This is to certify that the
dissertation entitled

REVEALING TENSIONS BETWEEN CURRICULUM AND
TEACHERS' VISIONS OF COMMUNITIES OF SCIENCE
PRACTICE

presented by

David J. Grueber

has been accepted towards fulfillment
of the requirements for the

Doctoral degree in Teacher Education

Charles W Anderson
Major Professor's Signature

8/8/08

Date

MSU is an affirmative-action, equal-opportunity employer

REVEALING TENSIONS BETWEEN CURRICULUM AND TEACHERS' VISIONS OF COMMUNITIES OF SCIENCE PRACTICE

By

David J. Grueber

A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Teacher Education

2008

ABSTRACT

REVEALING TENSIONS BETWEEN CURRICULUM AND TEACHERS' VISIONS OF COMMUNITIES OF SCIENCE PRACTICE

By

David J. Grueber

This dissertation studies how three middle school teachers used inquiry-based curriculum materials to construct classroom communities of science. Grounded in sociocultural studies of teachers' beliefs, knowledge, and practices of inquiry-based science this work draws on a sociolinguistic approach to compare and describe teachers' and students' contributions to science knowledge and inquiry practices in order to empirically explore how teachers' commitments and resources shapes the classroom community of practice. This study addresses the following questions: What did scientific knowledge and practice look like in each classroom? What do the teacher student interactions reveal about the social norms and sources of authority in the classroom? What were the teachers' commitments and resources to science content and practice that influenced their curriculum construction? The sites of my research are three middle school classrooms implementing a next generation curriculum materials, Investigating and Questioning the World through Science and Technology (IQWST). The study employs interpretive and discourse analytic methods to conduct in depth case studies of three teachers' curriculum construction. This study shows that three unique hybrid communities of practice result from a mixture of ways in which commitments to purposes of schooling and instructional strategies, and personal resources in terms of science content knowledge and pedagogical strategies for distributing participation.

Implications of this dissertation include questions related curriculum design principles and professional development.

ACKNOWLEDGEMENTS

First I would like to thank the faculty in the College of Education at Michigan State University who introduced me to so many new and interesting ideas about teaching and learning. Specifically I extend my appreciation to my advisor, Dr. Charles (Andy) Anderson who was always challenging, supportive, and patient. Also, I gratefully acknowledge the members of my committee for their support and guidance: Dr. Elizabeth Heilman, Dr. Ralph Putnam, and Dr. Michelle Williams.

Second, I would like to thank the members of the IQWST curriculum development team who without which there would have not been a curriculum to study: Dr. David Fortus, Jeff Nordine, Jeff Rozelle, Dr. Christina Schwartz, and Dr. Ayelet Weisman.

And finally, a special thanks to the teachers who enacted this curriculum and opened their classroom and shared their practice with me.

TABLE OF CONTENTS

LIST OF FIGURES

Chapter 1

State of Reform

In the 1960s an unprecedented effort of science education reform and curriculum development was undertaken (DeBoer, 1991). The focus was on increasing academic rigor and development of elite scientists. One result of the focus was curriculum designed by scientists who did not consider the teachers' role in enacting curriculum (Duschl, 1990; Powell, Farrar, & Cohen, 1985). A recurring reform theme in science education since at least the 1960's is the use of inquiry as a method of instruction. Yet, a present day look at classrooms continues to show that teachers use predominantly didactic teaching methods (Weiss, Pasley, Smith, Banilower, & Heck, 2003). With the didactic methods, teachers assume a role that maintains the mystique of science as an authority distinct from students (Lemke, 1990).

Current national reform documents (American Association for the Advancement of Science, 1993; National Research Council, 1996, 2000) and research literature (Krajcik, Blumenfeld, Marx, & Soloway, 2000; White & Frederiksen, 1998) argue for the importance of students understanding and engaging in communities of scientific inquiry practice. Learning a practice requires learning new disciplinary concepts (such as scientific models) and reasoning strategies (such as evaluating a candidate model's fit with observed phenomena). However, engaging in a practice is more than simply learning the steps of a process — scientific practices have an important social element (Fortus et al., 2006).

Varieties of inquiry such as project-based, or design-based have been designed in attempts to reform curriculum and encourage the use of inquiry in classrooms (DeBoer, 2002; Singer, Marx, Krajcik, & Chambers, 2000). Along with the design of curriculum that approaches science teaching and learning as participation in a community of practice, there is an important need to understand the relationship between science teachers' scientific practices, knowledge, and beliefs and the teachers' role in scaffolding student learning experiences consistent with reform-based agendas (Crawford, 2000; Keys & Bryan, 2001; Putnam & Borko, 2000; Remillard, 2005).

If this generation of inquiry designed curriculum materials is going to influence classroom practice, the curriculum materials need to include an educative feature that scaffold teachers to learn new roles when teaching inquiry (Ball & Cohen, 1996). Whether or not teachers can learn new ways of teaching may depend on their commitments to inquiry teaching and their resources to enact inquiry teaching. If the present reform efforts are to have a lasting effect, it is important to understand the differences between teachers' voices and curriculum designers' assumptions of the role of the teacher in the classroom (Keys & Bryan, 2001). The interactional turn in education research has provided the tools to examine the complex social interactions that occur when students and teachers make sense of their roles in the classroom (Erickson, 2006). To that end, I am studying teacher student interactions in science classrooms, because I want to find out why enacted curriculum looks different than designed curriculum, in order to understand how to design curriculum materials.

Tension between Communities of Practice

From a sociocultural perspective classrooms can be seen as distinct communities of practice formed when multiple communities of practice merge in the classroom to create a community that appears different from specific disciplinary communities (Hogan &

Corey, 2001; Keys & Bryan, 2001; Wells, 1995). Often this tension occurs when the intended practices of reform oriented communities of practice (Engle & Conant, 2002; Reiser, Krajcik, Moje, & Marx, 2003), merge with the traditional difficulties of teaching (Floden & Buchman, 1993; Munby, Cunningham, & Lock, 2000).

As practitioners, teachers are wrestling with the problems of the classroom world which is a hybrid space where the problems of the world are not just specifically the problems of academic disciplines but also include a mélange of historical and cultural instructional practices (J. S. Brown, Collins, & Duguid, 1989; Cohen, 1990). Some problems of a teacher's world include maintaining social order of the classroom and achieving a set of academic objectives within the time frame of a class period (Doyle & Carter, 1984; Mehan, 1979). From a teaching as practice perspective, it is important to understand the problems that teachers must solve, and their personal skills and knowledge that are used to solve those problems (Cohen, 1988).

Often through a combination of language use and reducing complexity of academic tasks (Carlsen, 1997; Moje, 1995; Page, 1999), teachers adapt academic tasks in such a way that maintains a "mystique of science" (Lemke, 1990) which portrays science as a body of fixed knowledge, and a process of verifying facts. Adapting academic tasks is an inherent part of enacting them, and the need for adaptation seems to be particularly prevalent for teachers developing practice associated with current reforms (Remillard, 1999).

Teacher Role and Distribution of Participation

With the current views of science teaching and learning curriculum developers are attempting to increase student learning and reduce the mystique of science by better coordinating the knowledge and practice of science (Bransford, Brown, & Cocking, 2000; Duschl, Schweingruber, & Shouse, 2007; Krajcik, McNeill, & Reiser, 2008). A number of curriculum design principles have been developed to help teachers develop a learning environment similar to the scientific culture of practice (Edelson, 2001; Engle & Conant, 2002; Singer et al., 2000). Within an environment of authentic disciplinary practice, the teacher's role is to choose activities that best afford opportunities for students to learn the knowledge and practices of a discipline and model those practices (Driver, Asoko, Leach, Mortimer, & Scott, 1994; Singer et al., 2000). A learning environment modeled after authentic disciplinary practices adds to the complexities of classroom teaching because teachers are now responsible for modeling both the cognitive practices (Collins, Brown, & Newman, 1989), and the distributing the social participation to afford students more authority in the production of knowledge (Engle & Conant, 2002).

Investigating and Questioning our World through Science and Technology (IQWST) is a curriculum designed to support teachers in the design of an authentic disciplinary learning environment with a learning goals driven design model and specific attempts to develop learning performances that coordinate the content knowledge and practices of science (Krajcik et al., 2008; Reiser et al., 2003). In order to help teachers reduce the empirical and social complexity in science classrooms IQWST attempts to provide teachers with educative curriculum materials as a tool to solve the problems of their classroom world (Ball & Cohen, 1996; Davis & Krajcik, 2005; Schneider & Krajcik, 2002).

However sustaining environments of authentic inquiry practice requires new forms of teaching and instructional goals for students, and along with those new challenges in the classroom (Crawford, 2000; Remillard, 1999). Lemke (Lemke, 1990) described teachers using language to maintain the authority and mystique of science. IQWST materials that are designed to reduce the mystique of science by providing teachers a tool with which they can construct a learning environment that creates for students the opportunities to participate in the cultural practices of science. From the IQWST perspective in order to construct this learning environment the teacher needs to enact what I have called a de-centered expert role. In this role, the teacher models the cultural tools, ranging from the meanings of words, to methods of identifying and solving problems, and the norms for appropriate methods of communicating arguments and critiques. The teacher also coaches students in the appropriate cultural practices and over time fades while distributing more legitimate participation opportunities to students. The teacher also provides feedback and adjusts activities for student learning (Singer et al., 2000).

However, while observing the pilot enactment of IQWST lessons during the 2005-2006 school year a number of instances occurred in the classrooms that appeared to be at odds with the IQWST vision of the teacher's role in modeling scientific inquiry practices. For example, at the beginning of one class period the teacher instructed the students to answer a question based on the evidence the students had collected. Students basing their answers to questions on evidence they collect from the phenomena is one type of inquiry practice intended to occur in the IQWST curriculum. Yet, at the end of the lesson the teacher instructed the students to ignore the data they had collected and use the data the teacher would supply because the student data had not turned out as the teacher expected.

This critical incident led to the consideration of the interaction between the teachers' commitments to science teaching and their personal pedagogical resources used to enact IQWST lessons, and the commitments to science teaching and necessary pedagogical resources implicit in the design of the IQWST curriculum. This has led to the following research questions that will frame this study:

1) What did scientific knowledge and practice look like in each classroom?
2) What do the teacher student interactions reveal about the social norms and sources of authority in the classroom?
3) What were the teachers' commitments and resources to science content and practice that influenced their curriculum construction?

Overview of the Enactments

The three teachers that enacted the IQWST curriculum actually maintained the mystique of science in quite different ways resulting from their commitments toward authentic science content and science practice, and their personal resources that they use in support of their commitments. In a sense where Lemke presented a case of maintaining authority, I want to make clear that all three teachers in this study did not attempt to maintain the mystique of science, but rather expressed as their personal goal creating and sustaining opportunities for their students to learn science. However, in effect their practice does maintain this mystique but in uniquely different ways and for different reasons.

Mr. Dee maintains the mystique of science with his enacted role as "the nature guy." Mr. Dee wants students to learn scientific explanations for the world around them. He uses rich experiences with natural phenomenon as the context for scientific explanations. For his students Mr. Dee values not so much the epistemic practices of science, but the stimulating wow factor of science. As a result with his emphasis on experiences with nature and the explanations of those experiences he does not include how science comes to know these explanations and in the process continues the mystique of science.

Ms. Kay maintains the mystique of science with her enacted role of "the gatekeeper." One of the definitions of a gatekeeper is one that tends or guards the gate. For Ms. Kay I want to emphasize the notion of tending the gate, because she does this by watching over and caring for her students' learning of science. For Ms. Kay she sees science knowledge as valuable and important to her students' lives and she is doing her best to prove to her students that science is valuable knowledge. Now, as this gatekeeper though she engages students in experiences with science, and she mines those experiences for examples that support and verify the already established scientific knowledge in order to prove to her students that they can do science. She maintains the mystique of science though when she tells students even though they were wrong they did a nice job and if they were paid to work as scientists they could go back and redo the experiments like scientists do.

Ms. Cee enacted the teacher role of "tour guide." Ms. Cee provides her students with access to science materials and experiments and then after students have talked about their experiences with the experiments Ms. Cee tells them what the scientific explanations for the experiences are. Ms. Cee maintains the mystique of science by leaving it a mystery what the connections are between the experiments and the explanations for those experiments. In part this is both due to Ms. Cee's commitment to inquiry that students should be free to explore with materials their own questions and discover their own answers, and her own knowledge that limits her ability to help students reason and make sense of their experiences in the development of that knowledge.

Dissertation Outline

Chapter 2 is a theoretical framework where I review three themes that frame both the research questions and the analysis of the pilot enactment. These themes include defining science as inquiry, social and socioscientific norms in a classroom community, and teacher commitments and resources for curriculum construction. Science as inquiry involves coordinating the content knowledge and practices of science for the purposes of either building arguments from evidence, or using models to understand and explain phenomenon. Within classrooms there are norms, roles, and responsibilities for teachers and students. Ideally, for current curriculum reform efforts to work these roles, norms, and responsibilities in some ways mirror the norms of scientific communities. And finally, in order to create classroom communities with scientific norms teachers need particular commitments to instructional goals and personal resources to construct that environment.

Chapter 3 is the methods chapter. This study comprises case studies of three teachers enacting the same curriculum unit. I am using an interpretive analysis to describe and compare the three cases in order to explain the source of tension between the IQWST model of a community of practice, and the three teachers' community of practice.

Chapter 4 is a description of what scientific knowledge and practice looks like in the three classrooms. I describe one lesson for each of the three teachers focusing on the science knowledge and the science practices that occurred in the three classrooms. So, what emerged are four different models of the relationship between knowledge and practice, the IQWST and each teacher's model. The relationship between science content and practice is important because teachers' particular views of science content influence the types of valued science practices that are modeled in the classroom.

Chapter 5 is a description of the social and socioscientific norms that distribute the participation in the classroom community. I describe the participation structures and the associated roles and norms that are established for the teachers and the students, and the associated rights and responsibilities for behavior on the part of students and teachers. The social and socioscientific norms are important because in order to distribute participation in a community of practice, the members of the community need to know what appropriate norms for interaction are, and without these norms a community modeled after scientific disciplinary practice will not be constructed.

Chapter 6 uses interviews from a viewing session with the teachers of the lesson analyzed in chapter 4 and 5 to use the teachers' voices in order to explain the underlying mechanisms for the three different communities of practice and enacted teacher roles.

Chapter 7 is a discussion of conclusions and implications for designing educative curriculum materials that are one element of the attempts to reform science teaching and learning.

Chapter 2

Theoretical Framework

It has been a steady argument that the structure of science education should include the key facts, procedures, and concepts of a discipline and their relationships to each other (Schwab, 1978), and this argument continues today as a part of national science education reform efforts (American Association for the Advancement of Science, 1993; National Research Council, 1996). Schwab (1962) argued that science curriculum development began to divorce the content and process of scientific knowledge so that science in school began to be portrayed as a fixed and steady body of knowledge. More recently other scholars have noted that the difference between the knowledge of authentic scientific practice and the knowledge taught and learned in school continues to exist (Duschl, 1990; Resnick, 1987).

Today the goal is still on the agenda of science education reform efforts with "the conviction that scientific inquiry is at the heart of science and science learning" and that "inquiry into authentic questions generated from student experiences is the central strategy for teaching science" (National Research Council, 1996). However, with contemporary views of science teaching and learning that focus on science as the process of participation in the community of scientific practices (Bransford et al., 2000; Duschl et al., 2007) there is a need to also attend to the cultural norms of participation in science classrooms. These cultural norms, or *syntactic structure* (Schwab, 1978), define what counts as appropriate methods of verification and justification of knowledge.

As a result of the coordination of both the substantive and syntactic nature of science implicit in today's reform oriented curriculum materials, teachers are being asked to enact new roles in classrooms (Crawford, 2000). The extent to which teachers enact these new roles is often a result of their personal commitments to what counts as the nature of science (N. W. Brickhouse, 1990).

The following literature review is organized to first establish a framework for describing the nature of science content and practice in the classroom. Then I describe ways to examine the syntactic or normative aspects of the distribution of participation in science classrooms. And finally, the relationship between teachers' commitments and resources used to support their aims of science instruction and their responses to both curriculum tasks, and students encounters with the curriculum tasks.

Science as Inquiry Framework

Attempts to understand science as inquiry is complicated by the fact that the practices of inquiry are embedded within the context of known and accepted science knowledge (Duschl, 1990). When the content and practices of science are separated, the fundamental nature of science as inquiry is changed. Therefore, learning should be situated in the context of authentic science activities (J. S. Brown et al., 1989; Driver et al., 1994) represented in national science education reform documents (AAAS, 1989; NRC,1996; NRC, 2000). Because the IQWST intent is to model the students' practice after scientists' I needed to develop a framework to analyze the nature of science in the classrooms which includes two aspects, the nature of the content and the nature of the practice. While I understand that the nature of science products and practice are contested and can be examined from a number of viewpoints including political, economic, gendered, and cultural views (Nancy W. Brickhouse, 2001), IQWST is designed with an overall modern view of the nature of science (Good & Shymansky,

2001) so I limit my framework to views of science in national science education reform documents.

Nature of Scientific Knowledge

Learning knowledge is one of the core activities of school, and the definition of what content is or should be taught in school is often debated (Bereiter, 1994). It has been argued that what counts as knowledge in traditional classrooms is "epistemologically flat" (Duschl, 1990), and studies show that what counts as accepted scientific content for many teachers and students are the patterns, or laws and truths of science (Akerson & Hanuscin, 2007; Gallagher, 1991; McComas, Almazroa, & Clough, 1998; Smith & Anderson, 1999; Yerrick, Pedersen, & Arnason, 1998). This traditional view of science presented in textbooks and understood by teachers and students stands in stark contrast to the view scientific knowledge as a product of disciplined ways of organizing and making sense of the natural world (McGinn & Roth, 1999; Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003).

What are the ideas, concepts, and theories of science that scientists use to organize and make sense of the world? There is the book of nature or the experiences with the material world, the symbolic world of science which includes the invented entities such as atoms, electrons, light rays, and scientific laws, and finally the organizing ideas such as models and theories (Dagher, Brickhouse, Shipman, Letts, & Sturt, 2004; Driver et al., 1994). Because IQWST is modeled after the authentic activities of science, I used a framework of scientific knowledge called Experiences, Patterns, and Explanations (EPE) (Anderson, 2003b) to identify the nature of the science content in the classrooms enacting the IQWST unit.

Within the EPE framework Experiences are the observable events such as light detector readings, seeing or not seeing an object in a room and any other additional experiences students have with the material world. Patterns are descriptive terms that refer directly to measurable properties of observable objects. For example, the pattern, "law of reflection," has the measurable property of the light detector readings and the descriptive term used for this pattern could be "v" shape. When combined with additional patterns such as how light interacts with different properties of matter also observable by light detector readings, these patterns can be represented by a few Explanations. Explanations are theories or models that allow scientists and students to predict and explain observable events like light detector readings to unobservable objects and events like light rays and paths of light which are represented in the ray-diagram model of light and vision. For an example of the experiences, patterns, and explanations in lesson 6 see Appendix Table B.

Nature of Scientific Practice

The type of content knowledge that is valued in classrooms and the science community has an implication for the types of practices that are common because the nature of the reasoning practices depends on the epistemological criteria (Hogan & Maglienti, 2001). With the epistemological criteria that science is a process of knowledge revision the social practices for knowledge production include coordinating the relationship between theories or models and evidence (Herrenkohl, Palinscar, DeWater, & Kawasaki, 1999; Smith & Anderson, 1999). Two important scientific practices for coordinating this relationship are building arguments from evidence (Anderson, 2003b; Driver, Newton, & Osborne, 2000; Sandoval & Reiser, 2004)., and model-based reasoning (Anderson, 2003b; Gilbert & Boulter, 1998; Windschitl, Thompson, & Braaten, 2008, in press).

In the reformed vision of IQWST curriculum materials (Fortus et al., 2006; Singer et al., 2000) and national reform documents (National Research Council, 1996, 2000) these important scientific practices are further broken down into a number of scientific practices. These practices include: identifying empirical questions; designing and conducting investigations; using appropriate tools and techniques to gather, analyze, and interpret data; developing descriptions, explanations, predictions, and models using evidence; thinking critically and logically to make the relationships between evidence and explanations; recognizing and analyzing alternative explanations and predictions; communicating scientific procedures and explanations; and, using mathematics in all aspects of scientific inquiry. The specific scientific practices I used for analyzing the practice in this study were drawn from the IQWST learning progression for sequencing scientific practices (Fortus et al., 2006), and listed in Appendix Table C.

This framework of science content and practices can be used to identify the types of science content and practices that can be used to describe the nature of the classroom community of scientific practice. It is important to do that because the activities of a classroom community are framed by its culture (J. S. Brown et al., 1989), and sociocultural research raises serious questions about relationship between what goes on in schools and the cultural practices in which the living disciplines are constituted (Bereiter, 1994; Keys & Bryan, 2001).

Social Norms

In the previous section I constructed my framework for the substantive structure of inquiry in the classroom in terms of the important content and practices. In this next section I look at the syntactic structure, or in other words what are the socioscientific norms that describe what counts as legitimate participation in the community?

Contemporary views of teaching and learning (Bransford et al., 2000) are grounded in the perspective that thinking and learning is situated in the nature of a context, and that learning a practice occurs best in a culture of authentic practice (J. S. Brown et al., 1989; Lave & Wenger, 1991). Teaching and learning science as inquiry is also a cultural activity that occurs within a classroom community (Duschl et al., 2007; Magnusson, Palinscar, & Templin, 2004), where teachers and students engage in practices that identify themselves as members of the community (Gee, 2004). As members of the community, teachers and students take on roles which are patterned sets of actions and behaviors.

There is a changing emphasis on the nature of teacher and student roles (Crawford, 2000; National Research Council, 1996). Lave and Wenger (1991) and Driver et al. (1994) argued from different premises toward a similar conclusion that teachers need to take a "de-centered expert" role in the classroom. If students are to take on the roles that occur in social contexts that support intellectual practices being a hypothesizer, evidence provider, maker of distinctions, checker of facts they must receive social support from teachers (O'Connor & Michaels, 1996).

For a number of reasons, an implicit intent of inquiry-based curriculum is to establish socioscientific norms and scientific inquiry practices that enable students to reason with evidence. First, reasoning with evidence is a central practice in the design of inquiry-based curriculum materials (Fortus et al., 2006; Singer et al., 2000). Second, evidence is the authority that fills the authority vacuum when teachers enact alternative instructional roles in the classroom (Minstrell, 1992; National Research Council, 1996). Third, quality learning and the spirit and practice of scientific inquiry are lost when the evidence and argument for scientific models are replaced by direct assertions by the teacher and text (NRC, 1996). Finally, curriculum should teach how science comes to know (Duschl, 1990; Schwab, 1962).

Participation Structures

While authentic practice for scientists is ordered by attempts to solve problems and produce knowledge that makes sense of the material world (Pickering, 1995), authentic practice for teachers and students is often ordered by the sequence of activities and contexts of a curriculum (Cazden, 2001). Classroom lessons have a particular structure of activities and events which help coordinate the completion of a lesson (Mehan, 1979). And within these events the organization of participation can shift on a moment to moment basis, and teachers and students must recognize their roles and interpret the relation between the teachers' language forms and the intended appropriate social action (Cook-Gumperz & Gumperz, 1982; Florio-Ruane, 1987). These smaller units of activity that orient the teachers and students in coordinated action are participation structures (Cazden, 1986; Erickson, 1982; Philips, 1972).

Participation structures have a set of social norms that order individuals' rights and responsibilities for establishing who participates (Cazden, 2001; Cobb, Yackel, & Wood, 1989). These social norms are implicit rules that teachers and students use to determine when it is appropriate for teachers and students to talk in the classroom, who has the responsibility for changing the topic in the classroom, and in what ways the students are teachers are responsible for listening to each other.

Participation structures also have a set of disciplinary norms (e.g., socioscientific) that orient members to what counts as appropriate disciplinary participation (Cobb, Stephan, McClain, & Gravemeijer, 2001; Engle & Conant, 2002; Erickson, 1982; Herrenkohl & Guerra, 1998; Tabak & Baumgartner, 2004). For example, socioscientific norms in the classroom are implicit rules that determine whether it is appropriate for the teacher or students to talk about science content or explanations, and whether or not it is appropriate for the teacher or students to make decisions about the validity of evidence.

With the view that learning occurs in communities of practice, and that authentic scientific practice is the production and use of knowledge, there is need for teachers and students to enact new classroom roles. I have described a framework for describing the distribution of participation in the IQWST classrooms that accounts for both the social and socioscientific distribution of participation.

Curriculum Construction Commitments and Resources

Enacting the de-centered expert role who models the social practices of the science community requires teachers to use their full range of professional knowledge and resources (M. Brown & Edelson, 2001; Cohen & Ball, 1999; Crawford, 2000; Schneider, Krajcik, & Blumenfeld, 2005). Enacting this role is a difficult task because the relationship between views of learning and pedagogy are problematic, and no simple rules for pedagogical practice emerge from a constructivist view of learning (Driver et al., 1994). Many studies demonstrate the influence of teachers' knowledge, beliefs, and commitments to science and learning on their enactment of curriculum materials (Blumenfeld, Fishman, Krajcik, Marx, & Soloway, 2000; Cronin-Jones, 1991; Roehrig, Kruse, & Kern, 2007; Tobin & McRobbie, 1996).

Curriculum Construction

The enactment of curriculum occurs within an arena that has been described as curriculum construction (Remillard, 1999). The curriculum construction arena is where teachers and students transform the planned tasks of a curriculum into the lived classroom events. The central teacher activity in the construction arena is task adaptation which is the teacher's unrehearsed adaption and adjustment to academic tasks in response to their reading of both the academic task, and their students' performance of the task. The teacher's responses to their reading of the tasks and students' performance are valuable indicators of teachers' aims and goals related to what it means to know and do science and their personal resources to improvise responses.

