn, Roey, Kastberg, & Brenwald, 2008). Yet, it is unlikely that classroom inquiry can ever be entirely emergent. Though scientific practice has served as the standard for inquiry-based models of teaching and learning, science itself, rather than being characterized by entirely open-

ended inquiry, often involves the mobilization of methods within constraints and in light of desired outcome (Kuhn, 1996; Latour, 1987, 1999; Proctor, 1991). Perhaps engaging students in inquiry with predefined learning goals is not a break from true scientific practice, then, but rather a break from the idealized version of scientific practice often observed in abstract, inquiry-based instructional models.

It should come as no surprise, then, that classroom inquiry can and does take different forms in different contexts (Songer, Lee, & McDonald, 2002). Recall that pedagogical design capacity (Brown, 2002; 2009) is ultimately a property of systems, not just individuals. The entire activity system, not just teachers and curriculum materials, ultimately afford a certain ability to engage students in inquiry to achieve particular goals and objectives. Therefore, the capacity for pedagogical design inherent to a given classroom system will be fundamentally unique since the combination of each teacher's knowledge, beliefs, identity, and other personal characteristics, the curriculum materials he or she uses, as well as features of his or her professional context, is itself unique. The context-specific character of inquiry practices should be supported and cultivated so long as the motive of activity, the explicit objectives for student learning, are met. Ultimately, the most effective model of inquiry teaching and learning can only be assessed in light of what we want students to know and be able to do.

Unfortunately, with few exceptions (Geier, Blumenfeld, Marx, Krajcik, Fishman, Soloway, & Clay-Chambers, 2008), there is little existing research to help shed light on the impact of different models of inquiry or specific inquiry frameworks on student learning. This is a question of causality that needs to be addressed using appropriate methods (AERA, 2006; Shavelson & Towne, 2002). Randomized trials in which groups of students are selectively engaged or not engaged in inquiry practices, or are selectively engaged in varying curriculum-based experiences designed around different inquiry models, are needed to establish causal relationships between student learning and inquiry-based instructional strategies. However, it is also important for such research to assess the effectiveness of various models of inquiry teaching and learning using different forms of assessment that are themselves aligned with particular learning goals and learning performances (Geier et al., 2008; Krajcik, McNeill, & Reiser, 2007; Ruiz-Primo, Shavelson, Hamilton, & Klein, 2002; Schneider et al., 2001). Ultimately, this kind of

research will help inform the design of formal science teacher education, science curriculum materials, teacher professional development, and the reform of institutional features of schools themselves so as to better support the teaching and learning of science.

Cultivating preservice teachers' expertise for science teaching in schools. The transformation of school science from a rigid, didactic version to a more open-ended, inquiry-based one will support preservice teachers to become the reform-minded science teachers that science education reformers and science teacher educators want them to be. Field experiences are critical components of teacher education programs (Clift & Brady, 2005; NRC, 1996; NSTA, 2003). They can and should serve as powerful complements to university-based teacher education experiences. However, precisely because of the obstacles experienced by the preservice teachers in this study, these field experiences too often become contexts in which preservice teachers begin to articulate a disconnect between teacher education and schools. This is essentially the beginning of the socialization process that continues during student teaching and the induction years of a teacher's career. Unfortunately, the dominant, institutional culture of school typically converts even the most committed teacher reformer to more widespread, institutionally-supported, and reinforced norms of professional practice (Lortie, 1975).

Why? Preservice teachers develop frameworks within which they engage and reflect on practice, as well as through which future learning can occur (Zemal-Saul, Blumenfeld, & Krajcik, 2000). Broadly defined, these frameworks speak to what Bourdeiu (1990) references as an individual's *habitus*, or "system of acquired dispositions functioning on the practical level as categories of perception and assessment... as well as being the organizing principles of action" (pg. 53). One's habitus determines his or her predispositions toward what is possible in a given activity. While an individual's habitus would be composed of one's knowledge, beliefs, and identity, Bourdeiu also describes how context plays a role. As individuals engage in practices within institutions, the institutions themselves are given form in the individual's habitus. As such, the early experiences that help shape one's habitus for a particular practice weight disproportionately. The implication of this for teacher education is that early field experiences can have a tendency to disproportionately influence preservice teachers'

predispositions toward teaching practice. Since, as already shown, elements of institutional cultures of schools tend to restrict inquiry-based teaching and learning, preservice teachers' habitus for science teaching will tend to reflect and reproduce these challenges in their future teaching. This ultimately diminishes teachers' pedagogical design capacity and leads to less inquiry-based science in the classroom.

These early field experiences, however, can instead serve a more productive role that is conducive to the promotion of inquiry-based teaching and learning. To promote the development of preservice teachers' pedagogical design capacity, as well as their habitus, for inquiry, they need to have experiences working in professional contexts where inquiry practices are supported. Effective field experiences for preservice teachers should be long-term and stable, involve the careful selection of cooperating teachers, and are tightly integrated with methods courses that promote reflective, intellectual, and professional teaching practice (Sim, 2006; Zembal, Starr, & Krajcik, 1999). To insure that today's preservice teachers become tomorrow's well-started beginning teacher, it is crucial that these features of effective field experiences are made manifest in the opportunities for learning afforded preservice teachers in their teacher education programs.

Implications for Theory and CHAT-Based Research

In the following sections, I discuss contributions of this study to theoretical perspectives on the teacher-curriculum relationship and teacher learning, as well as issues in CHAT-based research.

Theoretical Perspectives on Teachers and Curriculum Materials

In recent years, a strong body of scholarship has emerged focused on the relationship between teachers and curriculum materials. While this corpus of research has included empirical work on teachers' use of curriculum materials, equally-important have been its contributions to theory. In the work of Remillard (2005), Brown (2002, 2009), Cohen and Ball (1999), and others, one finds an implicit emphasis on Vygotskian and activity-theoretical frameworks in theoretical perspectives on the teacher-curriculum relationship. This study is strongly embedded in this body of research, drawing heavily upon Remillard's (1999; 2005) models of teachers' curriculum materials use and Brown's (2002; 2009) notion of pedagogical design capacity. However, it also moves

this research forward by making the activity-theoretical perspective explicit and applying CHAT to the study of preservice teachers' curriculum design for inquiry.