Commitments

Teachers on-the-spot adaptations of tasks are embedded in their commitments which can be defined as orientations to teaching which include teachers' beliefs about students and the learning process, about the role of schools in society, and about teachers themselves, the curriculum, and pedagogy (Pajares, 1992). These commitments include teachers' perceptions of and purposes for schooling which include providing credentials and rankings, and preparing students to become workers and citizens (Anderson, 2003a). Commitments include the forms of science content knowledge valued in the classroom (Anderson, 2003b; Yerrick et al., 1998). Commitments also include teachers' valued ways of thinking and acting in the science classroom which may be different from the habits of mind that occur in authentic disciplinary communities such as a commitment to instituting norms of peer review and respect for evidence in the classroom (Engle & Conant, 2002).

Resources

Resources include the knowledge (human resources) and tools (material resources) to teach for understanding (Anderson, 2003a; Shulman, 1987; Wilson & Berne, 1999). For example, these resources include the tools and teaching materials that support student engagement, and an ability to design additional materials. Resources include an understanding and ability to respond to students' reasoning. Resources also include a personal understanding of powerful ideas in science and scientific models, and the ability to relate them to students' ideas in order to establish the connection between data, personal experiences, and scientific models. Also important are the pedagogical resources to develop social norms for creating processes of building arguments from evidence in classrooms where different norms prevail. And finally, the management skills to maintain social control while holding a discussion that relinquishes control over evidence and conclusions partly to the students

Summary

This framework is intended to describe and compare versions of communities of practice. IQWST, through the curriculum material, has designed a community of authentic inquiry practice that coordinates the content and practice of science to produce powerful scientific models that can be used to explain phenomenon. In order to create this community though, teachers play an essential link in the relationship between teachers, students, and subject matter. It falls to teachers to establish the types of social participation structures that result from commitments to a view of science teaching and learning that values student participation in the construction of scientific understanding. If the IQWST vision of practice is to be enacted in classrooms, then teachers must have similar commitments to views of science and learning, and the necessary personal resources to respond to the ambiguities and complexities when teachers and students encounter the tasks.

Chapter 3

Method

Investigating and Questioning our World through Science and Technology (IQWST) is a curriculum materials development project that is addressing the problem of designing a next generation of curriculum materials that promote deep understanding of science while attending to national content standards, inquiry standards, and goals for science literacy. This project uses a design-based research and development approach which occurs in two stages (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003; Cobb et al., 2001). In the first stage, or the design stage, the curriculum material is designed according to a particular set of design principles (Krajcik et al., 2008; Reiser et al., 2003). Second, in the feedback stage, an interpretive analysis (Erickson, 1986) of the use of the curriculum material is performed to inform the revision of the curriculum material.

I used a comparative case study research design (Merriam, 1988; Yin, 2006) because I wanted to address the descriptive question of what happened in particular classrooms when three teachers used IQWST curriculum materials and understand why the teachers enacted particular instructional roles in order to further inform the design and revision of IQWST materials.

Seeing the Light: Can I Believe My Eyes? (Fortus et al., 2005) is a six-week physics curriculum unit designed for 6th grade students, and is one of the 18 units designed for the IQWST project. The enactment of the light curriculum served to bound the time and events of each case. Following is a description of the case according to the design principles of the IQWST project. Then the 3 contexts that the IQWST unit was enacted in including the data sources. And finally, the methods used to analyze the case.

The Case: IQWST Light Unit

The IQWST light unit was designed with the following design principles: learning goal driven design, motivating and contextualizing inquiry, preparing students for inquiry, supporting inquiry, anchored in multiple and varied phenomena and presentations, artifacts and culminating activities. Because the core focus of my analysis is on *Lesson 6: Scattering and Reflection of Light* I will describe each of these design principles in the context of lesson 6.

Learning Goal Driven Design. Learning performances are determined with a backwards design approach (Wiggins & McTighe, 1998). First, essential content is identified in the national standards, for example, "Light interacts with matter by transmission, absorption, or reflection (including scattering)" (National Research Council, 1996). Next relevant inquiry standards are identified such as, "Develop descriptions, explanations, predictions, and models using evidence (NRC, 1996, A: 5-8) and "Think critically and logically to make the relationships between evidence and explanation. (NRC, 1996, A: 5-8)." The content standard and the inquiry standard are then combined to develop learning performances such as the learning performances for lesson 6: "Students investigate the law of reflection" and "Students use a model of light to explain the difference between reflection and scattering."

Motivating and contextualizing inquiry. The driving question provides an authentic context for inquiry. In lesson 6, the driving question is, "Why can I see my reflection in a mirror but not a piece of wood?" The science content and skills identified in the learning performances are essential for answering the driving question.

Preparing students for inquiry. In order to help students develop understanding about the subject matter teachers need to know what students already understand and believe about the world. Lesson 6 begins with an activity in which the teacher reviews what students have learned about the light model that has been developed to explain how objects are seen. And the teacher learns about student experiences by asking them about their experiences when their eyes may have been fooled when light bounces off an object.

Supporting inquiry. Several strategies are used to support students in learning inquiry practices. Learning technologies are tools that support learners in authentic inquiry including light detectors and data tables in lesson 6. Opportunities for collaboration and discourse occur when students communicate scientific procedures and explanations, collect data, analyze data, and communicate their findings to the class, and query other students' explanations as a part of developing legitimate skepticism. For example, in Lesson 6 students analyze the data from light reflecting off a mirror identify and communicate the pattern that light reflects in a "v" shape pattern. And finally, scaffolds which are instructional supports that allow students to take part in tasks that otherwise would be less accessible or productive. Teachers scaffold learning by sequencing, modeling, coaching, and giving feedback. For example, suggesting to the teacher that students should recognize that the meter sticks attached to the light detector and flashlight "made a V" when the maximum light detector reading was recorded. Scaffolded learning materials reduce complexity and highlight concepts and inquiry strategies. For example, the student activity sheet for lesson 6 scaffolds the investigation design. Procedures are given that describe where to place a flashlight and a light detector in order to measure the amount of light that is reflected at different angles from a rough and smooth surface. And the student activity sheet supports the subsequent data analysis with data tables and questions to help students identify patterns with prompts such as, "describe any differences you noticed in the data you gathered for the mirror and the data you gathered for the piece of paper".

Anchored in multiple and varied phenomena and presentations. Students experience the phenomena through first-hand experiences in order to have concrete representations to tie the various explanations together. For example in lesson 6 the concrete experiences are with the light detector readings for reflected light from a mirror and a piece of paper, also students are shown different materials that reflect and scatter light, and a microscopic picture of paper to see the rough surface of paper. The experiences with the experiments and the different types of materials are tied together to explain why reflections can be seen in mirrors but not in wood.

Artifacts and culminating activities. Artifacts are embedded assessments or products students create as they conduct investigations. In lesson 6, artifacts include the predictions, and conclusion questions on student activity sheets, and the final product is a revision to the class ray-diagram light model that includes the ways light can interact with rough and smooth surfaces.

Context: Participants

The pilot enactment of the light unit occurred during the 2005-2006 school year in three classrooms. Three teachers piloted the enactment of the light curriculum. The three teachers enacting the unit were a convenience sample chosen to represent urban, suburban, and rural classrooms. The teachers in this study were recommended by fellow researchers and colleagues and chosen due to their willingness to pilot the light curriculum.

Classroom One: Mr. Dee

Mr. Dee had been teaching physics and physical science for 16 years. He taught in a variety of classrooms including a middle school in Florida with a mixture of urban and suburban students, a Department of Defense school in Germany, and currently in a suburban middle school in Michigan for the past six years. He has a B.S. degree in science education and an Ed.S. degree in curriculum and instruction with grades 7-12 certifications in general science, physics, and math.

The suburban middle school Mr. Dee teaches in has a student body that is 94% White, not Hispanic; 2% Hispanic; 2% Asian/Pacific Islander; 1% Black, not Hispanic. 11% of the students are eligible for free or reduced-price lunch. And on the state MEAP test the school average for math proficiency was 86% compared to the state average of 72%.

In terms of the physical setting of the classroom, the room itself is quite large with students seated at tables for two students. Displayed around the room are a number of devices that Mr. Dee uses to demonstrate science concepts including a pop bottle radio, a periscope from a military tank, etc. The class is well stocked with laboratory equipment. There are a number of additional instructional tools such as computers, printers, and an overhead projector that Mr. Dee has purchased on E-Bay or MSU surplus store in addition to the appliances such as hot chocolate makers and dishwashers that make Mr. Dee's classroom a social hub of the school as well.

Classroom Two: Ms. Kay

Ms. Kay had been teaching for six years. For all six years she has taught science in sixth and seventh grade at an urban middle school in a large city. She has a B.S. degree in education with a major in life science, and a minor in physical science. She is certified to teach all subjects K-5, with a general science endorsement.

The urban school Ms. Dee teaches in has a student body that is 98% Black, not Hispanic, <1% Asian/Pacific Islander, <1% Hispanic, and <1% White, not Hispanic. 15% of the students are eligible for free or reduced-price lunch program. And on the state MEAP test the school average for math proficiency was 91% compared to the state average of 72%.

In terms of the physical setting, Ms. Dee's classroom is quite cramped. There are six laboratory tables affixed to the floor with typically 5 or 6 students per table. There are cabinets along one wall with some laboratory equipment. And displayed around the room are student posters and presentations from prior years.

Classroom Three: Ms. Cee

Ms. Cee has been teaching in rural schools for the past 13 years. She has taught social studies, science, computers, and careers. She has a B.S. degree in elementary education with minors in math, science, and social studies, and a M.S. degree in educational leadership. She is certified all subjects K-8, with endorsements in math, science, and social studies.

The rural school Ms. Cee teaches in has a student body that is 94% White, not Hispanic, 2% Hispanic, <1% Asian/Pacific Islander, and <1% Black, not Hispanic. 31% of the students are eligible for free or reduced-price lunch program. And on the state

MEAP test the school average for math proficiency was 49% compared to the state average of 72%.

Ms. Cee's classroom is carpeted and serves multiple purposes as the science and social studies classroom, and the after school day care program. There is no running water or electrical outlets typical for a science classroom, and if Ms. Cee needs science equipment she borrows the necessary equipment from the High School teacher.

The researcher: Mr. Grueber

In a study of the contrast between fundamental changes in policy and one teacher's practice Cohen (1990) raised a critical question, whose perspective on change is most important, the observer's or the teacher's? Similar to the concern raised by Cohen, I seek to honor both the perspectives of the teachers' enacting the IQWST curriculum, and the design principles used to construct the IQWST curriculum materials. Because the observations and descriptions of the teachers' practice also occurs within the context of the researcher's background and personal history I include here a description of my own background as a classroom teacher, and relationship with the IQWST project design team and teachers.

I was a high school science teacher for six years. During that time one of the problems of my own practice that was particularly interesting to me was justifying to my own students the explanations I provided. Often my students would ask me how science had determined a particular explanation, and often my own explanation consisted of repeating the explanations I had learned from either the book or my own professors. This type of explanation often left both me and my students unsatisfied.

As a result of this and other dissatisfactions with my own practice I chose to pursue a doctoral degree in science education. During this time I became involved with the IQWST project and participated in the design of the "Seeing the Light" IQWST unit. I appreciated the attempts of the IQWST unit to coordinate through the experiments the content and practices of science for a number of reasons. One, the IQWST units are designed to connect the content and practice both across the lessons in one unit, and the entire 18 units. Second, the IQWST units are designed to include pedagogical strategies to support teachers in creating a learning environment that affords students opportunities to use evidence from the experiments as the basis of the explanations for the content.

I also appreciated and respected the efforts of the three teachers' piloting the IQWST unit. I was excited about working with Mr. Dee because I had attended his presentations at the state science teacher convention and looked forward to observing his teaching practice. Throughout the pilot enactment Mr. Dee contributed many valuable suggestions that became included in revisions to the light unit.

I had fewer personal interactions with Ms. Kay throughout the pilot enactment because in the school there were many demands on her time, and few opportunities to talk with me. However, during other professional development workshops I had more opportunities to sit and talk with Ms. Kay. During the enactment, one of the aspects of Ms Kay's practice that stood out to me was her classroom management skills, which I sometimes used as examples in the context of the pre-service teacher education course I was instructing.

I had the most personal interactions with Ms. Cee throughout the pilot enactment. Because of Ms. Cee's classroom schedule I had more opportunities to spend time with her during lunch and recess periods. Ms. Cee was also very comfortable discussing with me her difficulties with the lessons and expressed an interest in how the other two teachers had dealt with problems that arose during the lessons, and what the IQWST team had intended to occur.

So, against the backdrop of my own personal experiences with classroom teaching and being a member of the IQWST design team I often shifted between two points of view. From one point of view as an IQWST curriculum design member, I was interested in studying the fidelity of the enactment to identify ways to revise the IQWST materials. From the second point of view as a teacher, I was interested in studying the ways teachers bring together their own practices and the IQWST practices to create a new or hybrid unit.

Data Sources

Observations of practice. Observations (Hatch, 2002) of each classroom were made at least once per week for each classroom in order to understand the culture, and setting of the classrooms in which the IQWST curriculum was enacted. While present in the social setting of the classrooms, I recorded field notes of what the teachers and students were doing and saying in order to get a sense of the norms and expectations of each classrooms social and academic setting. Because the norms and expectations of social situations are so nuanced, videotaped recordings were used as the primary source of data. I personally observed Mr. Dee's classroom on 9 occasions, Ms. Kay on 9 occasions, and Ms. Cee on 6 occasions.

Videotape of practice. Raw video footage of each class period for the enactment was shot continuously with little movement of the camera. The main advantage of this kind of recording is that the video document provides a relatively comprehensive and neutral record of the social interaction (Erickson, 2006). On average 28 class periods of approximately 45–50 minutes were videotaped for each classroom. I transcribed and coded 22 class periods for Mr. Dee, 31 class periods for Ms. Kay, and 21 class periods for Ms. Cee.

Interviews. Semi structured interviews (Freebody, 2003) were conducted individually with teachers at the end of the year to clarify their perceptions of inquiry, how they managed the dilemma of what to do with problematic data, and their perceptions of personal strengths or weaknesses related to the event, including their thoughts on the students' responses to this approach to learning. In addition to demographic questions, and open ended questions (i.e., what they believe a good science teacher should know and be able to do), for each interview I prepared a set of 6 video clips from lesson 6 which I showed each teacher and asked them to comment on the clip (Erickson, 2006). Each interview lasted approximately 1.5 hours. All interviews were audio taped, and full transcriptions were made of each interview. The interview questions are in Appendix D.

In addition to the interviews, after the observations on occasion there were opportunities for personal communication with the teachers during which the teachers commented on what did or did not go well in the lesson. Also on occasion emails were exchanged with the teachers.

Additional artifacts. Classroom artifacts such as photographs, posters, charts, models, students' work, pre/post content tests, pre/post attitude surveys were also collected.

These varied sources can be used to facilitate data triangulation in order to improve confidence in the results of the findings (Hatch, 2002). In this study the primary data for question 1 is the curriculum materials and transcriptions of videotape recordings of entire lessons; for question 2, the primary data is the transcribed discourse of formulating patterns and explanations events; and for question 3, the data includes the field notes, transcribed discourse, and teacher interviews.

Analysis

Question 1: What did scientific knowledge and practice look like in each classroom?

In order to describe the authentic community of classroom science I found Remillard's (1999) framework for studying teachers curriculum construction useful because it frames both the teachers' selection of IQWST tasks in the design arena, and their response to the tasks in light of their personal aims and goals for science teaching and learning in the construction arena. In the first stage of my analysis, which corresponds to the design arena, I began by developing a coding framework for inquiry events in order to determine the boundaries of classroom events. Because I was interested in looking at the inquiry that happened in the classrooms I created definitions of events based on types of inquiry and general classroom events (Lemke, 1990; Mehan, 1979) such as beginnings to lessons, transitions, and classroom business such as checking homework. Using "The Five Essential Features of Inquiry" (National Research Council, 2000), and a learning progression of inquiry practices (Fortus et al., 2006) I developed four inquiry events: Formulating and Asking Questions (FAQ), Data Gathering (DG), Formulating Patterns and Explanations (FPE), and Connecting Explanations (CE). Two additional events were Other IQWST events, and Non-IQWST events. The descriptions of the events are in Appendix A.

The definition of events was necessary to be able to determine the context. A context is a socially constituted environment embedded in time that can change from moment to moment, and within each context there are particular actions that are considered legitimate (Erickson & Shultz, 1981). For example a student handling light detectors in a data gathering event is considered legitimate, whereas during a formulating patterns and explanations event this might be considered an illegitimate action. I was particularly concerned with the types of actions in the contexts that I have described as inquiry events.

Then I watched each videotape and made a rough transcript of the video, a rough transcript was simply as much as I could type while the video played in real time (Ochs, 1979). I then coded that rough transcript and wrote a narrative account of each class period. With these rough transcripts and narrative accounts I constructed "event maps" (Gearing & Epstein, 1982; Kelly & Crawford, 1997) of the inquiry events that occurred during the enactment of the unit and which helped to determine the teacher's selection and design of IQWST tasks.

Once I transcribed and coded each class period I selected two lessons to make a more detailed coding of what inquiry looked like in each classroom for the second stage of my analysis. I selected these two lessons because a core activity in both lessons was formulating patterns in evidence for the purpose of constructing and revising models. In the second stage of analysis, which corresponds to the construction arena, I made a full transcription of each lesson and micro analysis of the lesson episodes (Erickson, 2006).

An episode is identified by changes in the social setting, these changes were identified by either a change in the substantive content of the talk, or the participants involved (Lemke, 1990). I coded those episodes with a framework for science content and science practices. For my framework of content knowledge I coded the teacher guide and classroom lesson for examples of experiences, patterns, and explanations described in Appendix B. I coordinated the inquiry events with inquiry practices developed by members of the IQWST team and also coded the episodes for the types of inquiry practices defined in a learning progression for scientific practices and listed in Appendix C.

Question 2: What do the teacher-student interactions reveal about the social and socioscientific norms in the classroom?

For question 2, I used discourse analysis to find social norms in the classroom from an emic perspective (Gee & Green, 1998). I continued to use the episodes I had identified in the transcript for each lesson. At this point I was looking for the structure of the role relationships among the participants, in other words, how the teacher and students orient themselves to appropriate action. Participant structures can change within a single context and each participant structure has particular ways of speaking, listening, getting the floor and holding it (Cazden, 2001; Erickson & Shultz, 1981). Therefore to identify the norms for the participant structures I looked for instances where the interactional flow was disrupted (Cobb et al., 2001; Hymes, 1972). I focused on Formulating Patterns and Explanations events and looked for the typical patterns of interaction that occurred in the lessons. I then tested the typicality and a typicality of those participant structures in Formulating Patterns and Explanations events from lessons 2 and 6 across the entire spectrum of Formulating Patterns and Explanation events from all lessons and class periods in the entire enactment (Erickson, 2006). I used the inquiry narratives and event maps to identify the set of Formulating Patterns and Explanations events for each of the three teachers.

Question 3: What are the teachers' commitments and resources for constructing a scientific inquiry community of practice?

Throughout my analysis of the three teachers' curriculum design I looked for instances where the three teachers had the opportunity to make decisions that would result in instructional activities as IQWST envisioned them. For the purpose of investigation, commitments must be inferred, and this inference may take into account the ways individuals give evidence of commitments: belief statement, intentionality to behave in a predisposed manner, and behavior related to the belief in question (Pajares, 1992). I also looked across all the lessons for teacher actions and behaviors as indicators of commitments and resources that occurred in interviews with, and field observations of the three teachers. While the video tapes and transcribed text provided the bulk of the evidence of behavior related to the teachers' commitments and resources to the IQWST design principles, I also conducted a viewing session, or stimulated recall with each teacher to identify the teachers' aims and intents during the episode (Erickson, 2006). I chose six clips to show to each teacher, and asked questions to explore their thoughts about inquiry, their role, and their personal resources. The interview protocol is in Appendix D.

Chapter 4

Inquiry Analysis

When constructing a community of inquiry practice teachers must wrestle with the problematic relationships between scientific knowledge, the learning of science, and pedagogy (Driver et al., 1994). One way of solving the problem of teaching academic objectives in school has been to separate the knowing and the doing of science (J. S. Brown et al., 1989; Duschl, 1990; Schwab, 1962). Current reform efforts (American Association for the Advancement of Science, 1993; National Research Council, 1996, 2000) have advocated another solution to the problem of achieving academic objectives by engaging students in the authentic practices of science defined as inquiry. To engage students in the authentic practices of inquiry means viewing classrooms as a community of scientific practice in which the solution to the problem of achieving academic objectives is to engage students in the authentic practices of a community that combines the knowing and doing of science where knowledge is socially constructed, validated, and communicated (Driver et al., 1994; Duschl et al., 2007; Krajcik et al., 2008).

An inquiry community of practice constructs knowledge and understanding through the coordination of science content and the science practices. IQWST curriculum has been developed around learning performances that incorporate both the body of content knowledge and the practices of the community of science (Krajcik et al., 2008; Singer et al., 2000). One important premise of inquiry classrooms is that the science explanations are grounded in actual experiential evidence that has been validated in the classroom community. The IQWST light unit has implicit expectations for how the teacher models the use of the cultural tools of science including the knowledge and practices of science. To solve this problem and create a classroom of scientific practice it is essential for the teacher to introduce new ideas or cultural tools when necessary and provide support and guidance for students to make sense of these ideas and tools for themselves (Driver et al., 1994).

In the introduction to the IQWST light unit the commitment to authentic practice is expressed as the students' construction of scientific understanding as students analyze data and use scientific knowledge to interpret that data (Fortus et al., 2005). For example, in lesson 6, students first use their experiences with mirrors to generate questions and make predictions to test what happens when light interacts with matter. Then students build connections between their experiences with light detector data and patterns by analyzing data to validate the peaked pattern which represents the law of reflection, and a flat pattern when light is scattered. Next, using these patterns and a ray model of light students construct an explanation of phenomena such as why images can be seen in a mirror and not wood. This final explanation results from a combination of using the cultural tools of data tables and graphs, the law of reflection, and the reasoning skills to develop arguments from evidence.

In the construction arena of classroom curriculum design (Remillard, 1999), teachers adapt and invent the curriculum tasks to become classroom events. In the construction arena the central teacher activity is task adaptation, the on-the-spot decisions about how to adapt the curriculum in response to students' activities. Teachers' task adaptation reveals their goals for the task and their ideas about what students' understandings of scientific ideas should be. In this chapter I describe the community of classroom practice that each teacher constructed.

For Mr. Dee, the three IQWST tasks were adapted to be grounded in experiences with experiments in the curriculum material and additional experiences. However, the practice that Mr. Dee modeled was that experiences are illustrations for the patterns and explanations. Ms Kay worked very hard to adapt the tasks so that students collected evidence from the experiences that could be used to prove the patterns and explanations. However, Ms. Kay modeled the practice of selectively choosing evidence that supports, or proves, pre-determined patterns and explanations. Ms. Cee also relied heavily on the experiences associated with the tasks. However, she did not model expert practices to help students make sense of the experiences.

First, I present the results of stage one of my analyses of the teachers' curriculum design after I coded the entire unit for 6 types of classroom events described in the methods chapter, and illustrated in appendix table A. Then, from stage two which represents the teachers' constructed curriculum with a micro analysis of lesson 6, I narrate the results through a chronology of classroom events interspersed with up close detailed description and commentary of episodes alongside transcript text. The commentary focuses on the type of science content and practice occurring in the episode. Each commentary includes: 1) the observations for each episode that I coded for the science content (experiences, patterns, or explanations in Appendix B) and the inquiry practices (represented in Appendix C); 2) a description of the teacher's reading of the task and students' performance, and their task adaptation; and, 3) a contrast with the intended IQWST inquiry practice. Following the description of each classroom is a within-case summary of the results, and the chapter ends with a cross-case summary of all three teachers' classroom practice.

Results

Inquiry in the Classroom Context

The results in Figure 1 show the enacted inquiry events that resulted from each teacher's selection and design of curriculum tasks and events.

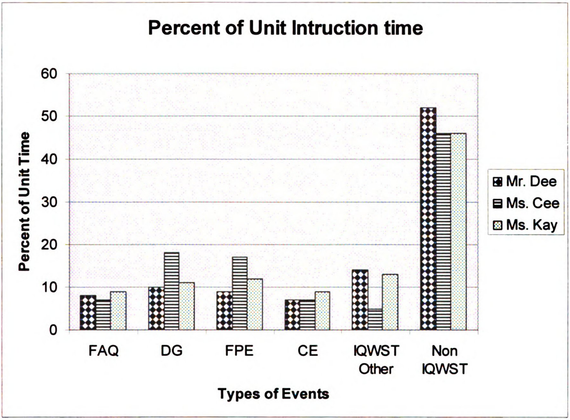


Figure 1. Enacted Inquiry Events.

The structure of events in all three classrooms included a balance of inquiry events, there was time devoted to the inquiry events of formulating and asking questions, data gathering, formulating patterns and explanations, connecting explanations. There were also other non-IQWST events such as the time teachers spent beginning each class period with attendance, or other classroom business. I have left these events out of the narrative for each lesson and focused strictly on the four inquiry events. One type of non-IQWST event that is included in the narrative are events where teachers adapted inquiry events in ways not suggested in the IQWST light unit materials. Ultimately, Figure 1 shows the teacher decisions in the realm of the design arena when teachers consulted with the IQWST materials to select and design tasks for students. What follows are the results describing how the three teachers constructed the curriculum in their classroom context. For each teacher first I present a timeline for lesson 6, and a summary of the main storyline that describes the patterns I will be developing for each teacher. Then the narrative describing lesson 6. And finally, a summary of how each teacher puts together the content and practice of lesson 6 compared to IQWST.

Mr. Dee

Mr. Dee enacted lesson 6 over two class periods. In the first class period Mr. Dee used the data from an IQWST experiment with mirrors to identify for students the pattern for how light reflects, and then the students experimented with light reflecting from paper, after which Mr. Dee again analyzed the data and explained to the students that data did not provide a good pattern. During the second class period Mr. Dee used demonstrations, and stories to explain to students the pattern for how light reflects from smooth and rough surfaces.

The key pattern in Mr. Dee's practice is that Mr. Dee sacrifices the IQWST practice of reasoning with evidence to construct a model of light and vision, and replaces it with a practice of constructing an intuitively appealing story that explains the pattern of reflection and scattering. Mr. Dee constructs this story by adding additional experiences to the curriculum in non IQWST episodes. The practice of reasoning with data is less significant to Mr. Dee because he quickly adapts the IQWST FPE episodes to dismiss the data from experiments. Instead, Mr. Dee adapts the IQWST FPE episodes to construct for the students intuitively appealing models of reflection and scattering rather than revising the IQWST light model.