This study builds upon and extends these theoretical perspectives on teachers' use of curriculum materials in a number of ways. First, a foundational assumption in these studies, as well as this one, is that teachers actively engage with curriculum materials, evaluating, critiquing, and adapting them. Both Brown (2002) and Remillard (1999; 2005) articulate a continuum of curriculum materials use, originally described in Chapter 2. On the one hand, teachers may tend to use curriculum materials 'as-is' through a process of *appropriation* (Remillard, 1999) or *offloading* (Brown, 2002). On the other hand, they actively interpret, critique, and adapt curriculum materials through a process of *invention* (Remillard, 1999) or *adaptation* and *improvisation* (Brown, 2002). This study expands Brown and Remillard's notions of teachers' *use of curriculum materials* by adding a second dimension that also accounts for their *mobilization of curriculum materials* (Figure 2.1).

Second, the use of cultural-historical activity theory for both a theoretical and analytical framework also builds upon Remillard's (1999; 2005) models of teachers' use of curriculum materials in a number of ways. Remillard (1999) describes three domains of curriculum development: design, construction, and curriculum mapping. The CHAT-based model of curriculum design used here (Figure 2.4) is similar in overall structure, with the curriculum planning activity representing Remillard's design arena and the curriculum enactment activity representing what she terms the construction arena. What the CHAT-based model affords that Remillard's model does not is a framework for describing and explaining the *internal* structure of each of these activities. Specifically, the CHAT-based model here accounts for the individual teacher, his or her motive or goal, tools and instruments, and culturally-mediating elements of the activity system, as well as how curriculum planning and curriculum enactment are networked and interconnected. As such, it serves not just as a conceptual model, but also as a robust analytical framework.

Third, teachers' use of curriculum materials is event-specific. As Brown (2002, 2009) argues, pedagogical design capacity is also lesson-specific. Remillard's (2005) conceptual model of the teacher-curriculum relationship includes each of the elements of

pedagogical design capacity – teacher, curriculum materials, and context – and is therefore aligned with Brown’s pedagogical design capacity. Remillard’s model provides an inclusive framework for considering various teacher characteristics (e.g., knowledge, identity, beliefs) and features of curriculum materials (e.g., representations of tasks and representations of concepts). However, to understand and derive generalized findings and principles from investigation of specific instances of teacher-curriculum interactions, it is necessary to understand these curriculum design cycles in depth. The CHAT-based model used in this study helps accomplish this by building upon Remillard’s model in two ways. First, it provides a finer-grained accounting of contextual factors influence pedagogical design capacity. Second, as with Remillard’s (1999) model of curriculum design, construction, and mapping discussed previously, it provides a useable and explicit framework for analyzing specific teacher characteristics, features of curriculum materials, and characteristics of context illustrated in Remillard’s (2005) framework of components of the teacher-curriculum relationship.

Theoretical Perspectives on Teacher Learning

The question of teachers’ knowledge, expertise, and learning has held a prominent role in education scholarship for many years (Berliner, 1986; Feiman-Nemser, 2001; Putnam & Borko, 2000; Shulman, 1986). The study here contributes to this literature by using CHAT in research on preservice teachers’ learning across the university- and school-based contexts of formal teacher education.

First, the preservice teachers’ learning was embedded in a process of curriculum design that involved moving between the abstract and the concrete. Consistent with the CHAT-based framework in which this study is situated (Figure 2.3), the preservice teachers first dealt with transforming the abstract (their inquiry frameworks) into the concrete (classroom practice). This process, according to Engeström (1987), is what characterizes expansive learning. However, Engeström also notes that the origins of expansive learning lie in the initial recognition of an emergent idea in response to existing contradictions in a given activity. So, in effect, the beginning of the process of moving from the abstract *to* the concrete is spurred by the articulation of ideas, truths, or other statements from experience, or deriving the abstract *from* the concrete. Ultimately, then, networked practices, as illustrated here with curriculum planning and curriculum

enactment, rely not just on moving from the abstract to the concrete, but also from the concrete to the abstract through a cyclical process of ‘doing’ and ‘representing’ (Engeström, 1987; Latour, 1999; Wenger, 1998). The preservice teachers here engaged in curriculum design to translate their espoused inquiry frameworks into classroom practice and, then, from their enactment experiences, revisited and revised their inquiry models.

Second, the exact nature of this cyclical and iterative process is unique to each individual teacher. An important contribution of the CHAT-based framework in this study was its role in the identification, description, and exploration of pervasive and systemic contradictions and tensions in the preservice teachers’ curriculum design activities. As shown in the results, particularly those in Chapter 6, it was the preservice teachers’ attempts to resolve these contradictions that provided explanations for their evolving curriculum planning, science teaching, and espoused inquiry frameworks. In effect, their learning and development of pedagogical design capacity was driven by these contradictions. However, the nature of each preservice teacher’s learning was unique because the configurations of their espoused inquiry frameworks, curriculum materials, and features of context were also unique. This finding is consistent with situated perspectives on teacher learning (Putnam & Borko, 2000) and reinforces previous research that found preservice teachers’ learning to follow unique trajectories (Anderson, Smith, & Peasley, 2000). However, it advances the field’s theoretical understanding of *how* and *why* teachers’ learning is situated by illustrating underlying contradictions that explain change over time in particular cultural contexts.

Finally, third, the preservice teachers’ learning was made manifest in the curriculum materials they produced through iterative cycles of curriculum design. CHAT emphasizes the material basis of activity, meaning that the products of activity are not just abstract concepts or ideas, but physical, tangible objects. Here, as boundary objects (Wenger, 1998) between curriculum planning and curriculum enactment, the preservice teachers’ lesson plans served a dual purpose as a working problem space for curriculum planning and a instrument to support curriculum enactment. The preservice teachers’ lesson plans served as representations of their developing expertise, as other have argued before (Ball & Lampert, 1999; Loughran, Mulhall, & Berry, 2004; Loughran

et al., 2001; Marx et al., 1998; Rosebery & Puttick, 1998; Shulman, 1986). However, they also served as vehicles for the transfer of this expertise across contexts. Given the challenges of promoting transfer (Bransford, Brown, & Cocking, 2000; Tuomi-Gröhn & Engeström, 2003), or learning across contexts, it is important to focus on the physical and material basis of transfer, or how representations serve as conduits for the transport and application of expertise in novel contexts.

CHAT-Based Research

Cultural-historical activity theory is a powerful descriptive and analytical tool but one that is only now beginning to be used in educational research (Roth, 2004; Roth & Lee, 2007). There is a great deal yet to be learned about how CHAT can be effectively wielded in research on science teaching and learning and how its application can be further refined for knowledge construction within the field of science education. This study informs the research process itself, providing grounds upon which to further refine CHAT as a theoretical and analytical framework for investigations of teaching and learning, and for the construction of theoretical understanding specific to teachers and curriculum materials.

While there is momentum in the educational research community to more heavily utilize CHAT, experiences doing so in this study have led to a number of questions and implications. While an affordance of CHAT is the concrete model of activity it provides, there are two significant issues that must be addressed by the CHAT-based research community for this agenda to move forward. First, there is a need to more adequately explicate research methods underlying CHAT-based research. Second, more work is needed to explore how the CHAT framework can be more effectively employed as an explanatory framework rather than a loose conceptual one. I present a more detailed discussion of each of these issues next.

Data coding and analysis. One methodological challenge of this study was translating the theoretical framework in Figure 2.4 into an analytical framework within which to situate data coding and analyses. Just as focusing research on a defined, workable set of activity systems is essential in CHAT-based research, so too is identifying and mobilizing appropriate data and data analysis methods (Williams, Davis, & Black, 2007). However, this process has led to methodological questions.

In this study, data coding involved a coding scheme explicitly aligned with the CHAT-based model in Figure 2.4. The objective of this approach was to identify contradictions underlying preservice teachers' curriculum design decisions and trace the resolution of these contradictions over time. However, the notion of a contradiction is itself open to interpretation. What, for example, distinguishes a contradiction, often described as a tension, from a simple observed relationship between nodes of the activity triangle or between activities? Here, the goal was to provide explanations for why preservice teachers made the curriculum design decisions that they did, explanations for which could be provided by either a contradiction or non-contradictory relationship. The question that needs to be addressed, then, is what criteria would help operationalize the notion of contradiction and distinguish between the two with the utmost of methodological rigor? While research methods employed here represent one answer to this question, these are lingering questions that need to be resolved for specific activities to be mapped on to conceptualized CHAT-based models.

At its core, this issue revolves around the use of appropriate research methods in CHAT-based research. Consistent with Vygotsky's (1978) emphasis on language, many CHAT-based studies have foregrounded the discursive nature of classroom activity (Barab, Barnett, Yamagata-Lynch, Squire, & Keating, 2002; Nardi, Whittaker, & Schwarz, 2002; Rainio, 2008; Roth et al., 2004). However, there are also some specific examples that employ other research methods. For example, Bodker (1995) provides an explicit observation framework for applying CHAT to the analysis of videocases. The approach advocated by Bodker relies on Engeström's emphasis on characterizing operations, actions, and activity, the three levels of activity originally articulated by Leontiev (1978). Ultimately, these contradictions are evidenced in observed shifts in actions that result from conflict between those individual actions and the collective activity. Similarly, Yamagata-Lynch (2007) describes the use of qualitative analytical methods to initially conceptualize the activity systems of teacher professional development. These studies are effective examples of how specific research methods have been used in CHAT-based research and provide at least modest insight into the mapping of specific analytical methods onto CHAT-based theoretical frameworks.

However, in existing CHAT-based research, both within education and outside, these studies are the exception. There is little guidance to be found in terms of mapping specific research methods onto CHAT-based theoretical frameworks. This trend risks creating a ‘black box’ scenario in CHAT-based social science research that is similar to that of research in the natural sciences (Latour, 1987), where the mechanics by which evidence collected, mobilized, analyzed, and used to make claims within CHAT-based research paradigms remains hidden. More clarity is needed to map the most useful research methods onto specific CHAT-based studies.

Using CHAT-based models as explanatory frameworks. One primary affordance of CHAT is that it provides a concrete model to apply to the analysis of various forms of activity. However, as with all models, the generalized version must be adapted to a particular activity setting of interest. A substantial amount of theorizing and model building must happen throughout the research process. In effect, theory building and data analyses are iterative processes. Just as one’s model can shape research, so too do findings shape one’s model. It is therefore critical for CHAT-based models to possess explanatory as well as descriptive power (Halverson, 2002).

So, in addition to mapping analytical methods onto CHAT-based theoretical frameworks, researchers must also map resultant claims back onto CHAT-based models and employ these models as explanatory frameworks. There are some effective examples of this in education research (Barab et al., 2002; Yamagata-Lynch, 2007). However, there are many other examples in which CHAT-based models and frameworks fail to reemerge in the presentation, interpretation, and discussion of research findings. One possible reason for this is that the CHAT model is difficult to employ as an explanatory framework for phenomena that change over time. The prototypical CHAT triangle model is most helpful in capturing a snapshot of activity at any given time. While change is inherent to the model, as Engeström (1987) argues, it nonetheless presents a challenge in actually representing change using the model in standard modes of research reporting and publication.