Law of Reflection

Lesson 6 began on Wednesday while Mr. Dee was at a school district meeting. The class completed the experiment for activity 6.1. Mr. Dee returned to the class on Thursday and continued with lesson 6.

Once the attendance was completed Mr. Dee checked the IQWST homework from lesson 5 about shadows. Mr. Dee stopped at each student's desk to evaluate answers, and sometimes joke with the students about the quality of their illustrations and questions about the content. The following episode begins with a student comment as Mr. Dee approached the student's desk.

Lesson 5 Non IQWST episode	
Student: mine's pretty see look at my teddy bear. Mr. Dee: pretty ugly Student: Ooohhh! Mr. Dee: I'm kidding Student: I think it's beautiful Mr. Dee: yeah well why's the shadow over here? Because there's light that can get to that. Student: well it's not real accurate Mr. Dee: well then it's not pretty is it Student: uhh!	The content for this episode was coded as an explanation for a shadow. The practice for this episode is using models to explain. Mr. Dee's question to the student and his own answer exemplify his goal for students' to make a correct prediction for the location of a shadow. His response to an incorrect prediction is to immediately point out why the student's predicted shadow location is not accurate. This represents an interesting contrast to the IQWST goal for this question. The IQWST goal was to use a model developed in lesson 5 to explain the formation of shadows. From an IQWST perspective after asking the student "why's the shadow over there", the teacher practice could be to follow that question with a prompt to use the model from the experiment in lesson 5 and

	explain why the predicted location is incorrect.

Thirteen minutes into the lesson Mr. Dee finished checking the homework, and briefly reviewed the correct response with the whole class. He based his summary of the homework on the themes he noticed in the students' work. The theme from lesson 5 was the relationship between shadow size and distance from a light source. In order to clarify this theme Mr. Dee drew on the whiteboard his model of a balloon expanding as the basis of the explanation for how shadows are made.

Lesson 5 Non IQWST episode	
Mr. Dee: Now, mostly you looked pretty good on those uh those models. This is what I saw mostly. I saw a light source. With light coming out all around it. Yup. I saw an eye, OK. And then I saw some object I'll draw one that I liked fairly well… So when the light hits the balloon it's bouncing off all over, ok? Is it bouncing off this way? Is it bouncing off this way? Students: No Mr. Dee: No? There's no light getting to it if we wanted to be sure here…We can see the shadow because there is light hitting here and bouncing off, but there is no light hitting here, from this light source…But when you see a shadow like that and there's only one light source you know we can see the shadow because its that dark spot where lights not getting to, OK?	The content of this episode still is from lesson 5 but it is an explanation, the explanation for how shadows are seen. And, for the inquiry practice Mr. Dee is using models to explain. In response to the student work he had just checked, Mr. Dee's practice is to use a model that intuitively explains students' experiences with shadows. As he draws the light rays he involves the students in making predictions for where the light rays will go. He then provides the explanation for how a shadow is seen. An interesting contrast here is that Mr. Dee's practice is to have students make predictions about experiences instead of the IQWST practice that models are useful for making predictions about scientific data.

Sixteen minutes into the lesson after Mr. Dee finished going over the shadow homework he transitioned immediately into recapping what the students had completed in lesson 6 the day before. For the first five minutes he recapped with the students the experiment procedures from activity 6.1 with the mirror.

Lesson 6 Formulating Patterns and Explanations (FPE) episode	
Mr. Dee: Yesterday you did a lab, where you had something like this set up. Oh I don't remember how many there were there were Student: Bout five. Mr. Dee: It was like five, three, something like that. Ok? So this was five four three two one, and you had something similar here. What was set up right here? Student: Mirror Mr. Dee: Ok, so we had a mirror here. That's our mirror.	The content in this episode was coded for experiences from mirror experiment 6.1. And the inquiry practice was selecting/using appropriate instruments. In terms of classroom practice, Mr. Dee reviews with students the experimental procedures. This type of episode where Mr. Dee prompted students to reply about the procedural setup of the experiment was a common practice Mr. Dee used to involve students[1]. The IQWST goal is to involve students in the science practice of identifying the relationship between variables and the procedures to control variables.

Once the details about the experimental setup were settled Mr. Dee asked students to report their results for the light detector data collected from the mirror in activity 6.1.

Lesson 6 Formulating Patterns and Explanations episode	
Mr. Dee: And so in this case give me the number you guys have for number one. Student: Um, we got 177 Mr. Dee: 177. What did you get for 2? Student: Um 126 Mr. Dee: 126. Three? Student: 20 Mr. Dee: 20?	The content here is also coded as experiences because it is the data from the mirror experiment. The inquiry practice here is recording data in an orderly manner as Mr. Dee recorded the students' results on the overhead for the class to see. Mr. Dee's classroom practice was to ask the students to report their data. The

[1] Going through the procedures is one way Mr. Dee uses to increase student participation. One class period [3-15] he went through the procedures in German while the students guessed what they were supposed to do. Afterwards he told me he sometimes used German to liven up going through the procedures. The students were excited because as they came in to classroom they were talking about the rumor that Mr. Dee spoke German in class today.

Student: 20 Mr. Dee: What did you get for four? Student: 4 Mr. Dee: 4? Student: mmhmm Mr. Dee: What did you get for five? Student: 2	inquiry practice of recording data was the third most common inquiry practice occurring in the episodes. Mr. Dee adopts this practice because he values students having experiences with data. The inquiry practice IQWST valued would have been students communicating the pattern in the data they had analyzed rather than the data itself which has not yet been analyzed.

After collecting the results from one other group Mr. Dee then asked the students if they were recognizing a pattern in the data.

Lesson 6 Formulating Patterns and Explanations episode	
Mr. Dee: What kind of trend are you seeing here? If the light's at one and the sensor's at one you get your biggest value. If the light's at two and the sensor is at two you get your biggest value. What does that tell you about these angles? (no student response)	In this episode the content is the math pattern that the peak detector reading is at the same position as the light. The inquiry practice is identifying a pattern. Mr. Dee's classroom practice is to point out to students that a pattern exists. When he asks students "what does that tell you" he's modeling the strategy that patterns in data should be immediately intuitive. This is a key pattern in Mr. Dee's practice that he explains in his interview in Chapter 6. The IQWST practice of students sharing their ideas of what the pattern is and then deciding as a group what should be the valid pattern did not occur.

After Mr. Dee's question no students volunteered an answer, and so Mr. Dee used a model to represent the pattern and answer his question about the angles.

Lesson 6 Formulating Patterns and Explanations episode

Mr. Dee: Ok. I assume that you have played pool at some point not necessarily a whole game. I mean even if you just rolled the ball with your hands... If I send the ball in at this angle which angle does it bounce off? Student: Inaudible Mr. Dee: I will give you four choices, OK? Will it go here, here, here, or here? A B C D. Students: D.	Mr. Dee switched the content focus to another experience not in the IQWST curriculum. With this other experience the inquiry practice is using a model to make a prediction. Mr. Dee uses a model that is intuitively comprehensible for the students to understand the pattern for reflection. He then checks the students understanding of the pattern by asking the students to make a prediction for which angle the billiard ball will bounce off the billiard table bumper. The use of intuitively appealing models is a key practice that Mr. Dee uses in his efforts to build an explanation of reflection. Asking students to make predictions is a method that Mr. Dee commonly uses to read students' understanding, which he also talks about in Chapter 6. Mr. Dee's practice is in contrast to the IQWST science practice in which students use the data from the experiment and patterns that have been validated as a group to revise the ray model in order to describe how light is reflected from surfaces like mirrors.

After many students correctly predicted position D, one student volunteered the explanation "because this side has to equal that side." After the student mentioned the sides had to be equal, Mr. Dee came back to his example of shooting pool and ended the activity with the comment "Alright, that's the way things happen."

Reflection and Scattering

Twenty five minutes into the lesson, Mr. Dee transitioned to activity 6.2 with the announcement that the students were going to continue the lab. Mr. Dee distributed the IQWST student activity sheet and read the purpose for the upcoming experiment to compare the light detector data from the mirror with the light detector data from the paper.

Lesson 6 Formulating and Asking Questions (FAQ) episode	
T Mr. Dee: Before you get up and get any equipment let's look at this. No I said let's listen. In the previous activity you learned the rule for how light rays bounce off of a smooth surface like a mirror. In this activity you will compare the way light bounces off a mirror to the way it bounces off a non shiny object like a piece of paper. This will help you to understand why a mirror looks different from a piece of paper even though light bounces off of both. You will use a light detector to keep track of light. Ok, where it goes after it bounces off of a mirror and a piece of paper.	The Episode content is experiences with the soon to be collected data from experiment with the paper and mirror in activity 6.2. The inquiry practice is generating questions. Mr. Dee read directly from the IQWST activity sheet to establish the purpose for the task. IQWST phrased the purpose as "this will help you to understand," and Mr. Dee did not change the word "understand." The use of the word understand in this case matches with Mr. Dee's practice of using experiences that he can use to teach students about reflection and scattering. The IQWST practice of generating questions was intended to be based on students sharing their predictions of what would happen with the rest of the class. These predictions would have been based on the pattern in evidence that was validated with the pattern in evidence from the mirror experiment.

After Mr. Dee looked at a few student predictions he announced to the whole class, "Alright from what I'm seeing you guys aren't really looking at those directions. Basically they're asking you what would be the brightness of the light at one two three four and five." After Mr. Dee identified the variables in the experiment, and the students individually wrote their predictions on their activity sheets, Mr. Dee instructed the students to start the lab and turned off the classroom lights. As the students settled in to work, it was apparent though that some students were still unsure of the purpose of the data they were collecting and asked Mr. Dee for help.

Lesson 6 Data Gathering (DG) episode	
Student 1: What are we doing? Mr. Dee: What are we doing? You need to look at your little procedure if you're not sure. You're going to put your light at three, then do it with the mirror, and then the paper. (Mr. Dee walks away) Student 2: I can't even see the light at five. Student 1: Mr. Dee, come back over here please.	The content in this episode is the experiences with the light detector readings from the mirror. The inquiry practice is select and use appropriate instruments. Mr. Dee's response to the student's question indicates his belief that the task students should be engaged in is the practice of following procedures and having experiences with data. The IQWST practice would be to help students understand the connection between the data and the scientific model and refer back to the patterns in the light model and determine how the variables in the model relate to the instruments being used to collect data to test the light model.

Fifty minutes into the lesson, the students finished collecting data from the experiment, returned the materials, and returned to their seats. Mr. Dee began recording student data on the overhead. First, he asked two groups to report their data from the mirror. Then, Mr. Dee saw the pattern in the data, "Seeing a trend here aren't we? Any surprises there?" The students replied "no" and Mr. Dee moved to the light detector data from the paper.

Lesson 6 Formulating Patterns and Explanations episode	
Mr. Dee: Situation 2, paper. Ok same thing, but here we go. Ok, what did you guys get? One two three four and five for the paper. Student: Um, for the paper um 4.04 Mr. Dee: 4	The content in this episode is experiences with light detector data from the paper surface. The inquiry practices are recording data, and comparing two groups of data. Mr. Dee decided in this episode to

Student: 6 8 8 8 and 8 Mr. Dee: That's not very good data. Why is it only down in the eights there? Did you have some setting on your? Doesn't sound right. Anyway let's here what you guys had. Student 2: Us?	announce to the class that the data was not producing a good pattern. First this indicates his belief that students are not responsible for validating the data. He thought the problem may have been due to students' experimental error when he asks them about the setting on their light detector and continued to poll other groups for their data. The key point here is that Mr. Dee assumes the responsibility for interpreting the validity or usefulness of the data. The IQWST practice was intended to have the students compare the variation in the data from the paper and the mirror and decided as a class that there was a difference in the patterns which would then be the evidence for the need to revise the light model.

Mr. Dee asked the remaining five student groups to report their data from the experiment. After he polled the entire class for their data he next asked the class what setting their light detectors were on because he was not satisfied with the data.

Lesson 6 Formulating Patterns and Explanations episode	
Mr. Dee: Well this is not nearly as clear as this data up here was. What would you expect to be the place where it's going to be highest? Students: Three Mr. Dee: Three. Also we do have some tendency toward that, it's kind of like in the middle here. But it's not great data. I think our flashlights probably spread out a little much Ok? And had some problems like that. And so our data wasn't quite as good. Do you think maybe it would have made a difference to set it on a more sensitive setting on the light sensor? Students: Yeah	The content in this episode is other patterns when Mr. Dee notes that the data is not as clear, and the content also includes other explanations when he introduces the explanation that the flashlights spread the light out. The inquiry practices Mr. Dee is doing are identifying data ranges, and using models to predict and explain data. Mr. Dee has evaluated the data the class collected implicitly in his head, and decided to check if the students understood that the data should have shown a tendency toward position three. After the students used the law of reflection pattern to predict the correct position, Mr. Dee explained the reason

	for the unclear data. This was a key pattern in Mr. Dee's practice he assessed both the data from the curriculum task and the students' understanding and then he himself provided explanations and suggestions for what problems with the task may have been. He modeled the practice of intuitively making sense of the data rather than using the predictions based on the IQWST light model. The IQWST practice was intended to have the students make the claim that the data either was or was not clear data and then collectively make a decision about the quality of the data. Also, the data was clear for the IQWST purpose of illustrating light scattering.

Mr. Dee then asked the students leading questions to think of some reasons the experiment setup could have been faulty and produce this unclear data. Then, he ended the class with the claim that there was light pollution from the flashlights, informed the students they had homework, and not to get up until the bell.

Friday lesson 6 continued when Mr. Dee began the class period with his explanation for the "strange data." Mr. Dee drew students' attention to the variation in the readings between the paper and the mirror. There was a large variation in the light detector readings from the mirror, and there was a much smaller variation in the readings from the paper. Mr. Dee explained that the smaller variation in the paper data was due to the flashlight beam being too wide because some students had flashlights with adjustable beams.

Lesson 6 Non IQWST Formulating Patterns and Explanations episode

Mr. Dee: We have a couple different kinds of flashlights. We have a flashlight, and the beam is really kind	The content of the episode is an other explanation and other experiences with the wide flashlight and the laser beam.

of wide. Then we have another flashlight that might even look pretty much the same, and the beam is really, kind of straight. It's more narrow (drawing the light beams). So which is going to be our high one when we take our data? Eh? (Starring position three on overhead). And if we had a really really narrow beam like a laser, it would be like zero zero a bazillion zero zero ok? Because it's only coming in the one spot. But what if we had one that was like, boy this is really a wide beam flashlight. Well we might get things that are you know all over the place. Might still be a little brighter in the middle. Well look at the data that we got for the mirror. We got, like 17 79 84 45 and 4. Huh, that that's definitely a kind of a wide beam flashlight.	The inquiry practice is using models to predict and explain. With the use of other explanations and experiences Mr. Dee chose to draw for students a model of light rays spreading from the flashlight drawn on the whiteboard and proposed data that more significantly illustrated a "peak" pattern with the variation between zero and bazillion. With the use of the intuitively appealing example of a laser beam, Mr. Dee demonstrated the variation in the data was due to more or less focused beams of light as he begins to construct an explanation for the data. Because the data that had been collected the previous day provided the evidence that IQWST intended, the IQWST practice at this point would have been for the teacher to introduce the content knowledge by introducing experiences with microscopic pictures of paper to introduce the pattern that some materials are rough and some materials are smooth.

Nine minutes into the lesson after accounting for the difference in the range of data from the mirror and the paper due to the width of the flashlight beam, Mr. Dee initiated a non IQWST event, the Grandpa story telling event. He instructed the students to "Gather round children. Grandpa's gonna tell you a story." Once the students were gathered around, Mr. Dee used the materials from the experiment to demonstrate what scattering and reflection would look like.

Lesson 6 Non IQWST Formulating Patterns and Explanations episode	
Mr. Dee: Now let me ask you this, Student: Woah Mr. Dee: Can't you see the light right now? Student: Yeah	The content in this episode is other experiences because Mr. Dee is using the materials from the experiment as the experience rather than the data from the experiment. The inquiry practice is

Mr. Dee: Ok coming in here we could trace this thing. Let me turn it to where. Ok, we could turn this thing you know we could trace it with a pencil and show you where it's going. It's pretty clear it's hitting the paper here. It's coming out here you know, if I change the angle. Ok, so obviously if I'm going to check the light the the level of the light, if it's falling right there that's going to be the most. If it's over here it should be less because there's less light falling right in there. And the more you go, that's less less less BRIGHT less less less, ok?	using models to explain. In this episode Mr. Dee's classroom practice is again using experiences other than what was in the IQWST curriculum material. Mr. Dee dismisses the use of the students' experimental data, and instead uses the experiment materials to illustrate his explanation for the connection between the symbolic light rays and light detector data that he had just drawn on the classroom whiteboard. He is on the spot constructing another intuitively appealing example of the reflection and scattering patterns. From the perspective of IQWST practice, it is not problematic that Mr. Dee has proposed the alternative explanation that the flashlight beams have spread and caused poor data. It is a problem however that Mr. Dee has not repeated the experiment to test the predicted data that should occur if the flashlight beams width was controlled.

Fifteen minutes into the lesson, once Mr. Dee had constructed the pattern, or explanation that because flashlight beams spread they cause a large variation in the light detector data, he continued with the grandpa story telling event to model the experience of light scattering and used this model to explain the light detector data from the paper.

Lesson 6 Other IQWST episode – introducing rough and smooth	
Mr. Dee: It's like what if I had? Bring me a couple more mirrors will ya? From over there. (flashlight fell to floor) Ahhh. Student: Smooth. Student: It's still on. Mr. Dee: Ok. What if I had a mirror like this, and a mirror like this, and a mirror like this, ok? These are all three different angles aren't they?	The content in this episode is once again using other experiences. To represent a rough surface Mr. Dee is using many little mirrors aligned in different directions to represent how light would be scattered in many directions from the light. The inquiry practice is again using models to explain a pattern. In this case the classroom practice is

What if I shined it at all of them? One's coming this way, one's going that way, one's you know. Even though, say this is tight, you can kind of see one of them is coming back at me, one is going this way, and this one I don't know where it's going, but I think it's going in to that one and then coming back out. Ok, it's all over the place, because they're all at different angles. That makes sense though doesn't it? You've got all these different angles of mirrors, you should get the light going out at different angles. What if I had a million of these little tiny mirrors? All at different angles.	introducing an explanation for scattering light with mirrors. Mr. Dee's goal is to demonstrate for the students why "it makes sense" that while the law of reflection is still true, the variation in the data pattern from the paper will be less than the variation in the data from the mirror. With the few mirrors he constructs an explanation that is at first intuitive, then expands that to an imaginary million mirrors ultimately for the purpose of understanding why the strange data from the paper made sense. The IQWST practice for introducing this explanation for scattering also occurred with introduction of experiences, but with a microscope picture of paper to show the rough surface of paper.

Mr. Dee ended the Grandpa story telling event and asked the students to return to their seats. Then he continued to illustrate the relationship between rough and smooth properties of matter and light scattering or reflecting with a bouncing ball analogy.

Lesson 6 Non IQWST episode	
Mr. Dee: Ok, so that helps to explain our data a little bit. Shhh shhh shhh. I have a ball, a rubber ball, and I'm going to bounce it on the floor. Here we go, ready? An imaginary ball, you ready? Bounce it. I caught it again cause I'm really good. I bounced it. Where was I waiting for the ball? It came down here I was waiting for it up here. Guess what? If I drop it again, guess where it's going to go, right up here. I can predict that because this floor is very very smooth compared to this ball. What if instead, I brought in a pile of bricks? I made myself instead of a sandbox; I made myself a brick box. And they were just piled in	In this episode the content is again using other experiences. And, the inquiry practice is using the model to predict where a ball will bounce from a pile of bricks. Mr. Dee decided to ask students to make predictions based on the model he has constructed to explain the variation in the data from the paper. He used the grandpa to explain the data, now he's using another intuitive experience with river rocks to give students a chance to apply what they have learned. Mr. Dee simplified the situation when he focused the science content on the law of reflection pattern and asked students to make predictions for where the ball will

there every which way, can you picture that? Students: Yeah Mr. Dee: Or, big river rocks, you know like as big as your fist they're all over the place. And I dropped my rubber ball in there, where's it going to go? Student: Any which way. Student: anywhere Mr. Dee: It depends on which rock it hits, and which part of that rock it hits. What if I had? Let's make it simpler...	go from a rough or smooth light source. The difference is that where the IQWST practice asked students to make predictions about data that was collected and analyzed with the light detectors, Mr. Dee is instead asking students to apply their model and make predictions to an analogy of balls bouncing from a pile of bricks. Then the IQWST practice was intended to use the model that includes scattering and reflection to make an explanation for how a person can see an image in a mirror but not a piece of wood.

Twenty minutes into the lesson, after Mr. Dee asked students to make a few more predictions of where the ball, and then light rays would bounce he introduced the term scattering. Earlier during the grandpa story telling event he had said scattering was a possible description for what happened to the light rays bouncing from the paper but now he specifically defined the term.

Lesson 6 Connecting Explanations episode	
Mr. Dee: But now let's draw another mirror, but this time (Mr. Dee is drawing a rough surface). Student: It's broken. Mr. Dee: Ok? Alright, and we will draw our light rays coming in, draw five of them, how's that? Guess how they're going to go? Student: Every which way Mr. Dee: Every which way. This one is hitting here is going to go off this way. This one is going to probably bounce here, hit this one and come up this way. This one probably this way. This one looks like a little bit up. This one looks like it might come up this way. They're all over the place. This is called scattering.	In this episode the content is the pattern that some surfaces are rough and scatter light to eye and smooth surfaces reflect light to eye. There was not an inquiry practice. Mr. Dee's practice is to draw a representation of a rough surface, and the light rays moving off in every which way, again he adapts the task to ask students to make predictions to read their understanding of the pattern, and finally introduces the name for the pattern for how light bounces from rough surfaces. The IQWST practice in this case also used a representation to show the way light rays bounced off a rough surface and introduce the term scattering for this

Student: What's it called? Mr. Dee: Scattering.	pattern.

Mr. Dee now has explained the relationship between the type of surface and whether light has reflected or scattered. He has demonstrated that the law of reflection always holds true even though the paper and mirror data were different. He used the analogy of billiard balls bouncing off the pool table bumper as an analogy for the smooth surface of mirrors reflecting light rays. And then he contrasted this with rubber balls bouncing at random angles from a rounded surface similar to light rays scattering from the paper.

Twenty five minutes into the lesson, Mr. Dee then used the IQWST microscope picture of a piece of paper to make the connections between the experiment, the mirrors, and ball analogies in order to explain the results of the light detector readings from the paper.

Lesson 6 Other IQWST episode – introducing rough and smooth	
Mr. Dee: And this is the corner of a piece of it, can you see how if you had light rays coming uh, see if I can get this under here. If you had light rays coming in to this thing and one of them landed here it might go this way but the next one came landed over here might go back this way. This going to give you scattering. Ok? You got light rays coming in that go out all over the place. So when we look back at that paper that we did yesterday, Ok? You've got scattering because the surface is so rough compared to how small those are, how small the little	In this episode the content is both an experience with paper and the pattern that rough surfaces scatter light. The inquiry practice is an explanation that includes a scientific principle. Mr. Dee decided to use the IQWST transparency with a microscope picture of a piece of paper to show the fibers that make the paper surface rough relative to light rays. The picture is one more tool Mr. Dee used to help construct the intuitive understanding of scattering. He ends the lesson after the explanation for scattering which indicates that Mr. Dee considered his

light beams are, the rays.	academic goal for the lesson had been achieved. The IQWST practice for the end of the lesson would have been for students to use this scientific principle to construct explanations for why images can be seen in a mirror but not in a rough surface like wood

Using the IQWST model to explain images

Mr. Dee did not use the IQWST light model to explain why images are formed in a mirror but not a piece of paper or wood. Twenty eight minutes into the class period, lesson 6 ended with the definition of scattering, and Mr. Dee began lesson 7 about transmission of light by saying "Today we have to continue our activity and what we're going to do is we have looked at how light bounces off, it either bounces off or it bounces off in a scattered way but you can see that light goes through this transparency this is transparent."

Summary Mr. Dee

The academic tasks in the IQWST curriculum unit are designed with a specific sequence to structure students' authentic performance of inquiry (Singer et al., 2000). This performance perspective suggests that students construct knowledge in a classroom community that requires them to use scientific inquiry practices to construct arguments from evidence that builds on prior content knowledge. Where authentic performance of science from an IQWST perspective is engaging students in a community that constructs and validates knowledge, performance of science from Mr. Dee's perspective is a type of "nature study" (Driver et al., 1994) where the teacher organizes and makes sense of curriculum tasks for students.

Mr. Dee adopted the IQWST tasks of collecting data with the light detectors and the mirrors. However, in response to the students' encounters with the IQWST experiments Mr. Dee constructed intuitively appealing models (Lehrer & Schauble, 2000) that could explain the pattern in the data. In Mr. Dee's community of practice he introduced the content, law of reflection, with the model of shooting pool. Then Mr. Dee adopted the IQWST experiment and students collected data from the paper. However he adapted the analysis of the data when he said the data didn't sound right. In the process he implicitly analyzed the data and modeled the science content as knowledge to be explained rather than constructed. In place of the use of the ray-diagram model as a method to coordinate the experiences and patterns he added new experiences when he used mirrors as a teaching model (Gilbert & Boulter, 1998) to represent how a rough surface would scatter light, and then used students' experiences with bouncing balls off rounded surfaces to explain the connection between the term scattering and the law of reflection.

Ultimately as a result of Mr. Dee's practice of dismissing the analysis of data, and instead explaining the data with the examples of balls bouncing the nature of the knowledge that Mr. Dee constructed is that scientific knowledge is not something that is socially constructed, but instead scientific knowledge is something used to apply to the world. Mr. Dee used the IQWST experiments as a set of experiences that needed to be explained, which he then explained in the context of what students already knew from their experiences with the behavior of intuitive objects such as balls and a pile of broken mirrors. IQWST intended the experiments with mirrors and paper as opportunities for students to test their ideas and evaluate those ideas with formal scientific practices and reasoning with evidence in the context of what was previously known of the light model, and ultimately revise a single powerful hypothetical-deductive model (Duschl, 1990; Lehrer & Schauble, 2000) model in order to understand and explain more experiences.

Ms. Kay

Ms. Kay enacted lesson 6 over the course of five class periods. In the first class period Ms. Kay prepared the students to collect data for how light reflects from a mirror. In the second class period the students collected data and Ms. Kay formulated the pattern for the law of reflection with a class vote. In the third class period students collected data for how light scatters from paper. In the fourth class period Ms. Kay announces to the class that their data did not prove the scientific truth she intended to teach. And finally in the fifth class period Ms. Kay repeated the experiment to collect data that did prove the law of reflection is always true.

In Ms. Kay's community of science, inquiry is a process used to validate the content and prove that the content of science is true. For Ms. Kay the IQWST data gathering activities are an important practice of science because correctly following procedures is necessary to eliminate error and collect data that can be analyzed to prove that science content is true. Ms. Kay adapts the IQWST FPE practices. However, when the practice of collecting and analyzing data does not work because classroom science does not have the time to repeat the procedures, Ms. Kay is there to explain to the students what the data was intended to show.

Law of Reflection

On Wednesday January 18 Ms. Kay began lesson 6 with two journal questions adapted from the IQWST teacher guide, and written on the overhead: "When light reflects it ___.; and, Can you name a time when reflection may have fooled your eyes into thinking an object was there but really wasn't? Describe it." After a few minutes she asked five students to describe their experiences when their eyes had been tricked.

Eight minutes into the class period, Ms. Kay transitioned from the first five IQWST lessons that built the light model with a review of the questions that had been studied on the Driving Question Board and what the students had learned about questions specifically related to shadows. Then she distributed the IQWST parent newsletter for the second set of three lessons and read with the class the newsletter for lessons 6 through 8. The IQWST newsletter is intended to communicate with the parents about what the students are doing, and actually provided answers to the questions students investigated in lessons 6-8.

Eighteen minutes into the class period Ms. Kay distributed the IQWST student activity sheet for activity 6.1 and asked the students to read the activity sheet and answer the question, "What's the purpose of this activity?"

Lesson 6 Formulating and Asking Questions episode	
Ms. Kay: Clarence is gonna uh give everyone *The Law of Reflection* six point one. Ok lesson 6 is going to happen in three lessons. We're going to do the first portion of uh lesson six today. You guys are just going to work with individuals at your tables. Uh, once you receive your sheet put your name on it, and I want you to quietly quickly read over what it is you're going to be doing… Students: (silently reading IQWST activity sheet) Ms. Kay: Ok what's the purpose of this activity? Latrel? Student: Uh light, how light bounces off of things. Ms. Kay: Ok, so it's to show how light	The content in this episode is the experiences in the form of the materials for the experiment with the mirror. And the inquiry practice is generating questions. Ms. Kay's classroom practice is to use the student activity sheet as the source of the purpose of the activity which is to "show how light actually bounces." She has changed the wording in the IQWST activity sheet for the purpose of this experiment from "investigate and compare" to "show." The change in wording of this activity demonstrates Ms. Kay's belief that scientific activity is a process of confirmation with experiments rather than a process of collecting data for

actually bounces off things. Good.	pattern finding and model building. The IQWST intended practice is to use students' experiences with mirrors that fool their eyes to suggest a question that could be investigated in contrast to Ms. Kay's purpose for showing how light bounces.

With that one student response for the experiment purpose, Ms. Kay immediately moved to explain the procedures for completing the experiment and prepare the students for data gathering. Again, Ms. Kay used the worksheet as the guide and directed students to read the procedures.

Lesson 6 Data Gathering episode	
Ms. Kay: I want you to look at those directions silently and I want you to describe what it is or tell me what materials you need. Tell me what materials are going to be necessary. Once you find the material you can write it, uh you can raise your hand and tell us. Cameron? Student: You need two meter sticks Ms. Kay: Ok good, you're gonna need two meter sticks. What else are we gonna need? Clarence?	The content in this episode is once again experiences, but with the materials of the experiment. The inquiry practice is selecting/using appropriate instruments. The teacher's practice for data gathering is students reading and following the procedures and gathering materials. For Ms. Kay correctly following procedures is an essential scientific practice which occupied a significant amount of the classroom time (15% of episodes) in lesson 6. The intended IQWST practice is to coordinate the question generated from student experiences, with the variables and the instruments that are going to be used to investigate those experiences, as opposed to the teacher's practice of following procedures to show how light bounces.

Reading the procedures and gathering the materials continued for the next 20 minutes and 43 minutes into the class period, the students were ready to collect data. Ms. Kay announced to the students, "Ok, you may begin" and for the remainder of the class period the students collected light detector data and Ms. Kay circulated the room, and checked on the students with comments like, "Ok, so now you complete and record for the first set. So, second time around you move the flashlight, you leave it but you continue to move the light detector."

The class period neared an end after 52 minutes, and Ms. Kay reminded the students about the skate party tomorrow and where to place the materials before she dismissed them.

On Friday, class period two, Ms. Kay spent the first 15 minutes reviewing how to set up the experiment in activity 6.1, "Ok, make sure you're being careful with your positions. For example, Corbin just moved the flashlight which means if he consistently does that you'll get some data but it may not be the right data."

Once the procedures had been reviewed the students continued to collect data for how light bounced off a mirror in activity 6.1. Eventually when some students were finished making observations with the light detectors and others were almost finished, Ms. Kay announced the students should be looking for a pattern in the data.

Lesson 6 Formulating Patterns and Explanations episode	
Ms. Kay: While we're waiting on uh this group to finish, I want you all to discuss any patterns that you observed as you look at your data. So any patterns that you observed from making your recordings I want you to take a look at those and talk about any patterns that you see. I do not want you to write because some of us have some great data, some of us have soooommmmee great data BUT it could be better, OK? Because it is what it is. You observed exactly what	The content of this episode is the "V" pattern that light makes when it reflects from a mirror. And the inquiry practice is identifying patterns in data. The teacher's practice is to announce to the class that they should be identifying patterns, they should identify the pattern by talking about what they see with their group members. But more revealing is the fact that she has also announced to the students her evaluation of their data when she said "Soooommmeeee great data BUT..."

you did so we need to talk about it. So before you write, I want you to just discuss any patterns that you possibly see.	she was using the tone of her voice to cast doubt the validity of some groups readings. Ms. Kay's comment is consistent with her purpose for the lab, "to show," and the value she placed earlier on correctly following the procedures. As she has been observing the students she noted that some students have followed procedures correctly and produced the right results, while other students failed to accomplish the purpose of the experiment. The teacher's suggestion that students talk about their patterns is in line with the IQWST practice of students sharing their ideas about the patterns. However Ms. Kay's evaluation and validation of the data is premature.

After Ms. Kay's announcement to look for patterns, the students completed recording the light detector readings and talked in groups about the pattern Ms. Kay instructed them to look for then put the materials away.

Forty minutes into the class period once the materials were put away Ms. Kay turned on the overhead and asked groups to report their highest light detector readings for each position of the flashlight and light detector.

Lesson 6 Formulating Patterns and Explanations episode	
Ms. Kay: Ok good, now when we had our light at position two where did you get your highest reading? Uh Adrielle? Student: Uh, position number one. Ms. Kay: Ok position number one. If you received your highest reading at position number one I need to see your hand. So for number two, for number two our light is here, if you received your highest reading at position one I need to see your hand. Two groups,	The content of this episode is the experiences set in the data from the experiment in activity 6.1. The inquiry practice is recording data. Ms. Kay's practice was to spend much of the class time in this fashion recording the data that students had collected. Ms. Kay spent the time recording the students' data because it relates to her purpose for the data, that scientific experiments provide data which will show students how light

Adrielle's group and Latrell's group. Ok so we had two. I said people but we know two groups. So we said two people for position one anybody else?	interacts with matter. The IQWST practice is intended to ask students to share with the class the pattern in the data that they had found as a group. Based on Ms. Kay's comment that some groups had good and bad data there was a rich opportunity for the IQWST practice of students sharing different patterns and potentially as a class deciding which pattern was valid.

After all the students reported their highest readings for each flashlight position Ms. Kay pointed out a pattern

Lesson 6 Formulating Patterns and Explanations episode	
Ms. Kay: Ok so it's a little messy but I'll talk about it as we go along. So we're going to circle, this is all of our data, this is what we came up with. So we're going to circle the highest number and see if we can develop a pattern there Ok? The highest number of groups. So usually when you vote the majority wins right? Student: Yes Ms. Kay: Ok, and then we'll talk about how we all did the same activity but we possibly came up with some different data.	The content in this episode is the math pattern that there is a peak detector reading when the detector and flashlight are at the same position or angle. The inquiry practice is identifying patterns. Ms. Kay's classroom practice is to use the majority vote to establish the valid pattern which is not a practice for evaluating data and finding patterns accepted as authentic scientific inquiry practice. As Ms. Kay state's here, the data is "messy" so she decided to use a vote as the method to analyze for students the correct pattern. And her last comment about how the students possibly came up with different data relates to the ways students did not correctly follow procedures. However, this is an important episode because of the three teachers in this study, Ms. Kay's vote was the only method explicitly used for identifying a pattern. Ms. Kay talks about her "on-the-spot" decision to use the vote in Chapter 6. The IQWST practice for identifying the "v" pattern was to use the data table on the student activity sheet to show that for each flashlight position the highest

	light detector reading occurred when the flashlight and light detector were at the same angle. Now what the IQWST material did not suggest was how a teacher should direct the class in deciding which group's detector readings was evidence for the most valid pattern in the data.

After circling the vote that had the highest light detector reading for each flashlight position, and tracing out on the overhead the lines connecting the light detector and the flashlight Ms. Kay identified the pattern for the law of reflection.

Lesson 6 Formulating Patterns and Explanations episode

Ms. Kay: What do you notice? What do you notice about the angle at which our light reflected or bounced off of our mirror? What pattern do you notice? Even if you didn't get those numbers, you look at it, you voted. So we just went through we picked the highest for each one. We just picked the highest. We voted based upon the data we collected. So even if, put your hands down. What do you notice? What pattern do you notice? At position one we had our highest reading at position one. Position two we had our highest reading at position two. Position three we had our highest reading at position three. Position four highest reading at position four. What do you notice about that angle? The angle at which. What pattern do you notice? Travis? Student: That the uh light reader is in uh the same position Ms. Kay: Ok what I want you to do for homework tonight.	The content in this Episode is the pattern "v." The inquiry practice is identifying patterns. The classroom practice that Ms. Kay used to validate the "v" pattern in the data is the vote. For Ms. Kay the goal of this activity is for the students to state the pattern. She repeats her question many times, "What pattern do you notice?" She reminds the students that the pattern in data is based on their analysis with the vote. She asked one student, and when the one student replied that the pattern is the light reader and flashlight is in the same position Ms. Kay evaluated that as a correct response and successful completion of the task to prove the reflection pattern. Also she asked one student and accepted one response which illustrates a key practice of individually proving the law. From an IQWST perspective Ms. Kay did model for the students the validating of the pattern with a type of strategy for validating the data. So it is an interesting improvisation by Ms. Kay that indicates her commitment to the need to validate data. However it would

	have been equally interesting to find out whether or not the additional students with their hands raised agreed with the pattern in order to validate the pattern as a community rather than individually by the teacher.

Fifty minutes into the lesson, after Travis answered with the pattern that Ms. Kay and IQWST intended the experiment to demonstrate, Ms. Kay assigned a True/False question and asked the students to use their data from the experiment to support their answer.

Lesson 6 Non IQWST episode	
Ms. Kay: Ok so you have a true and false question that you're going to answer. The statement is, the angle, what I mean by that the angle at which light is reflected off of our mirror, is equal to the angle at which light is redirected. Is that statement true or false? If it's true, you need to use this example. What you did to tell me why. If you believe it's false, you need to use this to explain why. So, it's deeper than just a true or false question. Explain based upon this [tapping on chart on overhead] why you believe that to be true.	The science content in this episode is again the pattern "v". The inquiry practice is making a claim and using evidence to support the claim. With the True/False question Ms. Kay has changed the IQWST goal for this activity from students using the data and patterns from the experiment to represent light rays in the light model, to demonstrating their understanding that the law of reflection is true. Ms. Kay created her own summarizing question and used this question to make sure students are connecting the data from their experiments to the law of reflection. While Ms. Kay had not modeled the IQWST practice of formulating patterns in evidence or building arguments from evidence with the data tables, she is making an addition to the IQWST practice that can be seen as modeling the practice of warranting explanations with patterns in data.

After checking to see if students had any questions Ms. Kay dismissed the students.

Monday the third class period for lesson 6 continued with Ms. Kay' reference to the investigation map, "Look at the investigation map this is where I want you to go. Take a look at that, the top right section. What currently are we studying?" After a student correctly replied, "Um why can I see my reflection in a mirror but not in wood?" Ms. Kay reviewed with the class the relationship between the pattern in the flashlight position and the position of the light detector with the highest readings from the mirror.

Next she checked students' responses to the True/False journal question assigned as homework, "How many of you uh, said true to that particular statement? [Students raised hands] Ok, Very good. Yes that statement was actually true. Those angles are equal." Ms. Kay then introduced the name for the "v" pattern which is the Law of Reflection.

Lesson 6 Non IQWST Formulating Patterns and Explanations episode	
Ms. Kay: Your data proved that at position one, well once we actually calculated, did the voting and shared between groups because we know a couple of tables. We see the correct data, but your data proves this. How do you know? Why? Because I had a light detector and at each point I tested the light intensity or how much light was given off at positions one two three four five does that make sense? Students: Yes Ms. Kay: Good so that statement was true. So, If we talked about the law of reflection, what Chris was specifically saying is the angle of reflection is equal to the angle of incidence and this was originally I believe the picture of the diagram that we showed here when we pointed out our "v" shape as we collected our data for fourth hour. The angle at which light reflects off a mirror is equal to the angle at which light is redirected, true or false? That	The content in this episode is the pattern or law of reflection. The practice in this episode is that a claim requires a at least one piece of evidence. Ms. Kay's goal for this episode is to introduce the term "law of reflection." Unlike Mr. Dee who introduced this explanation with the intuitively appealing examples of billiard balls, Ms. Kay is using the "correct data" to show the students that the connection between the data and the laws of science "make sense." From the perspective of IQWST the goal of activity 6.1 was to construct the ray model of light that shows light rays interacting with a surface in a "v" pattern. The law of reflection was mentioned as background knowledge for the teacher, but not deemed necessary to introduce to students.

statement was true.

After introducing the law of reflection Ms. Kay wrote the following problem on the board and asked the students to apply the law of reflection, "If light enters at a 50 degree angle light will leave at a _____." This question didn't take to long to answer, and after a student responded correctly, Ms. Kay transitioned to activity 6.2.

Reflection & Scattering

Twenty minutes into the class period Ms. Kay distributed the IQWST activity sheet for activity 6.2, read the introduction to the activity sheet, and instructed students to make predictions, "What I want you guys to do right now is to listen carefully, the first prediction you are going to make is for the mirror how do you think the light detector reading will change as you move the detector from position one through position five."

For the next five minutes students wrote their predictions, and started setting up materials for the activity. Then Ms. Kay asked one student for his prediction, the student replied, "If you move to position three you'll get the most reading and position five will get the least all the others they'd be in between either the least or the um most." After this she asked for two more student predictions for the paper experiment.

Thirty five minutes into the class period, after sharing three predictions Ms. Kay prepared students to collect the light detector data in order to compare the paper and mirror surfaces. As part of the preparation, Ms. Kay prompted the students for the important parts of constructing data tables such as numbers and labels for measurements, and columns to record the measurements. Once Ms. Kay felt the students were ready with their data tables she told them to begin collecting data, "Any questions? Ok, you may begin. You need to to move wisely and very quickly, wisely and quickly because I want all the data collected today."

Forty five minutes into the class period the students began collecting data for activity 6.2. However, not every group had been listening about how to make data tables, one group of students began asking each other what the chart was that Ms. Kay had just drawn on the board and what they were supposed to do next. Once this particular group began collecting their data they teased each other about who knew how to draw graphs, who was afraid of Ms. Kay, and argued about how many zeroes to record from their light detectors.

Fifty five minutes into the class period Ms. Kay prompted the whole class to think about why there were different light detector data from the mirror and piece of paper.

Lesson 6 Non IQWST episode - Closing class period	
Ms. Kay: Five four guys three. Everybody just freeze for a second right where you are. I definitely want you to get your data for six point two for both. Excuse me. The mirror and the piece of paper. We're way in. Getting your data. We will compare the data tomorrow. Take a look at your data. Compare your data, and see if you can figure out or start thinking about why your numbers were different in both of those instances. If the law of reflection is true, why did you get different numbers as you tested the smooth surface and then the non shiny surface from a piece of paper? You can leave your setup exactly as it is maybe it will save us a little time next hour. Just turn off the flashlight. You guys are dismissed.	The content in this episode is the experience in the form of data from experiment 6.2. The inquiry practice here is comparing two groups of data. Ms. Kay's classroom practice is prompting the students to compare the data but not providing the specific tool or suggestion that would be used to compare the data, a graph. What is important to note here is that again the pattern, the law of reflection, is what Ms. Kay is using to make predictions and the purpose for this activity is to test the truth of the scientific law of reflection. From the perspective of IQWST the purpose is not to test a law of science. Instead, the purpose is to use the content knowledge embedded in the light model for the way light interacts with matter to compare the predicted light detector data with the observed light detector data for

	the purpose of revising the model to explain why images can be seen in mirrors but not wood.

The next day, the fourth class period for lesson 6, began when Ms. Kay assigned a journal question from the IQWST transparency 6.3 which asked students to draw how light rays would reflect or scatter from rough and smooth surfaces. After five minutes Ms. Kay asked a volunteer to share on the overhead her prediction for where the light will bounce from a smooth surface. After the student drew light rays Ms. Kay asked the class to raise their hands if they agreed with the picture. A majority of the students raised their hands. Then, an interesting moment occurred after Ms. Kay asked the class how do you know what the student had drawn is true?

Lesson 6 Connecting Explanations episode	
Ms. Kay: Ok, How do you know that this is true? How do you know that this is true? What did we do in order to prove that this is true? What activity, Travis? Student: Yesterday when you told us the light goes at specific angles because of "v" shape Ms. Kay: Ok, yeah I did tell you that, and that's absolutely correct. Did you do an activity that proved that? Students: Yeah Ms. Kay: Talk to me. Tell me. It is important. I always tell you it's about what we observe in here, reading, writing, listening, and speaking. I'm glad that you were listening to what I said, but I only said that based upon an activity.	The content is the pattern that rough surfaces scatter light and smooth surfaces reflect light. The inquiry practice is that a simple claim requires evidence. Ms. Kay's classroom practice or goal for this episode is to help the students make the connection between the picture the student had just drawn, and the lesson activity that had provided the evidence to prove the student's picture was true. However, the actual practice that occurs is a student uses Ms. Kay's claims, in this case the "v shape" or law of reflection that Ms. Kay had told them about the previous day, as part of the explanations. However, she does not accept this answer but continues to prompt the students to talk to her, tell her what they had been doing the past few days because she is committed to the practice of using evidence to prove the content of science is true.

	In terms of the IQWST practice, Ms. Kay is attempting to support students' inquiry with verbal prompts that suggest students use evidence from the experiments rather than prompting the students to use the light model as a tool to think about what evidence they had collected.

Following Ms. Kay's prompt to "talk to me," one student responded "Well we did that uh investigation the first time, we showed that the, it had made v shape." After Ms. Kay accepted this response, she told the class to finish collecting their data.

While some students finished collecting their data, Ms. Kay asked other students a True/False question to scaffold pattern finding, "Ok, true or false were the measurements near zero at all positions except position three?" Once a group answered Ms. Kay moved to another group and continued asking her True/False questions to other groups.

Eighteen minutes into the class period, the students finished collecting data for activity 6.2 and the class came back together as a whole group. Ms. Kay first asked volunteers to review the experiment set up for students absent the day before, and in the process reviewed with the class the variables being compared. Ms. Kay also asked the students to look at the Driving Question Board to focus students on the purpose for this experiment, and how the experiment helped provide evidence for how light interacts with matter. Then Ms. Kay asked groups to report their light detector data from the mirror surface.

Lesson 6 Formulating Patterns and Explanations episode	
Ms. Kay: Let's hear from you guys. Student: Uh 0.07 Ms. Kay: 0.07 Student: The second one was 0 Ms. Kay: I'm sorry sweetie?	The content in this episode is the math pattern that there is a peak light detector reading at the same angle as the flashlight. The inquiry practice is identifying data ranges.

Student: The second one was 0.00, third one was 0.26, the fourth one was 0.19, and the fifth one was 0.00. Ms. Kay: Zero point? Student: 0 0 Ms. Kay: Ok so all near 0. However they did show a larger number here [marking position three]. Ok so we had one true, for this first question, and the rest were false. Ok, our second question, was the data for position three higher or lower? And I would imagine based upon those results one group, actually two groups, only two groups had, so for two groups high, the rest were low. Ok Any questions here? You guys are just analyzing, we're just taking a look at our data. We're not even starting to draw conclusions, cause we may have some problems with our data. Ok? Analyze your data.	Ms. Kay's classroom practice is to use a True/False question to scaffold students' identification of the data range. Ms. Kay expects that students will find a larger number at position three and make the True/False question true. However, four groups found the question false So, Ms. Kay's attempted scaffold did not support the pattern finding and prove the law of reflection as she intended. Instead she told the class they would not be able to draw conclusions from the data. So in effect what is evident here is how Ms. Kay attempts to use evidence but when that attempt does not work out, she tells the students what the evidence or pattern should be. From the perspective of IQWST practice, the data in this experiment if graphed did show the type of pattern that was expected from the experiment and the data did produce a pattern that could be used to explain light scattering from the paper.

Ms. Kay continued to ask students what their light detector data was from the paper surface. She continued to use her True/False questions to help students analyze the data. She kept track of the votes from groups as an attempt to validate the decision about whether or not the questions were true or false. Eventually though Ms. Kay abandoned the attempt to validate the data with the students' votes when she asserted an explanation that included the statement "our data contradicts the laws and truths we're trying to explain."

Lesson 6 Formulating Patterns and Explanations episode	
Ms. Kay: OK now our data in this class. First hour collected data today, we didn't analyze all of their data. However, we went through these same questions today and we came out with the correct data to make everything that we've done up to this point true. Now you guys all followed the same set of directions. Um, you all collected data. We came up with data, but our data contradicts what the laws and the truths are that we're trying to explain. Ok? So bottom line, this data doesn't fit what I'm trying to teach. Ok? Does that make sense? Students: Yes Ms. Kay: Now, if you take a look at, our first um, our first two questions, that question response that we were looking for, that was a true statement. But the problem is we had one group, only one group, that came up with the correct or proper responses	The content in this episode is an other explanation. There is no inquiry practice. Ms. Kay's classroom practice is to use the laws and truths of science as the method to validate the appropriate patterns and evidence that students were supposed to have found. She is consistent in her goal to show the students that if they follow the procedures of scientists they will be able to also prove what scientists know. This is an accepted practice in the class because the students reply "yes" after Ms. Kay asks if this "makes sense." The class has now come full circle from the beginning of this class period to support the implicit classroom practice illustrated earlier when Ms. Kay asked the students "How they know" and the student replied "because you told us yesterday." The IQWST practice is also intended to teach the students scientific content, the intended content learning goal is to learn about the ways light interacts with matter. But IQWST also intended students to construct that understanding through the participation in the practices of inquiry which includes the classroom community validating the evidence rather than the external authority of science laws and truths.

And then Ms. Kay explained how the one group came up with the proper response, "and you know just grace allowed our votes to come out appropriately, however, we did not all, come up with the exact same results." Once Ms. Kay asserted that the data was wrong and grace allowed the data from one group in this class and an earlier class period to be right she asked students what were possible reasons the data was off. The students provided a number of possible procedural reasons such as the flashlight beam being wide or narrow, the edges of the rulers not being lined up, or the paper angle sheet was not lined up. After the students postulated a number of potentially valid reasons why the data was "messed up" Ms. Kay told the students what happens in the real world of science.

Lesson 6 Formulating Patterns and Explanations episode	
Ms. Kay: So all possible reasons as to why, or reasons why, our data was all over the place, or our data is not going to line up with what it is that we're going to attempt to explain before you guys leave today. That happens in science all the time, you know that's why science changes every day, we have people investigating every single day. Now in the real world, if you were paid to do this every day you probably would do the entire experiment over until get the right results. Now it just so happened, I know exactly what it is that we were supposed to see, but if I didn't know what we were supposed to see, then our data was on two different sides of the fence, so how were you supposed to explain the concept where the data did not all line up or that did not match? But we gave some possible reasons as to why that could have been. Messed up, right? Ok, let's look at um, group one's data just because it was kind of data that matches what we were looking for.	The content in this episode is an other explanation. There was no inquiry practice. This is a key point for illustrating Ms. Kay's model of science practice. It is important because here she contrasts the authentic practice of scientists with the practice that occurs in school. She establishes two points. First, scientists practice science until they get it right. Second, she knows what the valid argument is supposed to be and she will show students what data and evidence they should have finished with which continues to illustrate her commitment to a positivist view of science content. This is in contrast to the IQWST perspective of science practice. IQWST assumes that science knowledge is socially constructed in a community of validators. If students are to learn science, an important part of that is also learning how a community validates knowledge. The teacher and the IQWST materials are meant to support students in learning this process of validating and constructing knowledge in the classroom.

Forty six minutes into the class period, after Ms. Kay reviewed what the students were supposed to have found she ended the class period with a homework question essentially the same as the journal prompt at the beginning of the class period, "Think about these two pictures _ _ . Why do you think these pictures look different?"

The fifth and final class period for lesson 6 began on Wednesday when Ms. Kay demonstrated for the class the experiment from activity 6.2. Sixteen minutes into the class period Ms. Kay had collected the following data set from the mirror 0.19, 0.26, 22.43, 4.04, and 0.19. The data set from the paper was 0.64, 0.77, 0.83, 0.70, and 0.64.