One possible solution to this is to explore multi-model forms of representation to employ with CHAT-based explanatory frameworks. The evolution of activity, consistent with the theoretical foundations of activity theory and the results from this study, depends

on a cascade of contradictions. In effect, the resolution of one contradiction often leads to another and so on until a new state of equilibrium is reached within activity. To account changes in activity, one needs to provide and illustrate a sequential accounting of the resolution of these contradictions. One cannot easily illustrate this in a static, unchanging CHAT-model. As has been argued by other education researchers (Ball & Lampert, 1999), new modes of representation should be explored and employed in education research. Here, animated versions of specific CHAT-based models could perhaps better illustrate the emergence and resolution of contradictions over time. Exploring new ways to enliven the CHAT model, and make it more dynamic, would help maximize the utility of CHAT as an explanatory framework.

Summary of implications for activity-theoretical research. The study presented here contributes to a growing body of CHAT-based education research. This body of research has begun to and will undoubtedly continue to yield new and useful insights into teaching and learning. However, as an emergent research domain, it presents many questions that must be addressed, particularly the methodological ones discussed here. As yet, however, the CHAT-based research community has not adequately addressed these issues. As one education scholar writes,

This triangle has become a ubiquitous slide or overhead at countless conference presentations I have attended and numerous articles published in U.S. and international journals. And yet I do not see in U.S. research, for the most part, its relevance to the issues under study...the activity triangle, much like the oft-trivialized ZPD of recent years, has become for many a means of affiliation with a fashionable theory rather than a conceptual tool for conducting a rigorous activity analysis (Smagorinsky, 2009, pg. 93)

To be accessible and optimally-useful, CHAT must become more than an identity for its adherents – it must become an explanatory tool or instrument and mode of communication for its users. It is through this shift that the much anticipated and touted promises of CHAT-based research may best be realized.

Limitations

As described in this chapter, this study has yielded many findings and holds important implications for elementary science teaching, science teacher education, and science curriculum development. However, it is also limited in a number of ways. First, this study is limited in its relatively small sample size and focus on one institution's

teacher education program. In the end, consistent with the scope of most teacher education research, these findings tell us a great deal about this particular group of preservice teachers, features of this particular teacher education program, and characteristics of the particular schools in which the preservice teachers worked. The scope of this study must be taken into account when considering the generalizability of these findings. This issue, which was also discussed earlier in this chapter, reinforces the need for rigorous, cross-site teacher education research that employ larger sample sizes, as well as qualitative and quantitative research methods that can establish causal relationships and longitudinal trends.

Second, an important element of CHAT-based research involves the rigorous analysis of activity systems (Engeström, 1987). However, while collecting and analyzing the preservice teachers' curriculum enactment activity in this study was relatively straightforward, investigating their curriculum planning activity proved more challenging. Unlike classroom teaching, which occurs in discrete episodes within specific physical contexts (i.e., classrooms), the timing and locale of the preservice teachers' curriculum planning activities were much more diverse. While examination of the material artifacts of their curriculum planning (lesson plans) and adaptations they made helped illuminate the production sub-process of curriculum planning, culturally-mediating dimensions of their curriculum planning remained somewhat elusive. Even during the methods semester, when the preservice teachers were provided opportunities to collaborate and co-plan with their peers, much of their curriculum planning occurred outside of class. This suggests a need to further explore how methods courses can be designed to serve as professional communities for preservice teachers (Sim, 2006). However, it also begs important methodological questions related to the study of activities such as lesson planning that often occur in isolation with only vicarious participation of community members. Through what data collection methods can researchers effectively capture teachers' negotiation of norms, community members, and divisions of labor in their curriculum planning?

Third, each of the preservice teachers in the focal group ended up in placement schools in the same school district and where new science curricula were being adopted and actively implemented. This consistent feature in each of the four preservice teachers'

school placements did not occur by design – rather, it was a random and unpredictable situation that developed prior to undertaking this research. What implications might this have had for the preservice teachers’ curriculum design for inquiry? First, it meant that each of the preservice teachers had access to full sets of science curriculum materials. This is not always the case for elementary teachers and, in my previous research with preservice elementary teachers in these same schools (Forbes & Davis, 2008), the types and availabilities of science curriculum materials they had available to them varied substantially. Future research should investigate, then, preservice elementary teachers’ curriculum design for inquiry when it is characterized by a higher degree of curriculum mobilization (Figure 2.1) when robust sets of curriculum materials are not readily available.

The availability of science curriculum materials (i.e., the implementation of the new curriculum) may also have contributed to the consistently-observed expectation that the preservice teachers try to enact the new science curriculum materials with relative fidelity. As shown in the findings, the preservice teachers’ efforts to adapt their lessons to make them more inquiry-based were often constrained by this particular feature of their curriculum planning contexts. In the absence of these norms and expectations, perhaps in schools where elementary teachers had few and/or varied science curriculum materials, would preservice teachers be able to adapt existing science curriculum materials to make them even more inquiry-based than was seen in this study? Would the inquiry-orientations of the existing science curriculum materials similarly influence the inquiry-orientations of their revised lessons? Future research should explore how the absence of such norms for the use of curriculum materials ultimately influences teachers’ curriculum design for inquiry.

Conclusion

To engage their students in inquiry practices, teachers need to develop robust expertise for science teaching. One domain of this expertise is centered on the effective use of curriculum materials they have to guide and structure their professional practice. These curricular tools have been and will likely continue to be essential tools for teachers and a primary means through which the goals of science education reform are translated into teaching and learning in the classroom. However, teachers are also professionals

who serve as the crucial pivot point between, on the one hand, science curriculum developers, scientists, education researchers, and policymakers, and, on the other, the students whose learning is the very purpose for which schools exist. In effect, teachers have the final word in curriculum design and development.

To help them evaluate, adapt, and enact curriculum materials effectively, teachers need to develop robust pedagogical design capacity. This is especially true for preservice teachers, who lack the experiential basis upon which to base their pedagogical design capacity. To enter the teaching profession as well-started beginners, preservice teachers need to at least develop their ability to translate their conceptions of inquiry into curriculum adaptations, as well as their ability to do so in light of affordances and constraints of specific classroom contexts. For preservice teachers to begin to develop their capacity for pedagogical design, formal teacher education must provide opportunities for them to do so.

The results of this study begin to shed light of preservice elementary teachers' development of pedagogical design capacity for science teaching by examining how they engage in curriculum design for inquiry. On one hand, these results are encouraging, and show that preservice elementary teachers are able to adapt existing curriculum materials to make them more inquiry-based and articulate espoused inquiry frameworks that are reasonably well-aligned with those in science education reform. However, on the other hand, these results illustrate the constraints imposed upon teachers' curriculum design by their professional contexts and the fundamental contradictions preservice teachers articulate in their attempts to engage in inquiry-oriented science teaching practices. Preservice elementary teachers' abilities to engage in inquiry-based science teaching practice in light of affordances and constraints of context should be leveraged to enhance their capacities to do so through teacher education and curriculum development. In promoting preservice elementary teachers' development of pedagogical design capacity for inquiry, we also better prepare them for challenges they will face in teaching reform-minded, standards-based, inquiry-oriented science as beginning elementary teachers. This is ultimately an effort to better support students' learning in science.

APPENDICES

Appendix A: Lesson Plan Format

Your name:

Name of school, course, grade level, and length of lesson:

Title of Lesson:

Purpose/ Rationale and Overview:

- Provide a short description of the lesson:

--

Connections to Standards/ Benchmarks/ Curriculum:

--

Learning Objectives:

- Students will be able to...

--

Context of Lesson:

- Briefly explain how the lesson fits with what came before, what comes after, and with the unit as a whole:

--

Materials:

--

Management:

- What will you do to manage materials/movement around the classroom/transitions?

--

Students' Ideas:

- What ideas should students understand before beginning the lesson?
- What potential alternative ideas might students hold?

Teaching Strategies: Intro

- What is your investigation question for the lesson?
- How will you illicit and draw upon students' existing ideas?

Teaching Strategies: Main Lesson

- Do activities and representations you use help make teacher and student thinking visible?
- Do activities you use support students in engaging in scientific inquiry?
- Do activities support students of all achievement levels? What will students do who finish an activity early? Who do not finish?

Teaching Strategies: Wrap-up

- What explanations do you want your students to construct?
- How do these explanations connect to your investigation question? How do they connect to previous and subsequent science lessons?

Assessment:

- How will you know that your students achieved the learning objective(s) for this lesson? What evidence can you gather that will provide this information? How will you collect this information?
- What assessments will help to make teacher and student thinking visible?

Next Steps:

- What are next steps you can take to support students in developing and using these ideas?

Appendix B: Lesson Plan Rationale

I. Use of Science Curriculum Materials

For your Reflective Teaching Assignment, you were asked to draw upon existing science lesson plans and curriculum materials to develop an inquiry-oriented science lesson. Please think a little about the curriculum materials you used and answer the following questions.

1. Which of the following best characterizes **how you started planning for this lesson**?
 - I had a general idea of the topic I wanted to cover but no materials yet
 - I had an idea for a student activity or investigation and built a lesson plan around that.
 - I had an existing lesson plan that I planned on using
 - Other

2. How **explicit was your learning goal** before you started developing your lesson?
 - Very explicit (I knew specifically what I wanted by students to learn and how they would demonstrate their understanding)
 - Somewhat explicit (I knew specifically what I wanted by students to learn)
 - Not very explicit (I had identified specific parts of a scientific concept I wanted my lesson to address but wasn't sure about exactly what I wanted students to learn)
 - I really didn't have a learning goal at first (I had a general sense of what scientific concept(s) I wanted my lesson to address but wasn't sure exactly what I wanted students to learn)

3. What **existing lesson plans, curriculum materials, and other resources** did you use to develop your lesson? Please list them here.

	Name/Title	Type of Resource	Source of Resource	Additional Information
1.				
2.				
3.				
4.				
5.				

- a. What did you like about features of the curriculum materials you used? What didn't you like? Why?
- b. Were they good choices for developing an inquiry-oriented lesson? Why or why not?
- c. What other factors did you have to consider in using these resources?

II. Adapting Science Curriculum Materials

In addition to pulling together science curriculum materials and resources to develop your lesson, you were asked to modify them to make your lesson well-suited to your students and classroom. In the following questions, please think about each of the changes you made and your reasons for doing so.

4. Please think about **each of the changes you made** to your lesson. List each one and briefly describe it. Then, **for each change** you made, please answer the following:
 - a. How did this change **improve upon** what was already in the existing lesson?
 - b. Did this change make your lesson **more or less inquiry-oriented**? If so, how?
 - c. What **other factors** did you consider in making this change?

5. **How inquiry-oriented do you think your lesson is?**

- Very inquiry-oriented
- Somewhat inquiry-oriented
- Not very inquiry-oriented
- Not at all inquiry-oriented

Please explain your answer to question #6. Why do you think your lesson was or wasn't inquiry-oriented?

6. Please include any other comments you have about your lesson.

Appendix C: Reflective Teaching Assignment Post-Enactment Reflective Journal

Now that you've taught your reflective teaching lesson, please reflect and comment on the following elements in a detailed and thoughtful CASES journal entry. We've specifically included some questions to help you think about teaching science as inquiry and using science curriculum materials to help you do so, our two big goals for the semester.