Ms. Kay asked the students which positions got the highest and lowest readings, and then she asked if anyone was surprised that the readings for both the paper and the mirror were highest at position three. Some students said they were surprised and others weren't surprised. Ms. Kay asked the students who were surprised to explain their surprise. One student was surprised because, "the other ones had uh had uh like different readings and I thought that uh it would be the same." Ms. Kay asked him "what other ones" and the student explained he thought this way because the light readings from previous class periods had not always had the highest reading at position three. To which Ms. Kay responded, think back to the light detector readings from activity 6.1 which demonstrated the law of reflection, and asked the students, "Did you think about that as we were doing 6.2? Make that connection, so automatically you would think that it had the highest reading at position three right?" Then she asked "those of you that were surprised that position three had the highest reading, are you sure? Ok, now I want you to…" she went on to ask the students to explain why since the law of reflection is true, they thought there was a difference in the data for the mirror and paper. She gave the students a chance to think about it, and then began to ask groups for their explanation.

Lesson 6 Connecting Explanations episode	
Ms. Kay: Ok uh, we'll start with table two. What did you come up with? Why do you think our readings were different? Student: I think our readings were different, the difference between a mirror and paper because the um they're two different objects, the mirror is like shiny and the paper isn't shiny. Ms. Kay: Ok, so maybe we have two different readings because we have two different objects. Ok. Um one is, you said, how did you describe it? Student: Shiny was one Ms. Kay: and one was Student: was not shiny. Ms. Kay: So two different objects, two different forms of matter.	The content in this episode is the explanation that part of the light model has been revised to include how light reflects off different surfaces. The inquiry practice is using a reason that includes a scientific principle. Ms. Kay's classroom practice is to ask the student what an explanation could be. And then after that student answers, Ms. Kay focuses the classroom attention on particular descriptions of matter that were in the student's response. From an IQWST perspective, while the content part of the student's answer is acceptable, the teacher's practice of emphasizing those terms is less acceptable. For example, to support inquiry the teacher should provide opportunities for discourse among the students. In this case, the communication was between the teacher and one student only.

Then Ms. Kay returns to her purpose for this lesson and asks the students what the law of reflection is, and they state the law correctly, then she asks the students if the law of reflection applies on a bumpy surface, the students reply "no." To which she replies "Who said no? We had our light at position three right? We received our greatest reading at position three for both the paper and the mirror right? Yes, so was our law of reflection still true? Absolutely true, but why is it that we get different readings?"

She then asked students for their thoughts, and three students replied, but here is where Ms. Kay appears to contradict the very law of reflection she's been trying to prove, "if we think about what Aja just said, we have a bumpy surface. Does that mean that the law reflection of reflection is totally false? Absolutely not. But you have a bumpy surface that means light is actually [drawing scattered on overhead] going out but its doing what? Starts with an S," and the students replied "scattering."

So, apparently Ms. Kay has explained that the law of reflection is true for all surfaces, but contradicted herself when she says hedges the rule with "totally false" to include a form of reflection, scattering occurs on bumpy surfaces. Ultimately, she attempts to explain that reflection and scattering are two different ways light bounces depending on the property of surfaces.

Lesson 6 Other IQWST episode – introducing rough and smooth	
Ms. Kay: Why do we get different results on the smooth surface versus the rough surface? It has all to do with the type of surface that it is. Key word there is surface. So, when you have light bouncing off of a very smooth surface that's called reflection. When light bounces off of a rough surface that's called scattering. So my question to you Erin was do you think that smooth surfaces and scratchy surfaces yield the same type of reflection? Student: Yes Ms. Kay: Yes, why? Student: Because its still light being, light bouncing off in ways in less light is going to show up Ms. Kay: I'm not asking you if we're going to see light, but do you think that the pattern of reflection is going to be the same? Student: No Ms. Kay: No, why? Student: Because like you said it bounces off a rough surface it scatters and if when um, in terms of surface if its smooth Ms. Kay: Ok, now you did a nice job responding to me, but does that make	The content in this episode is the pattern some surfaces are rough and scatter light while other surfaces are smooth and reflect light. There was no particular inquiry practice the teacher guide suggested the teacher introduce the terms. Ms. Kay's practice was to state that light scatters or reflects from different surfaces as suggested in the IQWST teacher guide. Then she asked a student to use the terms in an explanation as a method to check if students could apply the explanations of rough and smooth surfaces to different light detector readings. However, this is a significant episode because it illustrates a breakdown in the routine when the student can not explain the different readings. Ms. Kay feels that she has explained and emphasized the key point—that rough surfaces scatter light. The student is actually pointing to the contradiction between Ms. Kay's expectation for the paper and mirror experiments to demonstrate the law of reflection, and her explanation that light bounces off the two surfaces differently. The breakdown in Ms. Kay's lesson is in contrast to Mr. Dee who provided a

sense to you? Student: No Ms. Kay: Ok, I want to help you, what, what's the in the way part? Student: Um, I don't understand the the comparison. What I don't understand is, when light bounces off of rough surface how does it compare to smooth surface?	scientifically accurate explanation for the difference in the detector readings. The IQWST practice was for the teacher to introduce these terms, but after the ideas of smooth and rough surfaces had been anchored in multiple representations with experiences from the transparencies of a microscope picture of paper, and two iPod surfaces that were smooth and scratched. Ms. Kay did use the microscope picture, but her limited understanding of the light model caused her to run into problems when she attempted to explain the difference in the light detector readings.

After listening to Erin's question Ms. Kay provided an example to help out Erin and the other students.

Lesson 6 Non IQWST episode	
Ms. Kay: Ok, think about, and Erin says that she kind of understands, but she doesn't understand why light will scatter off a bumpy surface, and I don't know if this is a proper analogy but when light bounces off a smooth surface its called reflection. When light bounces off a rough surface its called scattering. I don't know if this is um, a safe analogy. Ok, so you have a car right? Now You guys are on your way down I-75, Ok? Going south right? You guys are cruisin, you're having a good time that's a nice well paved road right? Right, you see that? Now, the further you go down going into Ohio your road goes from being (drawing a bumpy road) smooth to what? Students: Bumpy Students: Rough Ms. Kay: Bumpy. You have your car, so are you having a nice smooth ride	The content in this episode is an other experience. The inquiry practice was using a model to explain. Ms. Kay's practice is resorting to the use of a model of light anchored in students' experiences with driving on a bumpy road as a metaphor for the way light interacts with matter. She is making an on-the-spot decision when she says "I don't know if this is a proper analogy but..." in order to achieve her purpose for proving the law of reflection, with this model she is saying that the law of reflection has two different names, scattering or reflection, depending on what type of surface light is bouncing off, a smooth or bumpy surface but there is still a true law. In the process she has abandoned the use of the light detector readings as the explanation for the way light interacts with matter. In effect she has used the road analogy similar to the way Mr. Dee

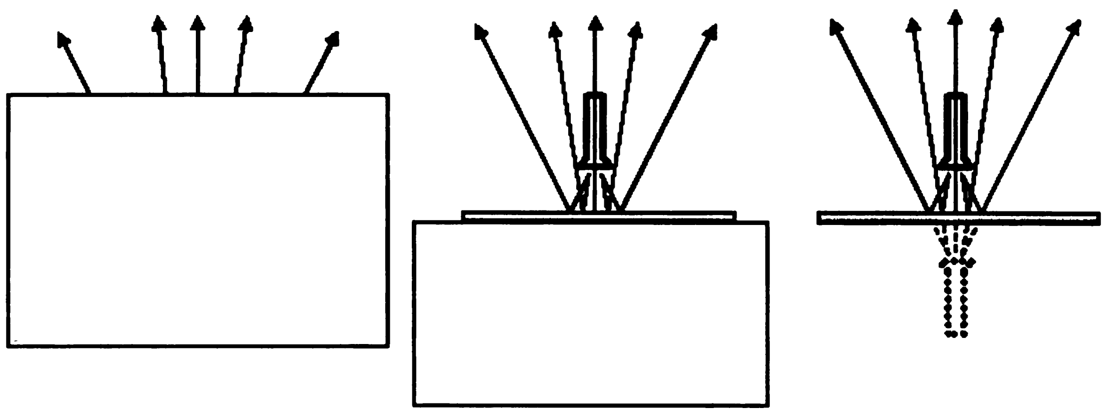
Trevor? Nice? No. You're going, right? Can you see that on the road? Does that make sense? So when light hits or enters a smooth surface its kind of smooth sailing (drawing V's off road surface) equal equal. But now, we have a rocky road here (drawing scattered light rays), so its still going to reflect, but you got more bumps, so lights going to go in more directions. Yes no? Students: Yes	used the bouncing balls analogy. However, where Mr. Dee abandoned the data early in the lesson, Ms. Kay continued to attempt to use the data until the very end of lesson 6 when it was evident that her attempts to prove the law of reflection with the data had failed. The IQWST practice was also intended to use experiences and a model, but those experiences were the microscope picture of paper, the iPods, and the IQWST light model.

Following the road explanation Ms. Kay asked Erin if she understood and Erin replied yes. Ms. Kay also commented that Erin's question was an excellent question and probably helped other students who didn't speak up and ask a question. After Ms. Kay asked the whole class one more time if they were sure they understood, she moved to the final activity of lesson 6.

Using the model to explain images

Thirty five minutes into the class period Ms. Kay used the IQWST transparency 6.4 (Figure 2) that was intended to provide an opportunity for students to apply the light model in order to explain why images can be seen in mirrors, but not in wood.

Show students the top half of transparency 6.4 by blocking out the bottom with a sheet of paper. Tell them that the rays represent light leaving a flashlight that is somewhere underneath the paper, and ask them to predict the location of the flashlight.



Transparency 6.4 Shown with the paper covering the bottom half, covering the mirror image only, and with the paper removed showing the mirror image.

Figure 2. IWST Transparency 6.4.

Lesson 6 Formulating Patterns and Explanations episode	
Ms. Kay: Ok. If I put this particular picture (Figure 2), show me the direction of my light source. Where is my light source point? Where is my light source point? So you guys see, I have those representing light rays coming up. Show me the direction of my light source. If you believe my light source is like this (holding up a flashlight) I want to see your hand. And I'm giving you options. We're going to give four options, so do you think my light source is like this (up)? Like this (to left)? Or like this (to right)? Or like this (down). Ok? Students: Yes ... Ms. Kay: Why do you think my light source is like this (up)? The ninety nine point nine percent of you. Cameron?	The content in this episode is the experience with images formed in mirrors. The inquiry practice is using models to predict or explain. Ms. Kay's classroom practice is also having students make a prediction. She has at this point spent a lot of time attempting to prove the law of reflection with the evidence from the light detectors, and finally explained it with her model. Now, she has adapted the IQWST task by giving students four choices for what could be causing the light rays on the transparency. However, the majority of the class answered wrong. But consistent with her practice, she asserts to the class that Travis's response is absolutely correct and that the rest of the class was wrong because they didn't have enough of the procedural details to answer this

Student: because the arrows are straight up. Ms. Kay: Because the arrows are going straight up, right? Student: yeah Ms. Kay: Ok why? Anybody else disagree? Well a ton of you raised your hand, you guys agree with his point? Ok how many of you picked here (down)? Travis, why do you think my light source is there? Student: Because if it were pointed down it could have been reflected and came back up. Ms. Kay: Did everyone hear that? Students: hmm hmm Ms. Kay: Absolutely correct. Students: Ohhhh Student: inaudible Ms. Kay: And if you're making connections between surfaces and angles you tell me details. That's the problem, if I don't give you all the factors you can't come up with the answers. So you tell me details. You ask me questions.	question, but if they had talked to her, and asked her for details they would have been able to answer the question. The IQWST practice was intended at this point for students to use the model that had been revised to include scattering and reflection in order to apply that model and make a prediction for what caused the light ray arrangement on the transparency. I actually think this is a faulty task in the IQWST material that doesn't really serve the purpose of students applying the model. However, Ms. Kay has chosen to adopt the task and repair this faulty IQWST task with her own practice of asserting to the class the answer because she knows the necessary details.

After this assessment and 40 minutes into the class period, Ms. Kay began to summarize and end lesson 6. She reviewed what had been covered in all six IQWST lessons up to this point, and specifically what students were to have learned from lesson 6.

Lesson 6 Other IQWST episode	
Ms. Kay: Ok., so scattering and reflection is determined by what? The type of what? Pat. Student: Surface. Ms. Kay: The type of surface we had. According to the law of reflection what two angles are equal? Taylor? Student: The angle at which light	The content in this episode is the pattern that the some surfaces scatter light and some surfaces reflect, and the law of reflection. There was no inquiry practice. Ms. Kay's classroom practice is to emphasize the content that had been learned in the lesson by asking students

enters Ms. Kay: And the angle at which light enters is equal to the angle at which light is reflected or comes off. Does that make sense? Student: Yes Ms. Kay: I don't know, we'll see. Um, Joi is going to give you all lesson 6 reading.	to state the terms. Her goal for this lesson was for students to identify two forms of matter that cause light to scatter or reflect, and define the law of reflection. The IQWST practice for ending the lesson was to have students use the light model to explain an answer to the question that contextualized the lesson, why can I see an image in a mirror but not a piece of wood? Then to use the next question on the Driving Question Board as a purpose to continue investigating and revising the light model.

After Joi had distributed the homework from lesson 6 Ms. Kay dismissed the students.

Summary Ms. Kay

Ms. Kay read the IQWST curriculum tasks and responses to the students encounter with the tasks from a traditional perspective of classroom science, a tradition that uses laboratories to allow students to verify a concept (N. W. Brickhouse, 1990; Roehrig & Luft, 2004), but when the verification failed the explanations were asserted with a "rhetoric of conclusions" (Schwab, 1962). Her traditional aims and practices were evident when she said "I know the laws and truths," and "if we were paid to be scientists we could go back and do this right."

A significant amount of Ms. Kay's teaching practice was devoted to making sure the experiment procedures were followed correctly. She also spent a lot of her effort analyzing the data and asking the students to think about "How do you know?" Ms. Kay valued the experiences in the form of data from the IQWST experiments, because the verification of science is an important academic goal for her. She wants her students to be able to reason for themselves and make connections between the experiments and the explanations, and not just accept what she told them the day before. However when the data didn't fit what Ms. Kay expected she used non inquiry reasoning strategies to make the data prove the content. Ultimately, in terms of the content of the lesson Ms. Kay emphasized experiences and patterns rather than the construction and revision of the IQWST light ray-diagram model. Rather than using the scientific practices of identifying patterns in evidence with charts and graphs, Ms. Kay created non authentic scientific inscriptions and reasoning strategies with the votes and True/False questions for the purpose of proving laws and scientific knowledge, versus the IQWST practice of a community that reasons with data and models to construct understanding of scientific knowledge.

Ms. Cee

Ms. Cee enacted lesson 6 in three class periods. In the first class period the students collected data for light bouncing from the mirror. Then in the second class period, without first formulating the law of reflection, the class collected data for light bouncing from the paper. In the third class period Ms. Cee led students to the definition of scattering and reflection.

In Ms. Cee's community of science practice the process of completing the experiments will enable students to investigate and express their own ideas about scattering and reflection. For Ms. Cee, the key pattern of practice is the process of doing science which means investigating with the experiments and sharing ideas after the experiments. The IQWST practice of formulating patterns in the evidence is not an essential part of constructing scientific knowledge in Ms. Cee's classroom.

Law of Reflection

Wednesday April 26 Ms. Cee began lesson 6 with the question from the IQWST teacher guide, "Alright so today we're going to talk about light and what happens when it hits an object. Have you ever had something that kind of hit an object and it kind of tricked you in way?" Students replied with experiences when riding in a car on the highway and seeing another car's wheels apparently rolling backwards, or moments when it looked like there were puddles ahead on the road. Ms. Cee commented that these were interesting experiences, but never returned to them to either use them as ideas to be tested, or explained at the end of lesson 6.

Two minutes into the lesson Ms. Cee told students what they were going to be doing today in class.

Lesson 6 Formulating and Asking Questions episode	
Ms. Cee: Cool. Ok so what you're going to do today is, we're going to study how light bounces off a mirror. Ok? What happens when it bounces off a mirror?	The content in this episode is the experiences with mirrors. The inquiry practice is generating questions. Ms. Cee decides the purpose for lesson 6 is to "study" light. Note the difference between Mr. Dee's purpose, "to understand" and Ms. Kay's purpose "to show." This difference will be explained in Chapter 6. For now it is important to note that Ms. Cee does not adapt the IQWST investigation to the student's experiences, nor does she return to the students experiences later in the lesson. Instead we begin to see Ms. Cee's emphasis on science as a process of study. The practice in Ms. Cee's classroom becomes a task to complete, as she often says "git er done." The IQWST goal is to use students' experiences as ideas to test, and ultimately return to those ideas and explain them with the model that is

	constructed by the class.

Following the introduction of the question to be investigated, Ms. Cee distributed the IQWST student activity sheet 6.1 with the procedures for the experiment and spent the next 15 minutes explaining how to set up the experiment with interactions similar to the following episode.

Lesson 6 Data Gathering episode	
Ms. Cee: Ok. This is what your setup is going to look like. I made this transparency so that we could figure out what was going on. Do you see how this is like a wall right here? Students: Hmm hmm Ms. Cee: And this is a flat surface. Ok? Everybody got that part? Students: Hmm Hmm Ms. Cee: Ok. So what you're going to do is, each group's going to get two rulers. To one ruler you're going to tape your light sensor and to the other ruler you're going to tape your flashlight. Ok? Students: Hmm Hmm.	The content in this episode is the experience with the materials of the experiment. The inquiry practice is selecting/using appropriate instruments. Ms. Cee's practice for the task is to focus exclusively on the process of data collection. Her strategy is to read through the directions with the students. This focus on following the procedures was a similar pattern among all three teachers. In contrast, IQWST envisions the inquiry practice here to be identifying the relationship between the variables of flashlight position, light detector position, and reflecting surface, and the use of the experiment instruments.

Twenty minutes into the lesson, Ms. Cee instructed the students, "Now you may find your spot and start getting set up," and the students began collecting data. As the students moved to their spots and began collecting data, there was a lot of confusion with the instructions on the student activity sheet 6.1. Ms. Cee moved around the room answering groups' questions about how to set up the experiment. As time went on, frustration became evident in both the teacher and students' voices.

Lesson 6 Data Gathering episode

Ms. Cee: Go ahead, what now?
Student: Then it says without touching the meter stick with the flashlight rotate the meter stick with the detector around on a point where all the lines meet on the point of the paper to find the position at which the reading.
Ms. Cee: Right. Now here's where you're going to do that.
Student: Well it says to do that with the one that has the meter detector.
(Ms Cee reading the directions)
Ms. Cee: You do that first, find out where the light detector it's the biggest number OK? And then draw the orientation of the two meter sticks. Draw what it looks like right there. So, till you find brightest spot and then you show me where the meter sticks are on here. Ok?
Student: Ok.
Student 2: Ok if you said we got to put it like that how do we hold that up? (sounds like a lot of attitude)
Ms. Cee: Part of this has to be flat, on the ground, or on the table. (said with some frustration in her voice)
Student 2: Oh, Ok.

The content in this episode is the experience with the materials for the experiment 6.1 with mirrors. The inquiry practice is selecting/using instruments.

Ms. Cee's goal for the task is for the students to successfully follow the procedures. The students had difficulty interpreting the procedures and Ms. Cee's response was to read and interpret the directions herself to make sure that she and the students knew what to do. However it was a common occurrence that Ms. Cee's strategy of adhering solely to what was printed in the IQWST materials was not effective because both she and her students often indicated their frustration.

Whereas the IQWST practice would expect the teacher to scaffold and inquiry support by making the connections between the variables, the instruments, and the question more explicit for the students since the activity sheet procedures were difficult for the students.

Thirty five minutes into the lesson, two students thought they had finished recording the light detector readings but when Ms. Cee asked them if they had done part two of the experiment the students replied, "oh, no." As students continued to ask Ms. Cee about the experiment it was clear that the students were focused on completing the procedural aspects of completing the data gathering.

Forty minutes in to the lesson near the end of the class period, some students had finished making the light detector readings and asked Ms. Cee for help to answer the last question on the activity sheet, the question is italicized in the following episode.

Lesson 6 Connecting Explanations episode	
Ms. Cee: I don't know if there's enough help in the world for you bills. Ok, *the diagram below shows the light rays as they leave the source,* ok? *Some light rays will hit the mirror shown in the diagram. Based upon what you've learned in this activity and how light bounces off a mirror, use the ruler to draw the path each light ray will take as it bounces off the mirror.* If the light hits there what path is it going to take? Student: It's probably going to hit there and go. Ms. Cee: Right. What about this one? Student: It's going to go that way. Ms. Cee: What's this one going to do? Student: It's going to go that way and this one's going to. Ms. Cee: That's what you got to do is draw those on there. Student: Ok, so we use the ruler? Ms. Cee: Yeah. Student: Ok	The content in this episode is the "v" pattern for light reflecting off a mirror. The inquiry practice is using models to predict where the light rays will bounce. The question the student is trying to answer is the last question for activity 6.1, and was intended to be answered after the teacher and class had collaborated to identify a pattern in the light detector readings. However, Ms. Cee decided to help the student answer this question now. Also, her strategy for helping the student is to simply read the question and focus the student's attention to one light ray at a time when she asks the student "if the light hits there…" For Ms. Cee the discussion related to "based upon what you've learned..." is not important because the student correctly draws where the light ray will go after bouncing off a mirror. For Ms. Cee the purpose for activity 6.1 is complete, the student successfully drew light rays in the "v" pattern. Ms. Cee does not see the use of data or patterns in data as an important part of the science process, her conception of evidence is discussed more in chapter 6. The IQWST practice intended before students answered this question to come back together as a class and see if the class noticed a pattern. A key point here is that there were class activities in between the data gathering and using the model in the last question from activity 6.1 that were not completed as a class to validate patterns and evidence.

Forty five minutes into the lesson, Ms. Cee announced "What we're going to have to do is we're going to have to shut things down for a minute alright? Since it's the end of the day, not to forget that we will be picking this up tomorrow." The students then packed up and put the materials away for the day.

Reflection & Scattering

Thursday morning Ms. Cee decided to use the social studies time as additional time for science. She began class with the announcement, "So this morning we're going to continue on with our 6.1 6.2 labs, OK?" The students asked a few questions about where to turn in their homework. Then Ms. Cee gave a few instructions about where materials were located, asked if the students had any questions, and sent the students to their task with the following statement, "Anything else? Ok. So, git her done."

Two minutes into the class period the students were up and moving about the room, gathering the materials for finishing experiment 6.1 with the mirror as the reflective surface. Ms. Cee did not have a discussion with the class about the results from experiment 6.1 before the students continued with experiment 6.2.[2] Those students that finished experiment 6.1 the previous day started experiment 6.2 with the paper as the reflective surface. The students' apparent confusion with how to do the experiment continued from yesterday because Ms. Cee was very busy checking on each groups' progress separately.

Twenty five minutes into the class period Ms. Cee recognized students were finished recording data for the paper in experiment 6.2 and told them to return to their desks and work on completing the activity sheets, "I would like you to, you've got your readings,

[2] In the interview with Ms. Cee she stated she organized the lesson this way because since the students already had the materials she didn't want to interrupt the process of completing the experiments.

continue working, and what we're going to do is when we come in this afternoon for science we're going to go over these two and then we're going to wrap it up with one more experiment."

Twenty nine minutes into the class period, as the groups worked on finishing the student activity sheet a critical incident occurred when one student initiated a question about the homework the student had been completing the night before.

Lesson 6 Formulating Patterns and Explanations episode	
Student: I have something to say about that homework When my mom read that paper that you told us to take home, she said that light doesn't bounce off rough surfaces. Ms. Cee: Did you try it? Student: No, because the only brick wall we have at home is our entire house, and I wasn't (inaudible). Ms. Cee: ok	In this episode the content is an other experience not in the IQWST curriculum. The inquiry practice was evaluating and comparing the IQWST model with his mother's explanation. Ms. Cee's decision about how to resolve this student's alternative idea was to ask the student if he had tried it. Her suggestion to the student to "try it" emphasizes her goal to prioritize the procedural process of science. Her practice is to ask students questions that prompt action, but do not give away the explanation because she wants students to construct and test their own explanations. In contrast to Mr. Dee and Ms. Kay, Ms. Cee does not use a model of any type to explain to the student why light does bounce off brick walls. From the perspective of IQWST Ms. Cee's practice could have been to refer back to the data that had been gathered in the experiments as evidence that light does bounce off rough surfaces.

Shortly after this discussion with the student, the rest of the students began turning in their activity sheets. Ms. Cee announced they would continue with this lesson in the afternoon and the class period ended after 31 minutes.

Thursday afternoon class period began when Ms. Cee asked the students about the patterns they had noticed in the experiments, "Oh you just sit right there, that's good. Bout ready? Obeekaby. What patterns? When you were doing your experiment with six one, what kind of patterns did you notice?" Ms. Cee then asked a few students about the patterns they noticed. In contrast to Mr. Dee and Ms. Kay, she did not ask the students to report the light detector data that had been collected. Instead after two students identified other patterns, Ms. Cee prompted a student to share with the class what he had noticed the previous day.

Lesson 6 Formulating Patterns and Explanations episode

Ms. Cee: Ok, one two three four five. Ok, so you noticed the brightest light when the flashlight was in what kind of a shape? You said it yesterday.
Student 1: Uh v
Ms. Cee: In a v shape
Student 1: Yeah
Ms. Cee: Right?
Student 2: All of them are v's practically.
Student 3: But like
Ms. Cee: That's true
Student 4: But
Student 3: At every angle
Ms. Cee: That's true
Student 3: The closest v shape.
Ms. Cee: The closest v shape. But they were all v shapes right? So that's when you were dealing with mirror, the light would make a what shape?
Student 3: A v shape
Student: v
Ms. Cee: And you found that the maximum amount of light was always. Always came about when this v shape was?

The content in this episode is the "v" pattern that is found with the light detector readings from the mirror. The inquiry practice is identifying patterns.

Ms. Cee's goal for this task was for the students to identify the "v" pattern in the data they had collected. She asked students for the pattern they saw until finally she called on a specific student who had mentioned the "v" shape the day before. For Ms. Cee it is important for students to come up with their own ideas and identify the pattern. As a result, she does not introduce the pattern herself, but calls on the student who she knows has identified the pattern. However, the underlying evidence for the "v" pattern is never introduced because Ms. Cee has achieved her goal of engaging students in the process of science and then directing students toward identifying the pattern just to make sure they're getting the right answer according to the IQWST teacher guide. What is also important to note is that unlike Mr. Dee and Ms. Kay, Ms. Cee did not distinguish between the variation in the data from the paper and mirror. This failure to distinguish the

	difference becomes an issue later when students' argue about what is a smooth or rough surface. The intended IQWST practice for identifying the pattern was to notice in the data that there was a peak in the light detector readings when the flashlight and light detector were at the same angles with respect to the reflecting surface.

Then Ms. Cee asked the students to apply what they had learned about the "v" shape. She asked the students what happens to a light ray when it hits the mirror at a 45 degree angle, and when the students replied it bounces off at 45 degrees, she summarized what the class had learned, "So we found out a couple things here. We found out that it likes to make a v shape, and we found out that we get the maximum when both of them are at the same angle, right?"

Four minutes into the lesson once the "v" pattern had been formulated without examining the mirror and paper data, Ms. Cee introduced the concepts of rough and smooth surfaces.

Lesson 6 Other IQWST episode – introducing rough and smooth	
Ms. Cee: Ok, now. Let's think about something else here. Lets look at uh what happened to the rays in six one, and to rays that happened in six two. You had two different surfaces there didn't you? The mirror surface was more of a what surface? Student: a surface that reflects light Student: shiny Ms. Cee: was a shiny surface and it was what? (pointing to student) Student: one that got like light bounced off a lot more. Ms. Cee: It bounced off a lot more,	In this episode the content is the pattern in matter that there are rough and smooth surfaces. There was no inquiry practice. Ms. Cee's goal for this task was to introduce the explanation for the different behavior of the light rays bouncing from the paper and mirror. Ms. Cee continued to use her practice of verbally leading students to produce the answer, although in this case she had to introduce the terms "smooth" and "rough" to be used in the explanation. This contrasted with Mr. Dee who

and we might call if we were going to say rough or smooth what would we call it? (eye contact with student) Student: smooth Student: smooth? Ms. Cee: we call it a smooth surface. And the paper was more of a? Student: Smooth Student: Rough Ms. Cee: Rough surface right? Student: It is? Ms. Cee: Ok. So, if we look at this, ok.	introduced the difference with intuitively appealing examples of rough and smooth, and Ms. Cee's example of a bumpy road. When the student asks "it is?" after Ms. Cee has achieved her purpose of directing students toward the idea that the paper was rough, unlike Mr. Dee or Ms. Kay she continues to move on with the lesson because the answer from the teacher guide has been produced, and the process can continue. In the IQWST teacher guide this was meant to be an opportunity when the teacher would introduce the terms of rough and smooth, with additional experiences such as a microscope picture of a piece of paper to demonstrate the rough surface.

Now, after only five minutes into the class period Ms. Cee had formulated the "v" pattern of the law of reflection and introduced the explanations for scattering and reflection depending on the types of surface that light bounces off. Next, Ms. Cee began the activity to introduce the terms "scatter" and "reflect" with the IQWST transparency of rough and smooth surfaces.

Ms. Cee asked a volunteer to draw the paths of light that would be expected to bounce from a smooth surface. When a student drew the all the light paths from the smooth surface with "v" shapes, Ms. Cee asked the class if anyone disagreed with the drawing. When the class all agreed the drawing was correct, Ms. Cee said "good" and asked for a volunteer to draw the light path from a rough surface.

The first student did not draw uniform "v" shapes and instead drew light paths in random directions after hitting the surface. Ms. Cee asked the class if they agreed with this, and students replied no. Then Ms. Cee asked other volunteers to draw what they thought was the correct path of light from the rough surface on the same transparency. The second student drew light paths that zigzagged in the air, the third student drew light paths in the same "v" as from the smooth surface, and the fourth student drew light paths bouncing back off the surface in the same direction. After the four drawings were completed on the same transparency, the end result was one picture with many scattered light paths bouncing off of the rough surface in random directions. The following episode shows the end of this sharing and drawing activity after which one student recognized there were four different theories and Ms. Cee's response to the different models.

Lesson 6 Connecting Explanation episode	
Student 1: Four different theories that's a lot of theories. Ms. Cee: However, we did have four different ideas but its going to end up pretty much in way we want it, and I'll tell you why in a minute. Student 2: Its going to go everywhere cause it shines more Student 3: Cause it goes everywhere Student 4: Cause its a brighter light, because it doesn't reflect as much Ms. Cee: Well, wh Student 1: That's why I put a little squiggly in mine because it Ms. Cee: It does what? It? Student 1: It spreads Ms. Cee: Spreads, Another word for that might be? Student: Everywhere Student 1: Separate Student: 5 Explodes Ms. Cee: Scatters? Students: Scatters Ms. Cee: Scatters.	In this episode the content is an explanation not in IQWST, and there was not a specific inquiry practice. Ms. Cee read the students' performance of drawing the scattered rays as a success because the students' drawing was similar to the drawing in the IQWST teacher guide. More about Ms. Cee's sense of success will be discussed in Chapter 6. She was about to continue her practice of moving on through the lesson, but the students were not willing to wait for "in a minute" and they proposed explanations. For Ms. Cee though this is not a problem, because students are coming up with ideas, and she uses this as an opportunity to "direct" students toward producing the answer when she asks students for what light does and eventually introduces the term ending in a question, "Scatters?" and when the students repeat scatters she has again achieved her purpose of directing students toward the appropriate content. From an IQWST perspective the appropriate practice would have been to

	validate the explanation for the drawing by connecting the drawing for scattering on the overhead to the pattern of even light detector readings from the paper and mirror experiment in activity 6.2.

Then Ms. Cee also took a moment to go back to the first drawing and introduce the term "reflecting" for when light bounced off smooth surfaces like the mirror.

Lesson 6 Connecting Explanations episode	
Ms. Cee: So we notice that when we've got the mirror, it goes down [pointing to the top picture in Figure 3] should be straight, reflects off and, Oops, I gave it away, eh, it comes off there and we call that reflecting cause its like the exact thing isn't it? Student: Hmm Hmm Ms. Cee: Same angle reflecting off. But, here [bottom picture Figure 2] it just goes willy nilly. It's all what? Student: Everywhere Student: Scattered Ms. Cee: Scattered, so it's scattering. So when we have a rough surface we have scattering. When we have a smooth surface we have reflection. Do we understand that? Any questions about that?	In this episode the content is an explanation not in IQWST, and there was not a specific inquiry practice. Using the two pictures in Figure 3 that the students had drawn, Ms. Cee has reached her goal of directing the students toward producing the explanation for the difference between scattering and reflection. Also, what is revealing in this episode is the "Oops, I gave it away." This mistake further indicates her goal that in inquiry the students should produce the correct conclusion. In her interview in Chapter 6 she talks more about her sense of success and failure in this episode. From an IQWST perspective the appropriate practice would have been to validate the explanation for the drawing by connecting the drawing for scattering on the overhead to the pattern of even light detector readings from the paper and mirror experiment in activity 6.2.

Using the Model

Thirteen minutes into the lesson, Ms. Cee distributed the IQWST student activity sheet 6.4, and introduced the activity by reading from the activity sheet, "In this activity you will use a model of seeing, the model of seeing, to explain why it is possible to see an image of yourself in a mirror, but not in a piece of wood, ok?" Next she reviewed with students the four conditions necessary to see an object that had been developed in previous lessons. Once the conditions had been reviewed she showed students the IQWST transparency 6.4 (see Figure 2), and asked students to predict where a flashlight would be to make those light rays. After students made their predictions Ms. Cee revealed the location of the flashlight, and many students responded.

Lesson 6 Connecting Explanations episode	
Ms. Cee: Well let me just, now remember this is our eye, remember what we said about seeing, so let me just show you a little bit more here. Students: Aahhhh student: Cheater, there was a mirror Ms. Cee: Cheater? [laughs] I don't think so. Student 1: You can see the light, you can still see the light if its coming right at you. Student: You didn't tell us there was a mirror there. Students: Yeah Ms. Cee: Now Student: You gotta be kidding me Ms. Cee: Now, what happened? Student: It reflected Student: Yeah Student 1: But I still think ours is right Student: It reflected Student 2: [to student 1] Yeah because it can go up and you can still see it. Student: You cheater Student: Is it how that looks up there? Student 2: So I think that my thing is still right Ms. Cee: Ok, that explains why (Ms. Cee revealed the third part of the transparency)	The content in this episode is students' experiences with images in mirrors. The practice is using a model to explain the experiences with images in mirrors. Ms. Cee's classroom practice was to follow the instructions in the IQWST teacher guide for what to show the students. When the students saw the actual location of the flashlight, they were disturbed and many students spoke out of turn, called Ms. Cee a cheater, and proposed their own explanations. Ms. Cee values the explanations with her laugh, because along with her aims for science, students are participating in the process and expressing their own ideas. In the end Ms. Cee still does not personally explain the answer, but allows the IQWST transparency to "explain why" to the students what their drawing should have looked like, but doesn't have them redraw the correct position of the flashlight. The IQWST practice here was intended for students to use the light model to explain the arrangement of light rays on the transparency. One problem with the IQWST activity itself was making the connection between this two dimensional model on the overhead and students three dimensional experiences with mirrors, and Ms. Cee

	didn't know how to resolve the multiple student claims about what was really going on in the diagram.

Ms. Cee pressed on with the activity, the next diagram is meant to illustrate what happens when light scatters off a rough surface like a piece of wood. And this time the students anticipated being tricked by the diagram. But once Ms. Cee reveals the answer for the diagram she attempts to conclude the lesson with an explanation for how people see.

Lesson 6 Formulating Patterns and Explanations episode	
Ms. Cee: So what does that tell you about the way that we see? Student 1: We see scattered light Ms. Cee: Ok, and what about a reflection? Student 1: We see reflected light. Ms. Cee: We do when we're, the smooth, like a mirror or that type of a surface. What if I had something like um, uh, a silver Student: Piece of plastic Ms. Cee: iPod. The real shiny silver. Is it sometimes we get a reflection in that? Student: yeah Ms. Cee: Smooth? Student: hmm hmm Ms. Cee: Ok. Ok. Student 1: But you don't get. You don't get reflection in all smooth things. Student 2: Yeah cause this is smooth (touching the side of the overhead projector) Student 1: You don't get reflections on paper. Ms. Cee: That's [referring to overhead projector] not smooth [laughs]. Student 2: It's smooth [touching overhead again].	The content in this episode is students' experiences with images in mirrors and wood. The practice is using a model to explain the experiences with images in wood. At this point Ms. Cee was just about to wrap up the lesson, she had used the smooth shiny iPod as an example to explain that images can be seen in smooth objects, but then the student challenged this claim that all smooth things make reflections. Now at the end of the lesson a significant breakdown occurs because the students are proposing ideas, which normally is an encouraged activity in Ms. Cee's classroom, but at this point she's already directed students toward the appropriate content with the iPod example that we see reflection in smooth objects. When the students challenged the definition of what was smooth Ms. Cee did not have an answer from IQWST to direct the students toward. With the interruption at the door she was able to suggest to the class that the process of the lesson continue and students could finish the activity sheet on their own. So in effect, the content issue was never resolved.

Ms. Cee: It's not smooth either. Ok, we'll talk about that. Student: Smooth things are like glass and stuff, like glass. Student: Glass you can see reflections off sometimes. Student: Is paper smooth? (a knock at the classroom door) Ms. Cee: Um, yup. Ok um finish up your conclusion on there, and then you have a reading assignment up there to work on.	For Ms. Cee, unresolved content was not a problem because her aim for authentic science is to provide students with experiences in the process of science and opportunities to express their ideas. The IQWST inquiry practice for resolving what was a very teachable moment to model building arguments from evidence would have been to go back to the data with both the mirror and the paper which felt smooth, there were different patterns in the data, and since the paper felt smooth, the sense of touch was not a valid criteria for defining a smooth surface that reflects light. The IQWST material did not support Ms. Cee in making sense of unintended student claims, and Ms. Cee did not have the personal resources to formulate an argument that would make sense to students.

Twenty seven minutes into the lesson as the students are working on the reading assignment, Ms. Cee moved to the corner of the room where I was sitting and commented to me about the students' responses in the class period, "I like the way they're inquisitive but when you're here it throws me." We then went on to discuss the sequence of student ideas and how she could have responded to the students' claims. At the end of this discussion she was excited about what she had learned from talking with me and commented that she would go back over this tomorrow with the students.

Summary Ms. Cee

In IQWST what it means to know and do science is an act of performing inquiry practices with the help of an expert to construct understanding of key scientific content. In Ms. Cee's curriculum construction arena a discovery-oriented process of "doing science" (Haigh, France, & Forret, 2005) and completing the curriculum tasks is considered authentic science practice. With a discovery-oriented teaching practice (Driver et al., 1994; Roth, 1991) it is believed that if students simply engage in the activity of experiments and have a chance to express their thoughts they will construct an understanding of science.

With Ms. Cee what it means to know and do science, or the classroom science practice, was to do the process of experimenting in the IQWST materials. Ms. Cee told the students to "git er done." When the students had questions she read the instructions from the IQWST materials. She spent two class periods experimenting during which both Ms. Cee and the students used the IQWST materials as a set of procedures to follow rather than treating the experiments as useful sources of data and experiences to test and build arguments with. When Ms. Cee needed to support the student performance of the curriculum tasks she did this by reading either the experiment procedures with the students, or reading what the teacher guide said. Where IQWST did not provide specific support such as in methods to find patterns in evidence Ms. Dee did not supplement this practice instead she introduced the key patterns as words or concepts which the students repeated. When students asked questions that IQWST did not provide answers for Ms. Cee did not provide answers either. When the students were talking out of turn and making claims about what was smooth Ms. Cee did not stop the student talk, in fact she valued students expressing their ideas.

In contrast to IQWST, Mr. Dee, and Ms. Kay the science content knowledge was not the scientific law, but instead a set of separate concepts or words to represent scattering and reflection. The inquiry practices associated with modeling and coordinating the relationship between theory and evidence were not practiced. In Ms. Cee's classroom practice meaningful science practice meant that the students were active by completing the tasks and sharing their ideas.

Discussion

In this chapter I described what the authentic community of scientific practice looked like in the three classrooms. The current science education reform efforts view authentic inquiry practice as both a form of teaching and a process of learning. It's a process of learning by participation in the practices of the science community (J. S. Brown et al., 1989; Driver et al., 1994) Participation in this community is being able to use both the essential content and the social practices of the science, because the objects of science are not the phenomena of nature but constructs that are advanced by the scientific community to interpret nature" (Driver et al., 1994).

IQWST is attempting to design curriculum materials that support teachers designing a classroom environment with a sequence of activities designed for student participation in science practice and construction of a deep understanding of the light ray-diagram model. However, teachers' read the purpose of curriculum tasks through their own, local context, aims and purposes for science content learning and authentic practice (Keys & Bryan, 2001; Remillard, 1999).

For Mr. Dee and Ms Kay inquiry practice, or teaching and learning, was a process of students' coming to comprehend and accept the ideas of science because these ideas are intelligible and rational, rather than the IQWST model that science ideas can be constructed by students. Mr. Dee made the ideas intelligible and rational with his use of intuitively appealing models and using those models to help students make connections between their experiences at the macro level with the world, and the micro level or symbolic levels of science. He did not find the authentic inquiry practices of IQWST useful. Instead, with his aim for teaching the laws of science content, his traditional linguistic practices (Cazden, 2001; Chin, 2007) of asking students to vote, but not explain their decisions for the vote became the accepted science practice in Mr. Dee's classroom community.

Ms. Kay also constructed a classroom science community of practice with the goal of students coming to comprehend and accept the ideas of science. Ms. Kay attempted to use the inquiry practices of science to prove that the ideas of science are intelligible and she asked the students often "does that make sense?" However Ms. Kay also used traditional linguistic practices with the cue of "does that make sense" to maintain participation in the classroom community, because she was unable to use the authentic science inquiry practices to prove the ideas were rational and resorted to appeals to scientific authority.

Ms. Cee on the other hand designed an inquiry classroom that focused on the processes of participation in science practice. However, unlike Mr. Dee and Ms. Kay, Ms. Cee neither supported the key practices or key ideas. Participation in the practices of analyzing and making sense of data were not modeled. While in Ms. Kay's classroom there was more opportunity for students to participate and propose their own ideas, there was not the important underlying scientific content and practices to support their ideas. Claims about key content ideas were left open on the classroom floor.

What I've described in this chapter is how the three teachers and IQWST all have different visions of classroom communities of practice. Depending on the view of the nature of science content, the teachers and IQWST all had different views of what is authentic scientific classroom practice. For IQWST's vision of science knowledge being socially constructed, the authentic inquiry practices of science are necessary. For Mr. Dee and Ms. Kay's vision of science content being externally fixed and true knowledge, that knowledge is constructed by the teacher and authentic student practice becomes a form of procedural display. For Ms. Cee, there is true science content knowledge, but what are more important is students' own ideas about that knowledge, and the authentic practice to construct that knowledge occurs when students engaged in the process of "doing" science.

Chapter 5

Social and Socioscientific Norms

In Chapter 4 I described the three classrooms communities of science practice. Essentially in each of the three classrooms, the science practice is a hybrid of both the teachers' vision and the inquiry-based vision of IQWST curriculum materials. In each of the three classrooms, the objects of science were either experiences or laws of nature, and the practices were closer to a form of procedural display. IQWST intends student learning to occur through socialization into the discourse and practices of the science community (Singer et al., 2000). However, this view of learning requires us to see that people's activities are also part of a larger community of practice which includes more than just the science community (J. S. Brown et al., 1989; Gee, 2004).

Because learning can be defined by the patterns of social interaction that occur in the classrooms, the question of what counts as learning (Gee & Green, 1998) from an emic perspective can be studied with discourse analysis to identify what the members of the classrooms need to know, produce, predict, interpret, and evaluate to participate appropriately (Gee & Green, 1998). In this chapter I am focusing on two aspects of appropriate participation, the social and socioscientific norms (Cobb et al., 2001; Erickson, 1982) that were considered appropriate in the three classrooms. The social norms govern how the teacher and students exchange turns at speaking and coordinate listening behavior (Cazden, 2001; Erickson, 1982). The socioscientific norms govern what counts as appropriate scientific practice for the teacher and student (Cobb et al., 2001; Erickson, 1982).

In a community of practice teachers and students are engaged in repeatable sorts of social practices. These repeatable sorts of social practices include ways that people talk, think, act and become recognized as a group. Within science classrooms in general, and IQWST classrooms in particular social practices include debating ideas, designing and conducting investigations, reasoning logically, using evidence to support claims, and proposing interpretations of findings (Fortus et al., 2005).

These social practices set up roles and networks of obligations that identify members of the community as legitimate and illegitimate members of the community(Cobb et al., 1989; Gee & Green, 1998). Roles are socially expected behavior patterns usually determined by a person's status in a particular social setting. These socially accepted behavior patterns, or norms, are principles of right action that guide members of a group in determining acceptable behavior. In classrooms social participation structures are a patterned sets of constraints on the allocation of interactional rights and obligations of teachers and students (Erickson, 1982). Two common roles in participation structures are speaker and listener roles. When one person is speaking the listener is obligated to listen, and the speaker has the right to nominate the next topic or speaker.

In classroom communities there are a set of teacher and student roles. In traditional classrooms one of the teacher's roles is to deliver information and the students' role is to receive information. And in IQWST there are also intended roles for the teacher and roles for the students (Singer et al., 2000). Included in the IQWST design principles (Blumenfeld et al., 1991; Krajcik et al., 2008; Singer et al., 2000) is commitment to an apprenticeship method of teaching (Collins et al., 1989; Lave & Wenger, 1991). In IQWST the teacher's role as a de-centered expert is to model, coach, provide feedback, and scaffold assistance facilitating over time students' enculturation into an IQWST classroom. The students' role is to find solutions to real problems by asking and refining questions, designing and conducting investigations, gathering and analyzing data, making interpretations, drawing conclusions, and developing authentic artifacts such as scientific models (Fortus et al., 2006)..

While IQWST has a commitment to the social norms of a scientific community of practice, this commitment is implicitly embedded in the design of the material, but when it comes to the teachers enacting the material their commitments and resources take the foreground. So, while IQWST is committed to inquiry and community of practice, this is a new role, with new types of responsibilities for teachers and students (Crawford, 2000). In this chapter I investigated the second research question, "What do the teacher student interactions reveal about the social and socioscientific norms?"

Results

In chapter 4 I described the classroom practices occurring in the three classrooms according to the four science social practices of formulating and asking questions (FAQ), data gathering (DG), formulating patterns and explanations (FPE), and connecting explanations (CE). Because describing the norms for all four social practices is too much for this chapter I chose to examine the norms evident in the participation structures associated with the social practices FPE events because building arguments from evidence is a core activity of inquiry practices (Driver et al., 2000).

In order to identify the typicality or atypicality of the participation structures in FPE events, first I identified the participation structures during FPE events in the microanalysis of lessons 2 and 6. For each episode I looked for the social interaction patterns of who talks and when, and the socioscientific patterns associated with who talks about experiences and data, patterns, and explanations or models and theories. Then, I compared the participation structures with participation structures in FPE events I had identified in all ten IQWST lessons during the initial rough transcription of the entire enactment.

I identified the participation structures as patterns by finding when the norms were broken (Cobb et al., 2001; Hymes, 1972). For example in Mr. Dee's classroom students are allowed to call out objects that Mr. Dee can use as part of an explanation, but these objects must fit with or be useful for Mr. Dee's explanation. The following two episodes illustrate the accepted and not accepted responses.

> Mr. Dee: Now mostly you looked pretty good on those uh those models…This is what I saw mostly. I saw a light source, with light coming out all around it, Yup. I saw an eye, OK. This is a eye with uh, yeah ok so you, you get it though. And then I saw some object I'll draw one that I liked fairly well.
> Student: A balloon.
> Mr. Dee: Ok, now these light rays are coming out all over the place. Not just to the eye to the balloon but everywhere, going in to the paper and out of the paper everywhere 3d.

Versus a similar episode

> Mr. Dee: It depends on which rock it hits, and which part of that rock it hits. What if I had? Let's make it simpler.
> Student: What about a football?
> Mr. Dee: Footballs bounce crazy. What if I had a boulder? A perfectly round sphere of a boulder and its down there half buried in the ground…

In both examples of this participation structure in terms of the social norm the students have the right to provide an answer without being called upon. In terms of the socioscientific norm, the students' role is to suggest an example. The teacher role is to provide explanations with everyday objects that students have experienced. In both episodes the social norm is maintained, there was no pause or indication that a norm had been broken when the student called out the answer. In terms of the socioscientific norm, students can suggest experiences, however it is the teacher's obligation to reject the suggestion of a football because it did not serve as a useful object for building an explanation because "footballs bounce crazy" and would not be useful for illustrating the science rule of the law of reflection since objects bounce predictably according to the law of reflection.

What I will do now is present the transcript of a critical incident for each participant structure, followed with an analysis of the structure, and a list of additional instances of the participation structure which includes the lesson, the date of the lesson, and the transcript line (e.g., Lesson 2 [12-5 line 56]. Each participant structure occurred in the context of IQWST activity 6.2 during an FPE event when the classes were reasoning with evidence from the paper and mirror experiment.

Mr. Dee

In Mr. Dee's classroom I identified four participation structures including the report data, predict, grandpa, and analogy participation structures. These structures are used to achieve "the types of interactions for the purpose of solving problems and carrying out academic tasks" (Collins et al., 1989, p. 488). In Mr. Dee's classroom the problem to be solved is how the teacher can best construct for students an explanation of scattering and reflection. While at the same time he is constructing the explanation, he does include students in the classroom practice by allowing them opportunities to make observations and predictions. So, in terms of the social norms in the participation structures Mr. Dee has established a community in which students are encouraged to talk about the topic that

Mr. Dee has nominated. However, consistent with his efforts to construct a comfortable atmosphere for the students Mr. Dee maintains the socioscientific norm that the teacher is ultimately responsible for determining what counts as an appropriate scientific claim.

Report Data Participation Structure

In the report data structure it is a social opportunity to afford students more chances to participate and open the floor to conversation, but ultimately for the socioscientific norms, the teacher makes the decisions for what counts in the data. Mr. Dee is asking students to report data from the experiment with paper.

1. Mr. Dee: Yeah so this was our position right? Ok and what other groups have not reported back on this?
2. Student: Ours
3. Mr. Dee: Ok tell me
4. Student: 3 4 4 4 4
5. Mr. Dee: 3 4 4 4
6. Student: 4
7. Mr. Dee: 4 All the same pretty much huh?
8. Student: Well yeah the the point numbers were different.
9. Mr. Dee: All right
10. Student: Hundreds
11. Mr. Dee: Yeah but not much difference.

In terms of the social norms for the teacher and the student roles, the teacher exercises the right and obligation to begin the episode by nominating a student to talk in turn 1. Once the episode has begun both the teacher and the students have the right to speak. The student's right to speak is evident in turn 10 when the student interrupts Mr. Dee and Mr. Dee acknowledges the interruption, and continues speaking indicating that the social norm was unbroken.

However, in terms of the socioscientific norm for the student role it is also evident in the exchange of turns that while the student has the right to speak about the data, in turn 11 it is evident the student does not have the right to evaluate the data when Mr. Dee discounts the content of the student's claim. For the socioscientific teacher role, in turn 7 and 11 Mr. Dee exercises his right to evaluate the pattern in the data and is not obligated to model his reasons for evaluating the data. Also, Mr. Dee decides that the variation in data is not enough, yet he is not obligated to explain why the hundreds reading on the light detector do not matter, he does not model his expert knowledge of the uncertainty of measuring devices.

Additional instances of the reporting data participation structure occurred in lesson 2 [2-07, line 462]; and Lesson 10 [3-13, line 127][3].