- a. How did it go? What went well? What didn't go so well? Were the changes that you made to your lesson before enacting it effective? Why or why not?
- b. Did your students meet your learning goals? Analyze your students' work and look for things they wrote that show alternative ideas that changed or lingered. Refer explicitly to student work to make evidence-based assertions about their learning.
- c. How did your enacted lesson compare to the lesson you planned? Did anything go differently than you expected? If so, please describe how. (*Please refer back to specific portions of your lesson plan*)
- d. What did you learn from this experience? How did this experience influence your understanding of inquiry-oriented science teaching and factors you need to consider in teaching science as inquiry?
- e. Based on what you learned from this experience, would you further modify this lesson? If so, how would you modify it for the next time you teach it?
 - Would you use additional resources and/or science curriculum materials? If so, describe them and talk about why.
 - What additional changes, if any, would you make to your lesson? Why would you make these changes?
- f. Please feel free to address anything else you think is relevant.

Appendix D: Journal Entry (Inquiry and Science Curriculum Materials)

Beginning of Semester

Our two big goals for the semester are for you to learn how to teach science as inquiry and to use science curriculum materials to help you do so. So far we've introduced each of these ideas and briefly discussed them in class. Please reflect on your ideas about inquiry-oriented science teaching and using science curriculum materials in a journal entry. In completing your journal entry, please think about the following questions:

1. How would you describe effective science teaching?
2. How would you describe inquiry-oriented science teaching? What does it mean to teach science as inquiry?
3. Do you think teaching science as inquiry is important? How does your description of inquiry from the previous question match up to your definition of effective science teaching?
4. What purpose(s) do you think science curriculum materials have in supporting science teaching?
5. What features of science curriculum materials make some better than others? Why?
6. Do you think it's important to critique and adapt existing science curriculum materials? Why or why not?

End of Semester

We've spent a lot of time this semester talking about teaching science as inquiry and using science curriculum materials to help you do so. Please reflect on your ideas and what you've learned about inquiry-oriented science teaching and using science curriculum materials in a journal entry. In completing your journal entry, please think about the following questions:

1. How would you describe effective science teaching?
2. How would you describe inquiry-oriented science teaching? What does it mean to teach science as inquiry?
3. Do you think teaching science as inquiry is important? How does your description of inquiry from the previous question match up to your definition of effective science teaching?
4. What purpose(s) do you think science curriculum materials have in supporting science teaching?
5. What features of science curriculum materials make some better than others? Why?
6. What do you hope to accomplish when you critique and adapt science curriculum materials? Do you think it's important to critique and adapt existing science curriculum materials? Why or why not?
7. How do you think your ideas about science teaching, especially inquiry-oriented science teaching, have changed over the semester?
8. How do you think your ideas about the use of science curriculum materials have changed over the semester?

Appendix E: Formal Interview Protocol

1st Formal Interview

Planning (central activity)

1. *Please describe your experiences developing lesson plans so far. How have they gone? Have you had any opportunities to plan and develop lesson plans for science? If so, please describe. (They probably won't have had any experiences developing science lesson plans)*
 - a. *What were you trying to accomplish when you developed lesson plans? Would this goal be similar or different for you when developing lesson plans for science? (goal/outcome)*
 - b. *Did you think it was important to develop lesson plans when you did so? Why or why not? Do you think it would be important to develop lesson plans for science? (object)*
 - c. *What were resources you used to develop lesson plans? Why were these important? What types of resources do you think you would use to develop lesson plans for science? (tool constellation) Probe for existing science curriculum materials.*
 - d. *When you planned and developed lesson plans, what were some things that helped you? What were some challenges you faced? How do you think these would be similar or different when planning and developing lesson plans for science? Probe for:*
 - Rules/norms – timeframe for planning, criteria for assessment of quality, guidelines for lesson plan formats
 - Community – Who is and should be involved? (other preservice teachers, cooperating teachers, etc.)
 - Division of Labor – Who is and should be doing what? What roles are people playing?
2. *Are there ways in which you would like to develop lesson plans differently than you have so far? If so, why and how?*
3. *How do you think the methods course can help you learn to develop science lesson plans? What do you think about the work we're doing this semester with critiquing and adapting science curriculum materials? (4)*

Enactment (object-activity)

4. *Please describe your experiences enacting lesson(s). How have they gone? Have you had any opportunities to teach science? If so, please describe. (They probably won't have had any experiences developing science lesson plans)*
 - a. *What were you trying to accomplish when you enacted your lesson(s)? Would this goal be similar or different for you when enacting science lessons? (goal/outcome)*
 - b. *Did you think it was important to enact your lesson(s)? Why or why not? Do you think it would be important to enact science lessons? (object)*

- c. *What were resources you used to enact your lesson(s)? Why were these important? What types of resources do you think you would use to enact science lessons? (tool constellation) Probe for science lesson plans.*
- d. *When you enacted your lesson(s), what were some things that helped you? What were some challenges you faced? How do you think these would be similar or different when teaching science? Probe for:*
 - Rules/norms – timeframe for planning, criteria for assessment of quality, guidelines for lesson plan formats
 - Community – Who is and should be involved? (other preservice teachers, cooperating teachers, etc.)
 - Division of Labor – Who is and should be doing what? What roles are people playing?
5. *If you have taught science, are there ways in which you'd like to do it differently? What do you think effective science teaching should look like in the classroom?*
6. *How do you think the methods course can help you learn to teach science effectively?*

Ideas about Inquiry (symbolic tools)

7. *What are your thoughts on inquiry-oriented science teaching so far?*

Ask them about each of the following dimensions of inquiry:

- Asking scientifically-oriented questions
- Gathering and organizing data/evidence
- Constructing explanations from evidence
- Evaluate explanations in light of competing evidence
- Communicate and justify explanations

For each dimension, use the following questions:

- a. *How would you describe [dimension of inquiry]? Is it important?*
 - b. *How could you change a science lesson to make it more [dimension of inquiry]?*
 - c. *How could you promote [dimension of inquiry] in the classroom?*
8. *Is this idea of inquiry-oriented science teaching consistent with your ideas about effective science teaching? Why or why not?*
 9. *Do you think most elementary teachers teach science as inquiry?*
 10. *How do you think the methods course can help you learn to teach science as inquiry? (4)*

Methods course (instrument-producing activity)

11. *What do you hope to get out of the science methods course? (goal/outcome)*

Bring in specific questions and probes here based on their initial journal entry

2nd Formal Interview

Planning (central activity)

1. *Please describe your experiences developing science lesson plans so far. How have they gone?*
 - a. *What were you trying to accomplish when you developed your science lesson plans? (goal/outcome)*
 - b. *Did you think it was important to develop science lesson plans when you did so? Why or why not? (object)*
 - c. *What were resources you used to develop your science lesson plans? Why were these important? Probe for existing science curriculum materials.*
 - d. *When you planned and developed science lesson plans, what were some things that helped you? What were some challenges you faced? Probe for:*

- Rules/norms – timeframe for planning, criteria for assessment of quality, guidelines for lesson plan formats
 - Community – Who is and should be involved? (other preservice teachers, cooperating teachers, etc.)
 - Division of Labor – Who is and should be doing what? What roles are people playing?
2. *Are there ways in which you would like to develop science lesson plans differently than you have so far? If so, why and how?*
 3. *How do you think the methods course helped you learn to develop science lesson plans? What did you think about the work we did this semester with critiquing and adapting science curriculum materials? (4)*

Enactment (object-activity)

4. *Please describe your experiences enacting science lessons. How have they gone?*
 - a. *What were you trying to accomplish when you enacted your science lesson(s)? (goal/outcome)*
 - b. *Did you think it was important to enact your science lesson(s)? Why or why not? (object)*
 - c. *What were resources you used to enact your science lesson(s)? Why were these important? (tool constellation) Probe for science lesson plans.*
 - d. *When you enacted your science lesson(s), what were some things that helped you? What were some challenges you faced? Probe for:*
 - Rules/norms – timeframe for planning, criteria for assessment of quality, guidelines for lesson plan formats
 - Community – Who is and should be involved? (other preservice teachers, cooperating teachers, etc.)
 - Division of Labor – Who is and should be doing what? What roles are people playing?
5. *Are there ways in which you'd like to do teach science differently? What do you think effective science teaching should look like in the classroom?*
6. *How do you think the methods course helped you learn to teach science effectively?*

Ideas about Inquiry (symbolic tools)

7. *What are your thoughts on inquiry-oriented science teaching so far? How do you think your ideas about inquiry-oriented science teaching have changed this semester?*
Ask them about each of the following dimensions of inquiry:
 - Asking scientifically-oriented questions
 - Gathering and organizing data/evidence
 - Constructing explanations from evidence
 - Evaluate explanations in light of competing evidence
 - Communicate and justify explanations
 For each dimension, use the following questions:
 - a. *How would you describe [dimension of inquiry]? Is it important?*
 - b. *How could you change a science lesson to make it more [dimension of inquiry]?*
 - c. *How could you promote [dimension of inquiry] in the classroom?*
8. *Is this idea of inquiry-oriented science teaching consistent with your ideas about effective science teaching? Why or why not?*
9. *Do you think most elementary teachers teach science as inquiry?*
10. *How do you think the methods course helped you learn to teach science as inquiry? (4)*

11. *How successful do you think you were this semester at translating your ideas about inquiry into your science teaching?*

3rd Formal Interview

Planning (central activity)

1. *Please describe your experiences developing science lesson plans so far. How have they gone?*
 - a. *What were you trying to accomplish when you developed your science lesson plans? (goal/outcome)*
 - b. *Did you think it was important to develop science lesson plans when you did so? Why or why not? (object)*
 - c. *What were resources you used to develop your science lesson plans? Why were these important? Probe for existing science curriculum materials.*
 - d. *When you planned and developed science lesson plans, what were some things that helped you? What were some challenges you faced? Probe for:*
 - Rules/norms – timeframe for planning, criteria for assessment of quality, guidelines for lesson plan formats
 - Community – Who is and should be involved? (other preservice teachers, cooperating teachers, etc.)
 - Division of Labor – Who is and should be doing what? What roles are people playing?
2. *Are there ways in which you would like to develop science lesson plans differently than you have so far? If so, why and how?*
3. *How do you think the methods course helped you learn to develop science lesson plans? What did you think about the work we did this semester with critiquing and adapting science curriculum materials? (4)*

Enactment (object-activity)

4. *Please describe your experiences enacting science lessons. How have they gone?*
 - a. *What were you trying to accomplish when you enacted your science lesson(s)? (goal/outcome)*
 - b. *Did you think it was important to enact your science lesson(s)? Why or why not? (object)*
 - c. *What were resources you used to enact your science lesson(s)? Why were these important? (tool constellation) Probe for science lesson plans.*
 - d. *When you enacted your science lesson(s), what were some things that helped you? What were some challenges you faced? Probe for:*
 - Rules/norms – timeframe for planning, criteria for assessment of quality, guidelines for lesson plan formats
 - Community – Who is and should be involved? (other preservice teachers, cooperating teachers, etc.)
 - Division of Labor – Who is and should be doing what? What roles are people playing?
5. *Are there ways in which you'd like to do teach science differently? What do you think effective science teaching should look like in the classroom?*
6. *How do you think the methods course helped you learn to teach science effectively?*

Ideas about Inquiry (symbolic tools)

7. *What are your thoughts on inquiry-oriented science teaching so far? How do you think your ideas about inquiry-oriented science teaching have changed this year?*

Ask them about each of the following dimensions of inquiry:

- Asking scientifically-oriented questions
- Gathering and organizing data/evidence
- Constructing explanations from evidence
- Evaluate explanations in light of competing evidence
- Communicate and justify explanations

For each dimension, use the following questions:

- How would you describe [dimension of inquiry]? Is it important?*
 - How could you change a science lesson to make it more [dimension of inquiry]?*
 - How could you promote [dimension of inquiry] in the classroom?*
- Is this idea of inquiry-oriented science teaching consistent with your ideas about effective science teaching? Why or why not?*
 - Do you think most elementary teachers teach science as inquiry?*
 - How do you think the methods course helped you learn to teach science as inquiry? (4)*
 - How successful do you think you were this semester at translating your ideas about inquiry into your science teaching?*

Appendix F: Pre- and Post-Enactment Lesson Planning Interviews

Pre-Enactment

So tell me a little bit about your lesson...