Predict Participation Structure

The predict structure usually occurred when Mr. Dee wanted to determine if the students can apply the explanation he has constructed. Once again, this is a social opportunity for students to talk to Mr. Dee and participate as legitimate members of the classroom community. Also, by reducing the complexity of what counts as scientific participation, the socioscientific norm that the teacher will supply the explanation increases students' participation in the community. In this episode Mr. Dee is asking students to predict what they think the light detector readings from the paper should be.

1. Mr. Dee: What would you expect to be the place where it's going to be highest?
2. Student: Three.
3. Student: Three.
4. Mr. Dee: Three. Also we do have some tendency toward that, it's kind of like in the middle here but it's not great data. I think our flashlights probably spread out a little much? Ok? And had some problems like that. And so our data wasn't quite as good.

In terms of the social norms for getting the turn, the teacher nominates the topic, which is asking the students to make a prediction. All students are granted the right to

[3] Lessons 4, 5, and 7 also had data that was collected, but consistent with Mr. Dee's practice of dismissing data, after the students collected the data from the IQWST experiments he skipped the students data altogether and modeled the results.

speak with the request for a prediction. Then the teacher listens to and evaluates the students' predictions in turns 2 and 3. When the students reply with a correct prediction Mr. Dee is obligated to provide an explanation for the prediction.

In terms of the socioscientific norms for the teacher role, the teacher is obligated to nominate the scientific content, or pattern that students use to make their predictions in turn 1, and the teacher is responsible for providing the explanation for the pattern in turn 4. In the student role, students are responsible for providing a predicted experience which in this case is where the light detector reading will be the highest. The students are not obligated to talk about why they thought position three would be the highest.

Additional instances of the predict participation structure occurred in Lesson 6 [2-23 lines 714, and 303; 2-24 line 189]; Lesson 8 [3-1 lines 144, and 191; 3-6 lines 100, and 112]; and Lesson 10 [3-14 line 90; 3-15 line 114].

Grandpa Participation Structure

The Grandpa structure usually begins when Mr. Dee wants to demonstrate something for the students and it begins with the comment, "Gather round…" It is a structure that Mr. Dee uses to repair instances of what he called "strange data." This is another social opportunity for the students to comment about their observations. However in terms of the socioscientific norms, the grandpa structure is an opportunity for Mr. Dee to use evidence that is more intuitively appealing than the IQWST evidence to support his scientific claims.

1. Mr. Dee: Gather round children. Grandpa's gonna tell you a story.
2. Students: Yeah.
3. Student: No.
4. Student: (inaudible)
5. Mr. Dee: Not to close.

6. Student: Look at it.
7. Mr. Dee: Yeah. Now let me ask you this,
8. Student: Whoa.
9. Mr. Dee: Can't you see the light right now?
10. Student: Yeah
11. Mr. Dee: Ok coming in here we could trace this thing. Let me turn it to where, oops sorry. Ok, we could turn this thing you know we could trace it with a pencil and show you where it's going. It's pretty clear it's hitting the paper here, it's coming out here. You know if I change the angle, ok? You know? Alright, yeah. Ok, so obviously if I'm going to check the light the the level of the light, if it's falling right there, that's going to be the most. If it's over here it should be less because there's less light falling right in there. And the more you go, that's less less less BRIGHT less less less, ok? Now, when we do this with a piece of paper... lets do it like this. We're going to use this to hold it up... Where's my flashlight...We'll make a couple of creases here to hold things in place...oops that mirror is flexible buddy. Ok, so now we've got a nice piece of paper that is, can I see your envelope there whoever's it is? That's ok. Ok, if I shine this in there yeah I get some kind of like reflection back, but is it so clear like the mirror was?
12. Students: No
13. Mr. Dee: Well, no it's kind of blurrier, what's another word? Um spread out maybe
14. Student: Fuzzy
15. Student: Scattered
16. Mr. Dee: Fuzzy, scattered, maybe that's it. Ok.

In terms of the social norms for the teacher role, Mr. Dee nominated the topic of showing students the pattern for how light reflects when he initiated turn 1. In this structure both the teacher and students have speaking rights, there are no interruptions after which a participant told not to speak. The students in their role, have the right to speak when Mr. Dee asks a question, and, in turn 8 for example, students have the right to comment on the demonstration or apparatus. Again Mr. Dee has the listening responsibility of checking to see if the students are following along, in turn 13 Mr. Dee evaluates the response in turn 12 as a correct response and exercises the obligation to explain and continue nominating new topics.

In the teacher role, the socioscientific norm for the teacher can be seen in turn 11 when Mr. Dee uses the materials students are looking at as "physical models" (Lehrer &

Schauble, 2000, p. 41) that draw on resemblance to sustain a connection between the physical world, the light detector data, and the world being modeled, the scientific pattern of reflection. Later during this grandpa episode Mr. Dee used many small mirrors to model a "rough" surface that scatters light. The socioscientific norm for the student role in the grandpa structure is to report what they see the teacher showing them.

Additional instances of the Grandpa structure occurred in: Lesson 1 [2-1, line 76] Lesson 2 [2-7 lines 524, and 693; 2-8 lines 413, 491, and 524]; Lesson 3 [2-9 lines 70, and 115]; and Lesson 7 [2-27, line 140].

Analogy Participation Structure

Mr. Dee uses the analogy structure to provide explanations after giving students the opportunity to provide explanations. Consistent with the social norm that students' have the right but not responsibility to talk about the topic, Mr. Dee opens the floor with wait time after asking a question. He also maintains the socioscientific norm that the teacher will provide the scientific explanation.

1. Mr. Dee: This is called scattering.
2. Student: What's it called?
3. Mr. Dee: Scattering.
4. Mr. Dee: Why would this happen? (silence 3 seconds)
5. Mr. Dee: Because the surface is too rough. These are like little mirrors. Each little part is reflecting a part. Now, I have a piece of paper. I should be able to see my lovely uh well, my face, ok? But this paper is really rough. You know what if, if the paper was on the floor and I bounced a ball on it, not rough to that ball. But the little light rays they're so tiny little, they're cute they're so tiny.

The social norm for the teacher role the teacher nominates topic with a question in turn 3, the teacher has the listening responsibility of waiting and signals an opening in the conversation for students to speak with the pause, however if no student responds, then the teacher has the obligation to provide a response to his own question. In the student role, the students have the right to speak and volunteer explanations when the teacher pauses after asking the question in turn 4, but there is no obligation to respond.

The socioscientific norm for the teacher role is to provide terms for patterns such as scattering in turn 1. The teacher's obligation is to provide explanations for why the pattern occurs in turn 5. Usually the teacher does this with "syntactic models" (Lehrer & Schauble, 2000, p. 43). Syntactic models are analogies based on the epistemological claim that one system functions like another, similar to this episode where the teacher claims that multiple tiny mirrors function much like the multiple fibers in a piece of paper.

Additional instances of the analogy participation structure occurred in: Lesson 2 [2-23 line 290; 2-24 line 225]; Lesson 6 [2-23 line 290]; Lesson 8 [3-6 line 128]; and Lesson 10 [3-13 line 75; 3-14 line 97].

Summary of Mr. Dee Participation Structures

In the IQWST community of practice, the teacher is expected to enact a de-centered expert role in order to model *in situ* the norms or patterns in behavior of the members of a community of scientific practice (J. S. Brown et al., 1989; Singer et al., 2000). In this role, the teacher needs to balance both the social norms of maintaining order, and the socioscientific norms of participation in a scientific culture which includes practices such as debating ideas, designing and conducting investigations, reasoning logically, using evidence to support claims, and proposing interpretations of findings.

Mr. Dee enacted a teacher role which I have labeled, the nature guy. As the nature guy the social order Mr. Dee maintained provided students the opportunities to speak when they felt comfortable, in the predict structure he allows the students to call out responses, in the analogy structure he asks a question but continues if no students have an explanation.

As the nature guy, Mr. Dee enacted socioscientific norms where the teacher was solely responsible for the scientific practices of reasoning logically when he comments on the data in the report structures; using evidence to support claims when he uses imaginary numbers in the grandpa structure; and proposing explanations of the findings like the flashlight beam spreading in the predict structure. The student socioscientific norm was to participate by demonstrating their understanding of Mr. Dee's explanations with simple predictions. However, the students were not responsible for proposing explanations for their predictions.

Mr. Dee's nature guy role supported his aims of explaining the content, and the classroom practice of constructing scientifically accurate and intuitively appealing explanations that I described in Chapter 4. In one way Mr. Dee's role paralleled the de-centered expert role as the person who models for students the appropriate scientific claims. However, his enacted role contrasted with the IQWST de-centered expert role as a teacher with the responsibility of modeling the distribution of participation in the classroom to provide opportunities for students to propose and evaluate ideas as a group.

Ms. Kay

In Ms. Kay's classroom she established three participation structures including reporting data, express understanding, and evaluate use of terms to organize the interactions in the classroom for completing the academic tasks Ms. Kay's purpose for the IQWST tasks was to use evidence to prove the scientific patterns and laws. She also had the goal of providing her students opportunities to express their understanding of these scientific laws. The social norms for when students talked were much more strictly governed by Ms. Kay, Ms. Kay initiated the turns for students to speak. This social norm is consistent with Ms. Kay's socioscientific norm that what counts as appropriate scientific practice is proving the laws of science because Ms. Kay maintains the responsibility to find the evidence in the student experiments that supports the scientific claims. Ms. Kay then checks the students understanding of these claims by how well the students can use scientific terms as part of their responses to her questions.

Reporting Data Participation Structure

Ms. Kay used the reporting data participation structure to collect the student data from the experiments. The social norms for initiating turns to talk is strictly controlled by Ms. Kay for the socioscientific purpose of Ms. Kay gathering evidence to talk about the data and develop a pattern. In this example the students are reporting their data from the mirror experiment.

1. Ms. Kay: Uh, last one, Latrell lets go with your group. At position five where did you have your highest reading?
2. Student: At position four
3. Ms. Kay: At position four.
4. Ms. Kay: If at position five you had your highest reading at position four I need to see your hand. Two groups. Ok, so two groups at position four. Ok someone else. Uh, Adrielle what did your group have?
5. Student: We had our highest one at level, I mean, at position five.
6. Ms. Kay: At position five. Ok so if you had your highest reading and your light was at position five if you had your highest reading at position five, let me see your hand. So we got one two, is that an up or down? One group, two groups, three groups, four groups, that's four groups at position five.
7. Ok so it's a little messy but I'll talk about it as we go along. So we're going to circle this is all of our data, this is what we came up with. So we're going to circle the highest number and see if we can develop a pattern there Ok?

So in terms of the social norms associated with the teacher and student roles. As the teacher Ms. Kay nominates both the turn in the conversation and the topic in turn 1 and turn 4. Students do not have the right to nominate the topic or the turn, each turn a student takes occurs after an initiation by Ms. Kay. Ms. Kay has the obligation to listen to the students and record the students' observations without judgment while recording the data. Ms. Kay maintains a tight social ordering and control of the classroom.

In terms of the socioscientific norms Ms. Kay in the teacher role organizes the students' reporting of their experiences, or data. Once the students have reported the data in turns 2, 4, 5, and 6, Ms. Kay nominates a new topic in turn 7, evaluating the data. She is responsible for the scientific practice of evaluating the data when she comments that the data is messy, and she suggests the method of evaluating the data. The students are not given an opportunity to talk about any patterns they may have noticed in the data.

Additional instances of the report data structure include: Lesson 2 [12-06 line 463]; Lesson 4 [12-14 line 130]; Lesson 6 [1-20 line 120, 1-24 line 149, and 1-25 line 87]; and Lesson 8 [2-8 line 126].

Express Understanding Participation Structure

The express understanding participation structure is an initiate-respond-evaluate type structure which I described in Chapter 4 as a common classroom practice of procedural display. In terms of the social norms, Ms. Kay expects the students to take a turn at speaking and express whether or not they understand the science explanations. And for the socioscientific norm, what counts as appropriate practice is for Ms. Kay to provide the explanations while the students are responsible for expressing agreement or disagreement with the explanation. By asking students to express whether or not they understand but not explain what they understand Ms. Kay is able to introduce the scientific laws the data was intended to show. This example occurs after Ms. Kay has analyzed the data from the paper with True/False questions.

1. Ms. Kay: OK, now our data in this class, first hour collected data today, we didn't analyze all of their data. However, we went through these same questions today and we came out with the correct data to make everything that we've done up to this point true. Now you guys all followed the same set of directions. Um, you all collected data. We came up with data, but our data contradicts what the laws and the truths are that we're trying to explain. Ok? So bottom line, this data doesn't fit what I'm trying to teach. Ok? Does that make sense?
2. Students: Yes.
3. Ms. Kay: Now, if you take a look at, our first um, our first two questions, that question response that we were looking for, that was a true statement. But the problem is we had one group, only one group that came up with the correct or proper responses.

In the teacher role, it is the social norm for the teacher to nominate the topic in turn 1 and ask the students if the topic makes sense. The normative response for the students is to reply "yes," and when the students reply yes the teacher can continue with the topic. It is the students' obligation to indicate their understanding in turn 2. Also, when the students reply no, the express understanding rule is broken and the teacher may either re-explain the topic, or ask the students if they are sure the answer is no, at which point the students can change their answer to yes without having explained why they changed their answer, and the teacher continues with a new topic.

In terms of the socioscientific norm, the norm for the teacher role is to provide the explanation or pattern that the students should have been able to produce. The students are not obligated to describe their ideas about data, patterns, or explanations, unless a student replies no, at which point the teacher attempts to determine why the student is not replying yes.

Additional instances of the express understanding participation structured occurred in the following lessons: Lesson 2 [12-05 line 264; 12-06 line 284; 12-07 line 390]; Lesson 6 [1-24 line 125, and 397]; Lesson 7 [1-27 line 95]; Lesson 8 [2-9 line 90]; and Lesson 9 [2-27 line 59].

Evaluate Use of Terms Participation Structure

This is an important participation structure for Ms. Kay because it represents the type of interaction that is important for Ms. Kay's goal for her students to participate successfully by repeating the correct scientific terms.

1. Ms. Kay: So was our law of reflection still true? Absolutely true, but why is it that we get different readings? What happens to the light on this bumpy surface? Smooth surface light's angle of incidence is equal to the angle of reflection. What about on this bumpy surface? Travis, what are your thoughts?
2. Student: It's not completely reflection on a bumpy surface.
3. Ms. Kay: Did you get some reflect, did you see some light? You saw some light right? Aja?
4. Student: Well uh,
5. Ms. Kay: Huh?
6. Student: It was like different angles in different direction.
7. Ms. Kay: Ok, so it's gonna go [drawing on overhead]. I'll take that. And then Jarrod, let's see what you have to say.
8. Student: Oh um, when we watched that movie Bill Nye the science guy, it said uh, it said uh [inaudible] and if it's not a smooth surface then it will slow down and change directions. So maybe because the paper is not that smooth it slowed down and it changed directions and it didn't get all the light.
9. Ms. Kay: Ok good. So, if we think about what Aja just said, we have a bumpy surface. Does that mean that the law of reflection is totally false? Absolutely not. But you have a bumpy surface that means light is actually [drawing scattered on overhead] going out but its doing what? Starts with an S
10. Student: Scattering.
11. Ms. Kay: It's actually scattering. What causes light to scatter versus smooth reflection? The type of what?
12. Students: Surface.
13. Ms. Kay: Does that make sense?
14. Students: Yes.

In terms of the norms for social participation, the pattern is much the same as the other two participation structures. Ms. Kay initiates the topic in turn 1 and has opportunities to talk in turns 1, 3, 7, 9, and 11. Students have the right to talk about their own ideas represented by the three separate student turns in this episode. Ms. Kay though has the responsibility to listen to the student turns, and while Ms. Kay listens she decides to refer back to Aja's correct use of terms in turn 6.

In terms of the socioscientific norms for who talks about what, in this structure students have the speaking rights to express their ideas for the explanations. However, the teacher has the right to ultimately make the final decision about which student idea is most appropriate as indicated in turn 9 when after having nominated three separate turns to provide an explanation Ms. Kay accepts Aja's explanation in turn 6 where Aja used the words angle and direction which are parts of the description of the law of reflection. Ms. Kay does not distribute the participation to other students to consider which of the three student explanations may be most appropriate. In effect, the students are obligated to use scientific terms "scattering" and "surface" for their explanations in turns 10 and 12, which Ms. Kay has decided is the science goal for her explanation.

Additional occurrences of the evaluate use of terms participation structure include: Lesson 2 [12-07 line 349, 373, 387, and 412]; Lesson 6 [1-25 line 177, and 212]; Lesson 7 [1-27 line 86, and 90]; and Lesson 9 [2-15 line 18].

Summary of Ms. Kay Participation Structures

In Chapter 4 I described Ms. Kay's authentic community of practice, as one in which the objects of science are the laws and truths of science, and the practices are intended to use evidence to prove explanations. One of the ways Ms. Kay sustains this community of practice is with her social authority, in each of the three participation structures it is the social norm for Ms. Kay to initiate the topic and the turns to speak. She also maintains the social norm of the teacher's responsibility to listen and make sense of student ideas.

In terms of what counts as appropriate scientific participation for the teacher and students in Ms. Kay's classroom similar to IQWST, the students have opportunities to communicate their findings with reports of their data, and they have opportunities to propose explanations in the evaluate use of terms participation structure. However, in contrast to IQWST, there is not a norm obligates students to critique and evaluate each other's data and explanations, that responsibility is left to the teacher. In the express understanding participation structure Ms. Kay models the practice of evaluating claims as comparing the claims to a standard of scientific truth rather than the evidence collected in the classroom.

Ms. Kay uses both her social authority who distributes participation and academic authority as one who happens to know what the answers should be to determine what counts as explanations and so instead of the IQWST socioscientific norms associated with students supporting arguments from evidence, Ms. Kay's establishes the socioscientific norm for supporting claims with social authority. This is different from Mr. Dee who similar to Ms. Kay, has the social authority to maintain classroom order but in contrast uses students' experiences and intuitively appealing models and analogies to establish the socioscientific norm for explanations.

Ms. Cee

In Chapter 4 I described Ms. Cee's classroom as a community in which the science practice is doing the process of science, and the science content are descriptions of experiences, in contrast to the explanation of scientific laws in Mr. Dee and Ms. Kay's classroom. In Ms. Cee's classroom community there were three types of participation structures in FPE events including the tour guide, moving on, and IQWST teacher guide that organized participation in the community.

Tour Guide Participation Structure

The tour guide participation structure occurs for the purpose of identifying the key patterns or explanations that Ms. Cee wants the students to come up with after completing experiments. Because Ms. Cee values students expressing their ideas, it is the social norm that students can express their ideas without specific nominations from the teacher. However, for the socioscientific norm Ms. Cee decides which ideas are scientifically correct and is responsible for identifying the correct ideas. The following example occurred after students had collected data from the mirror and the paper.

1. Ms. Cee: Ok, so you noticed the brightest light when flashlight was in what kind of a shape? You said it yesterday [points to student 1].
2. Student 1: Uh a "v"?
3. Ms. Cee: In a "v" shape.
4. Student 1: Yeah.
5. Ms. Cee: Right?
6. Student 2: All of them are "v's" practically.
7. Student 3: But like
8. Ms. Cee: That's true [replying to student 2].
9. Student 3: But
10. Student 4: At every angle
11. Ms. Cee: That's true [replying to student 4].
12. Student 3: The closest "v" shape.
13. Ms. Cee: The closest "v" shape. But they were all "v" shapes right? So that's, when you were dealing with the mirror, the light would make a what shape? [head nod to student 3]
14. Student 3: A "v" shape.
15. Student 2: "v"

In terms of the social norms for the teacher role, in turn 1 the teacher has the right to nominate the topic, the teacher has the right to respond to students but not an obligation to reply to all students for example, the teacher responds in turn 8 to an earlier student response in turn 6. Once the topic is identified, the students have the social right to decide when to speak also, in turns 4, 6, 7, 9, 10, 12, 13, and 15 students talk without being specifically nominated for a turn to speak by the teacher. In turns 3, 8, 11, and 13 the teacher has the listening responsibility of pointing out the correct student comments.

In terms of the socioscientific norms associated with the teacher and student roles, the teacher has the responsibility of identifying the topic the students should be expressing their ideas about, in this case the topic the teacher had nominated is the pattern that the students saw in the results. It is the students' responsibility to pick up and use this description of the pattern. In turn 6 one student actually questioned the value of describing the pattern as a "v" shape because all the shapes were "v's practically." And in turn 12 a student proposes the v shapes that matter were "the closest." However, ultimately the teacher in turn 13 has the responsibility of pointing out to the rest of the students which expressed idea is the correct idea. So, what the students contribute ideas, but ultimately what counts for the final explanation is what the teacher has pointed out to the students.

Additional instances of the tour guide participation structure include the following: Lesson 2 [3-29 line 427, 468; 4-11 line 66, 230, 304]; Lesson 4 [4-14 line 86, 101]; Lesson 5 [4-24 line 51]; Lesson 6 [4-27 line 70; 4-28 line 7]; Lesson 8 [5-5 line 64].

Moving On Participation Structure

Moving on is a participation structure that occurs when Ms. Cee decides to not provide feedback to a student response. This structure is consistent with the social norms of the classroom because Ms. Cee encourages students to share their ideas. The structure is also consistent with the socioscientific norm that what counts is the presentation of scientific ideas because Ms. Cee presents the explanation from the IQWST teacher guide, and the student presents her own explanation. This example occurs near the end of lesson 6 after Ms. Cee has explained the difference between scattering and reflection.

1. Ms. Cee: So it's scattering. So when we have a rough surface we have scattering. When we have a smooth surface we have reflection. Do we understand that? Any questions about that?
2. Student: Why do we have light in our room? Because we have a rough surface out there. I decided that.
3. Ms. Cee: Uh huh, that's good. You're putting it together in the real world, that's good.
4. Ms. Cee: Alright, now, I'm going to have Ms Katie, that's you. Would you hand these out please dear?

In terms of the social norms, the teacher nominates the topic in turn 1, but the students also have the right to add to the topic in turn 2. So again, both teacher and student have the right to speak, in turn 2 the student was not specifically nominated by the teacher. However, unlike the tour guide participation structure, in turn 3 the teacher does not have the obligation to listen for a specific student response instead the teacher replies with a generic positive evaluation, and in turn 4 Ms. Cee moves on to the next curriculum task.

In terms of the socioscientific norms that determine who talks about what, in the moving on structure in turn 2 it is appropriate for the student to initiate either a question about an experience, or in this case an explanation for the experience. In turn 3 when Ms. Cee comments the student is putting it together followed by turn 4 moving to the next topic, the norm that student expressing their ideas is an appropriate contribution to the process of doing science, but because the teacher doesn't ask what the student meant, or nominate another student to respond, but instead moves to the next activity this structure also demonstrates the norm that what counts as science practice is continuing doing the lesson. What distinguishes the moving on structure from both the tour guide and teacher guide structures is that it usually ends with student ideas not specifically identified in the IQWST teacher guide.

Additional instances of the move on participation structure include: Lesson 2 [3-29 line 348]; Lesson 4 [4-11 line 273]; Lesson 5 [4-20 line 88; 4-24 lines 43, and 68]; and Lesson 6 [4-27 lines 492, and 603].

IQWST Teacher Guide Participation Structure

This participation structure is similar to the both the tour guide and moving on structure because the students express their ideas which is the social norm that Ms. Cee values in the community. However, in this structure Ms. Cee is unable to draw the appropriate response from the students and instead reads the expected response directly from the teacher guide which represents the socioscientific norm that what counts as appropriate explanations actually comes from the IQWST teacher guide. The following example occurred after an episode described in chapter 4 using an IQWST transparency to apply the light model. Ms. Cee has now revealed the location of the flashlight and is explaining why the flashlight should be pointing at the mirror.

1. Ms. Cee: That explains why we can see things in the mirror.
2. Student 1: Cause light reflects off of it.
3. Student 2: But, I was
4. Ms. Cee: So you thought you saw it down there right?
5. Student 3: You can still see it.
6. Ms. Cee: But if you remember
7. Student 4: You can still see it with your eye.
8. Ms. Cee: Yeah, [response to student 4] but if you remember we said that the light bounces off to the eye.
9. Student: I didn't know there was a wall.
10. Ms. Cee: So it's actually the what? That's coming back.
11. Student 2: Oh, it would have to hit something.
12. Student: Reflection.
13. Student: The mirror is the object.
14. Student 3: Reflection or light.

15. Ms. Cee: Ok? Ok. So, in activity 1 your drawing should look similar to this right here.
16. Student: Darn.
17. Ms. Cee: Except for the dotted lines don't do that part.
18. Student 3: Do we have to draw it again?
19. Ms. Cee: No we're just telling ya. Ok?
20. Ms. Cee: Ok, so our eye is the detector of the light rays that hit it. Ok, like I said before we can only see based upon what actually hits our eye. This is why our eyes can be fooled by a mirror. It makes it seem like our eye, to our eye, like the light is coming from a different place where the light source actually is.

Similar to Ms. Cee's other participation structures, the social norm for the teacher is to nominate the topic in turns 1 and 20, but Ms. Cee does not nominate the students to speak in turns 2, 3, 5, 7, 9, 11, 12, 13, 14, 16 and 18. The teacher talks to particular students in turns 4 and 8 because these student comments about reflect and eye relate to the topic she nominated for this episode. The episode ends when the teacher reads the answer for the topic from the IQWST teacher guide.

In the IQWST teacher guide participation structure it is IQWST that is responsible for providing the explanation. In turns 1 and 15 Ms. IQWST talks through Ms. Cee when she reveals the different parts of the transparency. Both the students and the teacher talk about their own ideas. It is interesting to note that Ms. Cee's ideas are also incorrect in turn 17. The dotted lines are important for the explanation, but Ms. Cee doesn't recognize this and tells the students not to draw them. So, when Ms. Cee then reads the IQWST explanation in turn 20 it is evident that IQWST is responsible for the explanation that is considered appropriate.

Additional instances of the teacher guide participation structure include: Lesson 2 [4-11 line 32] Lesson 4 [4-14 line 80]; Lesson 5 [4-20 line 67, line 90, and line 99]; Lesson 8 [5-4 line 58, line 75].