1. How did you start planning for this lesson? What was your goal?
2. How inquiry-oriented do you think your lesson is? Why? How does it engage students in...
 - Asking scientifically-oriented questions?
 - Gathering and organizing data/evidence?
 - Constructing explanations from evidence?
 - Evaluate explanations in light of competing evidence?
 - Communicate and justify explanations?
3. What curriculum materials did you use to develop it? Why did you decide to use these particular curriculum materials?
 - Why were these good choices for developing inquiry-oriented science lesson?
 - What particular features of these curriculum materials were especially helpful or unhelpful in developing your lesson?
 - What other factors did you have to think about in choosing these curriculum materials?
4. What changes did you make to your lesson? Why did you make these changes?
 - How do you think they made your lesson more inquiry-oriented?
 - How did the curriculum materials you used make this easier or harder?
 - What other factors did you consider in making these changes?
5. In general, how did you think the planning process went? *Probe here for elements of the curriculum planning triangle (e.g., inquiry, context, etc.).*
 - What were some challenge you experienced? Why were these challenging?
 - What were some things that helped you or supported you? Why?
6. Based on your experience planning your lesson, how do you think you might do things differently next time?
7. What are you most looking forward to in teaching your lesson? What are you most nervous about in teaching your lesson?

Post-Enactment

Let's talk some more about your experience teaching your lesson...

1. In general, how did you think your lesson went?
 - What was/were your goal(s) for this lesson? Did you meet your goal(s)? Why or why not?
 - How did your lesson engage students in inquiry?
 - How did you support your students' inquiry practices during your lesson?
 - What were some challenges or tensions you experienced? Why were these challenging? *(Probe here for rules/norms, community, and division of labor).*
 - What were some things that helped you or supported you in teaching your lesson? Why?
(Probe here for rules/norms, community, and division of labor).

- How was the enacted lesson different from the lesson you planned? If it was different, why do you think it was?
 - Based on your enactment experience, what do you think of the lesson you developed?
2. Based on your experience enacting this lesson, how do you think you would teach it differently next time?
- Would you use additional curriculum materials to revise/refine your lesson? If so, what types? Why would you use these particular curriculum materials?
 - Why would these be good choices for inquiry-oriented science teaching?
 - What particular features of these curriculum materials would be especially helpful or unhelpful in developing your lesson?
 - What other factors would you have to think about in choosing these curriculum materials?
 - Would you make changes to your lesson? If so, what changes? Why did you make these changes?
 - How do you think they would they make your lesson more inquiry-oriented?
 - How would your lesson make these changes easier or harder to make?
 - What other factors would you consider in making these changes?
3. Will this experience affect how you plan in the future? Why/how? Specifically, what have you learned about...
- Inquiry-oriented science teaching?
 - The use of science curriculum materials?
 - Other factors you need to consider in planning for science teaching?

Appendix G: Lesson Enactment Observation Protocol

BACKGROUND INFORMATION

Name of Teacher _____
Location of class _____ (district, school, room)
Subject Observed _____ Grade Level _____
Observer _____ Date of Observation _____
Start time _____ End time _____

CONTEXTUAL BACKGROUND AND ACTIVITIES

In the space provided below, please give a brief description of the lesson observed, the classroom setting in which the lesson took place (space, seating arrangements, etc.), and any relevant details about the students (number, gender, ethnicity) and teacher that you think are important. Use diagrams if they seem appropriate.

DESCRIPTION OF EVENTS (INDICATE TIME WHEN THE ACTIVITY CHANGES)

Planned Lesson	Time	Enacted lesson - Notes

Appendix H: In-Class RT Co-Planning and Debriefing

Co-planning is a process by which teachers share, critique, refine, and practice their lesson plans before teaching. Think about co-planning as a conversation about teaching, a chance to engage with other professionals and improve your work.

If you are sharing, answer the following questions about your draft:

1. Provide an overview of your lesson plan. For example, ...
 - What do you need to teach? What are students supposed to learn?
 - How will you begin?
 - What kinds of representations (charts, diagrams, writing on board, etc.) will you use?
 - How will you close the lesson?
 - How will you assess students' learning?
2. How inquiry-oriented do you think your science lesson is? How does your lesson support students to:
 - Engage in scientifically-oriented questions?
 - Gather, organize, and make sense of data and evidence?
 - Make evidence-based explanations?
 - Evaluate explanations in light of alternative explanations, particularly scientific explanations?
 - Communicate and justify explanations?
3. What changes did you make to this lesson? Why did you make these changes? Do these changes make your lesson more inquiry-oriented? If so, how?
4. In preparing to teach your lesson, what are you excited about? What concerns do you have?

If you are listening, think about the curricular, instructional, and management issues that might arise during this lesson.

1. Ask questions about different parts of the draft, such as:
 - How does this part of the lesson engage students in inquiry?
 - What do you imagine will be challenging about this part of lesson?
 - What will the students need to focus on / think about / do during this part of the lesson? How will you make sure they know it?
 - How do you anticipate that students will respond during this part of the lesson?
 - What will you say? What will you do? Show me.
2. Make constructive suggestions.
 - It might be interesting to see...
 - I wonder what would happen if...
 - I suggest...

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