Summary of Ms. Cee Participation Structures

So, for IQWST, the teacher needs to balance both the social norms of maintaining order, and the socioscientific norms of participation in a scientific culture which includes practices such as debating ideas, designing and conducting investigations, reasoning logically, using evidence to support claims, and proposing interpretations of findings.

In a sense the social norms that Ms. Cee maintains, allowing students to voice their ideas, is close to a culture that affords opportunities for ideas to be debated. For Ms. Cee all three structures serve her purpose of allowing students opportunities to express their ideas, but the moving on and teacher guide structures reveal her goal of also doing the science when she moves on without making sense of the students' ideas. The process of making sense with appropriate methods of debating and reasoning need to be modeled by the expert. In many cases Ms. Cee does not model debating ideas, in the tour guide structure, Ms. Cee uses a strategy of "guess what I'm thinking" to lead students toward the appropriate idea when she selects student answers that are what she intends to direct them towards.

Discussion

In communities there are participation structures with implicit norms and roles which include rights and obligations for legitimate participation in the community (Erickson, 1982; Gee & Green, 1998). IQWST aims to establish norms for participation that include the distribution of the right to propose explanations and ideas to the students. The IQWST de-centered expert teacher role is to model, coach, and provide feedback for 1) the science reasoning practices, 2) the social opportunities for critique, and 3) the language or tools to put the practice of building arguments with scientific reasoning practices into practice (Fortus et al., 2006). Yet in all three cases the teachers' established norms that maintained the teacher's right to contribute the final explanations and ideas that were deemed correct.

In part this difference in distribution of participation can be linked to the different views of content and practice described in chapter 4. While both IQWST and the three teachers value the goal of maintaining social order and completing the academic goal for the lesson (Doyle & Carter, 1984; Mehan, 1979). The IQWST goal to grant students legitimate opportunities to formulate patterns in evidence and in the process construct their understanding of a scientific model, asks teachers to assume new roles that place different challenges and responsibilities on the teachers. Not only are the new IQWST roles difficult for teachers to manage, this role must also be read through the teachers' purposes and aims for authentic science practice (Remillard, 1999). What I described in this chapter are the patterns of interactions in the three teachers' classroom that served the purpose of supporting their aims and goals for authentic practice described in chapter four.

In chapter four, I described what is considered authentic classroom practice indicated by the ways the three teachers adapted and improvised the IQWST tasks to achieve their goals for knowing and doing science. IQWST has as its goal that the community constructs with practices of science the scientific ray model of light. The three teachers have a different goal for the final product of the lesson. In all three classrooms the socioscientific norms established in the classrooms did not hold teachers accountable to modeling disciplinary norms (Engle & Conant, 2002).

Mr. Dee himself is constructing a story of reflection and scattering with the grandpa and analogy structure that is scientifically accurate and intuitively appealing to the students, he does the reasoning practices when he dismisses data from the report structure and proposes explanations but doesn't model these reasoning practices for the students. Ms. Kay demonstrates that the reasoning practices are unimportant in the express understanding structure because the students didn't prove the law of reflection and emphasizes the use of vocabulary in the term structure. Ms. Cee provides many opportunities for students to voice their ideas in all three structures, but does not model critique of the ideas, or model the use of the reasoning practices and tools, instead organizes interactions that support doing the experiments by moving on to the next activity. In the next chapter I will use the teachers' commitments to science content and practice, and their personal resources for constructing that practice in the classroom to describe the patterns in their classroom communities.

Chapter 6

Commitments & Resources

In the previous two chapters I have described a picture of three teachers' curriculum construction and classroom community of practice. For IQWST curriculum materials designed with an inquiry-based community of practice in which students and teachers coordinate the science content and the science practice, the teacher plays an essential role in adapting and responding to students' ideas and performance with academic tasks (Driver et al., 1994; Singer et al., 2000). The selection of tasks and adaptation to students is a very difficult part of curriculum construction for a number of reasons. For one reason, the relationship between views of learning as participation in a culture or community of practice and pedagogy is problematic and there are no simple rules for pedagogical practice in a constructivist classroom community (Driver et al., 1994). A second reason orchestrating the balance of organizational, social, and cognitive norms intended in inquiry-based curriculum is difficult because it requires commitments to the knowledge, practices, and habits of mind associated with scientific inquiry, and classroom management resources to enact such lessons (Schneider & Krajcik, 2002).

As the teachers designed their curriculum and classroom community they were engaged in two processes of task selection and task construction (Remillard, 1999). During task selection teachers decide which IQWST activities to select and alter, and then as they interacted with the students and the subject matter they continued to construct adjustments to the tasks. Both of these processes occur as teachers actively shape the classroom community according to their commitments to the purposes of school, scientific ideas, and their personal resources for enacting that vision (Anderson, 2003a; M. Brown & Edelson, 2001; Cohen & Ball, 1999).

In order for teachers to design the IQWST vision of inquiry the teachers need to have similar personal resources and commitments to science content, scientific practices, and social and socioscientific norms. It is also possible that while the teachers may have the commitments that parallel IQWST when it comes to making the practice of analyzing data and formulating patterns and explanations the teacher's may not have the personal resources to realize their commitments to instructional goals. And, it is also important to recognize that personal resources are not the only influence on changes in teacher practice, teachers are historical beings working within a profession with a complex mixture of past and present practices (Cohen, 1990).

I have constructed a picture of the classroom community of practice each teacher constructed with all the associated forms of science content, science practices, and norms. I constructed that picture by examining the choices and decisions teachers made during the enactment in response to their reading of the tasks which reveal their commitments and resources relative to the IQWST vision of practice. In this chapter I use the teacher's interviews to explain their choices, why they at times chose to adopt IQWST tasks, and at other times adapt and invent their own tasks. First, I will briefly review the findings from the previous two chapters that represent a model of the three teachers' community of practice. I have organized the headings according to chapters 4 and 5. Chapter 4 described the teacher's community of practice that I have continued to describe according to their commitments and resources for science content and science practice. Chapter 5 described the social and socioscientific norms, and the participation structures those norms were embedded in.

Results

Mr. Dee

In Mr. Dee's community of science practice he enacted a teacher role which can be described as "the nature guy." He has a commitment to a model of science teaching and learning which consists of explaining the story of science knowledge. However, he has the necessary personal content knowledge resources to enact the IQWST inquiry model if he chose to. As the nature guy, Mr. Dee is committed to the knowledge of experiences and explanations. As a result of this commitment, he envisions his role is to organize the experiences and explanations in the curriculum to provide students with the best chance to learn the content and explain their understanding. Because he views his role as providing the connections between experiences and explanations Mr. Dee uses the students' experiences and his own scientific models to help students make connections between their experiences and the scientific explanations instead of engaging students in the practice of formulating patterns. The social and socioscientific norms in the classroom are Mr. Dee is expected to show students science phenomena, students are allowed opportunities to make predictions about phenomena volunteer explanations, and finally Mr. Dee provides the abstract scientific explanations.

I begin with Mr. Dee's commitment to his aims and goal for the purpose of science as it relates to his decisions about what to teach. This comment I think in part explains why Mr. Dee is not as committed to the IQWST practice of students constructing scientific models.

> "I guess there's also decisions made about which topics maybe are more important. Let's say if we had to do astronomy kinds of things, ok? Is it important to know? Yeah. Is it going to affect any part of their daily life? Probably not. But what about friction? Well that affects everyone everyday. So do you spend more time with that, things that are going to affect business or affect

> how up to date someone is on a certain topic when they go to vote on things. Because we're educating people to be citizens, voters, problem solvers, and whatever other reason we have for teaching science…so if I have to short change something I have to look at those issues."

This comment along with a personal communication following the IQWST lesson 3 about models, during which Mr. Dee commented that the lesson was busy work, explains Mr. Dee's decisions to construct explanations for his students. He makes his decisions based upon a personal commitment that the purposes of schooling is to provide students with the information they need to know to be a citizen which contrasts with the IQWST purpose of learning to participate in scientific community of practice.

Content Commitments and Resources

Content Commitments. Mr. Dee departed from the IQWST design and invented many non IQWST tasks because for him, the authentic science content is the patterns in science (e.g., the law of reflection) in contrast to the IQWST commitment to scientific explanations in the form of the light ray model. His goal for science teaching is "to have kids understand it." He later goes on to describe what the "it" is when he described his purpose for using discrepant events, "with discrepant events, or whatever, they're really interested in you know, knowing the explanation, which is what you want them to do in the first place. You know is to understand this thing."

In addition to his interview comments from lesson 6 Mr. Dee introduced the purpose of the experiment is "to understand" which contrasted with Ms. Kay's purpose "to show" and Ms. Cee's "to investigate." And finally, Mr. Dee's last words in lesson 6 were another indicator of his content commitment to explain scattering, "You've got scattering because the surface is so rough compared to how small those are, how small the little light beams are, the rays." The commitment to explain the content contrasted with the

IQWST content goal of ending lesson 6 with a revision to the scientific model that could be used by students to explain additional phenomenon.

Content resources. Of the three teachers, Mr. Dee has a deep understanding of the science content. During the interview while he was remembering the context of a video clip he mentioned, "Now we hadn't really talked about whether it's going to be the angle of incidence compared to the normal or the angle between the bumpers or the flat part of the mirror or something like that." Angle of incidence and normal are two specific science terms, and knowledge of science terms is one way to capture teachers' science knowledge (Wilson & Berne, 1999).

However, Mr. Dee's reading of the content purpose for the data from the mirror was different from the IQWST purpose which may have led Mr. Dee to quickly dismiss the data, "Because I think that the beam was diverging quite a bit and causing it to read high in like several areas where it shouldn't, I mean it shouldn't be spiking but it should have been a little more obvious." So in effect, while Mr. Dee has a wealth of content knowledge necessary to respond to students' reasoning, he was at the same time reading the IQWST task with a different conceptual model of what the data should have been representing. What the tension in the content resources shows is the intimate link between the content and the practices Mr. Dee used to complete the academic task.

Practices Commitments and Resources

Practices Commitments. Mr. Dee departed from the IQWST tasks in part because he had different beliefs about the purpose of learning science. I asked Mr. Dee what students should be able to do with science and he said, "be able to apply it to you know everyday situations." The practices associated with applying knowledge are certainly one important aspect of science. However, IQWST also is committed to students learning the inquiry practices associated with systematically producing science knowledge by formulating their own ideas about the patterns in experience and proposing arguments to support those patterns with the social practices of science.

Mr. Dee expressed a commitment to a different type of science practice for producing knowledge when he commented that the IQWST experiment procedures were to prescriptive.

> "Now with some activities you don't want to have such prescribed procedures. It might be we did this one with mirrors, but how would you set this up to see what happens with paper and reflection...To where they're experimenting to see what's happening. It's kind of like that messing around with science stuff."

In a way Mr. Dee is describing a practice similar to the IQWST practice of testing ideas based on a model, but Mr. Dee is emphasizing the students' experience with the mirror as a point to start from and then students can mess around.

Because for science a part of messing around is the analysis of the results, I asked Mr. Dee about the purpose of graphs and he replied, "With graphs, I mean that's just a visual representation of the data." So, this also indicates his commitment to the practice of science being intuitive, and explains his practice of dismissing the data quickly and providing other examples like the billiard and bouncing balls. For which he explained his reason, "I think probably getting to the playing the pool thing was tying it to other situations they've seen that eh, acted in a similar way, and probably at least touching on the idea of light as a particle."

Practice Resources. The previous comment also indicates Mr. Dee's wealth of personal resources for thinking quickly about examples that are visually appealing and scientifically accurate for explaining the content. Mr. Dee easily creates other ways to visually relate the students' experiences with the light detectors and scientific data to science content. He often added other non IQWST activities because the IQWST activities were not rich enough, for example he talked about the anchoring question for the IQWST unit, "There wasn't enough difference to have much interest in that activity so the kids were uh, feeling, you know like it's a waste of time." And in many of the other lessons he added stories like controlling variables with the carburetor on his lawn mower, why the shirt color he picked at home in his closet looked different at school, and had many objects like polar bear fur and periscopes to illustrate science concepts.

So, because of his personal knowledge and pedagogical resources for explaining concepts, when the IQWST data wasn't illustrative enough, he quickly found other examples to illustrate the content as a substitute for utilizing scientific practices. In fact, some of the additions Mr. Dee provided were incorporated into the revision of the IQWST materials.

Social Norm Commitments and Resources

Social Norm Commitments. A common concern of teachers and the IQWST materials as well, is that a learning environment is developed in which students feel that their contributions to the classroom will be valued. Mr. Dee is committed to providing a comfortable social classroom atmosphere in which students feel as though they are part of the classroom conversation and safe when their ideas are shared. Mr. Dee's use of the predict participation structure is consistent with his commitment to maintaining a social norm where each student can safely participate with their own individual predictions.

Mr. Dee is able to draw on the predict structure because of his personal resource knowledge of situations for which students can make predictions including the rubber bouncing ball prediction, and predictions from other lessons about how hot a potato will get, or what color a shirt will be. He uses the predict structure as a tool to both structure the participation by limiting the opportunities for student failure, and as way to provide students more turns in the academic conversation.

> "But I've found in other situations where I want to do a prediction, and I really want them to have a stake in it is I'll have them all stand up. I'm like Ok, if you think this is gonna happen sit down, that way by the end everyone has voted, there's no one left, unless you're left standing. So I tell them there's going to be three options, you can vote this way, or this way, or if you think something else might happen but you're not necessarily sure, Ok? And uh, so by the end of it they vote, well, they think that every single person in the room has noticed what their vote was, and no one cares a bit, ok? But they're like I've put it out there, you know?"

IQWST also use predictions as method to make ideas public and stimulate the purpose for testing investigations, but Mr. Dee changes the nature of the prediction to both stimulate participation and control the floor of scientific ideas.

Social Norm Resources. It is interesting that Mr. Dee expressed the idea that he uses the grandpa structure as a pedagogical strategy to change up the participation structure and allow students more opportunity to be involved.

> "I think that having them come close that's good because it's more of a conversation kind of like the nature guy, come here and oh, look at this plant, you know. Everybody gathering around looking at it, you know it's more of a relationship kind of discussion or explanation. Rather than you know here it is flowing this way from the podium kind of thing."

However, my analysis in chapters 4 and 5 both show that all that really changes in the social norms for participation is the physical proximity. In the end his commitment to his role of clarifying knowledge changes the tool he intends to use to distribute participation into one more strategy for maintaining the social norm that students have the opportunity to share ideas with Mr. Dee but those turns maintain the teacher student dyad relationship rather than the student to student sharing of ideas.

Socioscientific Norm Commitments. In contrast to Ms. Kay and IQWST, Mr. Dee did not value the practice of analyzing data. He commented about what he was doing when he asked groups for their data and pointed out the trends in the data to the students during the report data participation structure, "I guess I was trying to walk them through the data." So in Chapter 5 when Mr. Dee discounted the student's claim about the values of the data, Mr. Dee had decided it wasn't important for walking the students through the data because of the model he was using that there should be more variation. In other lessons Mr. Dee continued to quickly dismiss the data, for example in lesson 8, when the data from the experiment was not rich enough, he quickly demonstrated a different experiment. Walking students through the data is consistent with Mr. Dee's role of the nature guy because it enables him to show students what the data represents.

But Mr. Dee also has a commitment to students being active thinkers in the classroom which he supports with the predict participation structure, and so when the data threw Mr. Dee he instead asked the students to predict where they thought the light detector reading should be the highest. And he did this because,

> "I think that um I was trying to keep the kids from grabbing on to a misconception as being the truth, and that happens sometimes when you have something that doesn't work out, and you're quick to oh it did this, but that's not the way its supposed to have worked, there's something else going on here."

So in contrast to IQWST where students are intended to reason with the data and decide that the data is bad, Mr. Dee adapts the task to make the task simpler. Also he doesn't believe students will reason with scientific norms.

> "some of it I think has to do with the kids that you've got, if they're a fairly sharp group, that can handle having various opinions and being able to hear them all and then you know finally stick on one even though maybe another one seems more popular"

So, while the IQWST commitment is to the practice of building arguments from evidence which requires that some arguments are to be made. Mr. Dee however purposely adapts tasks to avoid alternative ideas either because the data was faulty, or he believes students will decide what counts based on popularity rather than the analysis of the data so he does not even attempt pedagogical strategies to establish the scientific norms of peer review and critiquing arguments. Instead, he uses the grandpa participation structure because the norm is for the teacher to

> "Know lots of different ways of explaining something, to be able to create equipment or demonstrations or something as the need arises to get kids to understand something if a question comes up, or you know just part of your regular curriculum."

Here Mr. Dee defines the socioscientific norm for the teacher as having to move kids to the instructional goal with different ways of explaining which includes making materials that represent those explanations. And as a part of that norm it is necessary for the teacher to be confident in the activities, "its important that it get clarified, and that the kids are confident that the teacher understands it. Because I think that the day before it probably came across that I was not liking the data." In the end Mr. Dee is committed to the socioscientific norm that the teacher should clarify knowledge, and it is the teacher's responsibility to be confident in those clarifications.

Mr. Dee altered the IQWST practice of modeling when he used models to relate students' experiences with intuitive objects to connect the data from the experiments to the explanations he constructed. He values the analogy participation structure because his role is to identify intuitively appealing explanations for students, "I'm trying to get them from something that seems very obvious with mirrors that they would understand to this more abstract diffuse reflection thing." Again once more we see the commitment to his role as being responsible for making the connections for students between their experiences and the explanations. And he sees the need for this because the classroom does not have the tools of science,

> "There are so many things in science that are too small, too big, too fast, too slow for kids to experience. We don't have the materials, the equipment to magnify this and have kids see the light's coming in this way and reflecting off all these different ways. So we have to have a model of some sort."

When in effect, IQWST intended the data tables to be the tools, or equipment of science to show students the ways light comes in and reflects off. So, what is evident here is a different socioscientific norm from IQWST in which students together construct the explanation, whereas for Mr. Dee what counts as an appropriate scientific explanation must be intuitive.

Socioscientific Norm Resources. What is interesting is that Mr. Dee used the report data as a way to maintain the social order in the classroom while he is personally responsible for evaluating the evidence.

> "I think what happened was I was probably thrown by the data...That's why I polled the whole class, to see holy cow are we having a problem with equipment here? With this group I was like, ok, anybody else? You know give me some more data, something's not working out here."

In lesson 6 Mr. Dee stated to the class that the data "didn't sound right" and no student questioned that claim. It was clear that the socioscientific norm of Mr. Dee providing explanations had not been broken.

Mr. Dee is quick to depart from IQWST tasks and use analogies because he can which is consistent with his wealth of personal content and pedagogical content knowledge resources. In the interview while watching the clip, on the spot he came up with another way to get the students from something obvious to abstract,

> "So, these mirrors that are all at different angles and that would probably be an interesting thing to do, with like Styrofoam or something like that, is to have a sheet of all these little mirrors that are all at different angles, Ok? And have that be a model of the diffuse reflection."

And Mr. Dee does use as a personal resource equipment and demonstrations. After the interview in his classroom he showed me a lot of equipment that he has built to demonstrate concepts, and throughout the pilot enactment he made numerous suggestions about how to improve the experiment materials.

Summary

In a culture of scientific practice the role of the teacher is to mediate scientific knowledge for the students…rather than to organize individual sense making about the world (Driver et al., 1994). I think Mr. Dee operates more with this role in mind of organizing the sense making of the students. With his comments about walking students through data, and his construction of materials that are neat, interesting, and useful for clarifying concepts Mr. Dee instead attempts to "extend his students' knowledge of phenomena – a practice perhaps more appropriately called nature study" (Driver et al., 1994, p. 8). Also, necessary to a community of validators of knowledge, Mr. Dee does not share with IQWST the core commitment to a community inquiry practice in which teacher and students "problematize the content" (Engle & Conant, 2002). Instead, he purposely does not introduce or allow students alternative ideas in the classroom because he believes it is possible that students will remember the alternative ideas rather than the canonical explanation.

Ms. Kay

Ms. Kay's enacted teacher role is "the gatekeeper," she has the commitment to a model of scientific inquiry practice that proves science content. However, her personal resources in terms of content and practice conflicted with the view of knowledge in the IQWST inquiry community. Ms. Kay engaged students in the practices of gathering data, and analyzing data but ultimately when the data does not fit the scientific laws and truths that Ms. Kay is trying to teach, Ms. Kay chooses the data that provides the patterns science has claimed as true. While Ms. Kay's role is to provide the final authoritative explanations for what the truths are, she also has the role of making sure her students feel successful at their work, and the students have the responsibility to talk to Ms. Kay and let her know when they do not understand the science laws.

Ms. Kay adopted many IQWST tasks because she is committed to using inquiry in her classroom.

> "I think that ever since this popular inquiry has come up...I think that it is definitely important that the teacher has had some sort of opportunity to be in some sort of inquiry workshop, or see some sort of example as to what inquiry should look like...this new age science teaching."

However, in the following sections I will show that her commitments and resources to more traditional forms of content and practice mix with her commitments to the IQWST design to explain why she enacts the gatekeeper instructional role.

Content Commitments and Resources

Content Commitments. In order to indicate the form of science knowledge that Ms. Kay valued and contributed to her mixture of reform-based IQWST and traditional practice, note her introduction to the experiment in lesson 6 was "to show." She also indicates her commitment to knowledge with the way she ended lesson 6, the last point she stated was the law of reflection. In effect, Ms. Kay has a commitment to content that differs from IQWST, because Ms. Kay is committed to proving patterns or scientific laws in contrast to the IQWST commitment to the construction of scientific models.

She states a number of things in the following quote that indicate the law like nature of the science content she values. First she explains the value of data, then that the lesson was a good attempt to follow the IQWST curriculum, and finally what she was looking for.

> "It was a good day if you get good data, but here it didn't work. So, this is great because it's a true sign of somebody reading a booklet and attempting to produce what's in black and white, you know?...But, 'initially it didn't work guys, this ain't what we're supposed to have. I told you, we have this truth and this was supposed to prove that truth and it and it didn't.' So now you're [Ms. Kay] caught between a rock and a hard place, so that's where I was… but you're looking at a teacher that had to have black and white. Develop question, we're going to work through, and that's how I operated you know. So to me, there it was a freak out."

In Ms. Kay's description of the events of lesson 6 it is evident that Ms. Kay saw breakdowns in the lesson, or as she said "a freak out" because the experiments had not provided data to prove the black and white science content she valued.

Another way Ms. Kay differed in content commitment from IQWST is the difference in learning goals. An IQWST learning goal includes both the content and the scientific practice, whereas Ms. Kay focused on the content as her learning goal.

> "I always know learning goals, that was just something day one. I was like ok I can teach it… I know what the learning goal is, and I'm now if I worked through all the junk, I can handle the craziness, but I understand my real purpose in mind."

Ms. Kay values the content of the learning goals because as she stated here in all the uncertainty of a class day, the one thing that she can rely on being certain of is covering the content in the learning goal.

Content Resources. Later in the interview we were talking about how to help students make connections between the experiments and the learning goals and it was here that Ms. Kay stated the IQWST learning goal of revising models never occurred to her. I had just asked her how IQWST could put in the teacher guide an emphasis on revising models,

> "Good point, yeah how could you? Cause I think that that's so important early on… to have that in your mindset…and the big thing there was models, and making your models work and revising when you come up with a new discovery, or new idea, or new phenomenon or whatever…so I think it's a very important component, something I hadn't even thought about...but that was the furthest thing from my mind you know. I'm thinking of the immediate, this data got to prove something."

So what was missing here is her personal resource understanding of the purpose of models, and the second half of IQWST learning goals, the practice of revising models. And on that note of personal understanding necessary to teach the IQWST learning goal, it was also evident when I observed Ms. Kay's classroom and talked to her after class that Ms. Kay's content understanding of the data pattern her class collected in lesson 6 was different from the IQWST content. The data pattern had in fact supported the IQWST goal for representing scattering and reflection. But it was apparent that in the class period two days later, that Ms. Kay understood the data pattern should provide evidence that the law of reflection still applies to paper and other rough surfaces. So, similar to Mr. Dee she was also using a conceptual model different from the IQWST model.

Practices Commitments and Resources

Practice Commitments. In Chapter 4 I described Ms. Kay's science practice as a process of verifying science knowledge. Yet verifying knowledge is not the intended IQWST process of constructing knowledge, so why did Ms. Kay adopt the IQWST use of experiments and evidence? Ms. Kay stated "the initial attraction to the whole IQWST, was bridging that gap. Um, to foster… their own learning through investigations, hands on, the desire, you know to kind of learn." For Ms. Kay the valued way of thinking is using science ways of thinking in their everyday life, "to get kids to understand that science contrary to belief is needed in everyday life, bridging that gap from in the classroom to outdoors… letting them know, hey this is real world you see it in so many life applications."

But here is where the interesting contradictions between Ms. Kay and IQWST begin when she stated, "So, I guess I just feel deep down passionate about certain things as it relates to keeping kids convinced." This is interesting because IQWST envisions students bridging the gap from in the classroom to outdoors through a process of constructing understanding of knowledge that has been validated as a community. Ms. Kay values a way of thinking and acting in the classroom that keeps kids convinced, which is why in terms of the IQWST practices of students reasoning with evidence Ms. Kay is not as quick to adopt the scientific reasoning practices in IQWST.

Her beliefs about students and the learning process of science is that students expect the process and product of science to work.

> "So just from some sort of experience in my early years with something not working, kids get sick of 'Oh yeah, trial and error. It didn't work, human error.' So I've come to realize that things are not going to work. It's just kids expect stuff to work and when it doesn't, 'Hey what happened? Because you said you know this, you said research tells us this is supposed to work, and if this surface is in fact smooth, it's supposed to be equal. What happened?' You know. So that's just kind of how I operate"

So, in lesson 6 when Ms. Kay stated to the class that their data did not support the laws she was trying to teach, she was operating with her commitment to the relationship between science content as proven research and the practice of science does not work in the classroom. In effect there is a tension between the IQWST commitment to the practices of constructing understanding, and her commitment to the practice of proving what science knows and what kids expect to happen.

Practice Resources. Ms. Kay adopted the IQWST driving question board as a tool to help students establish the connections between their daily life and their classroom experiences.

> "And you know you have this driving question...getting them to understand that every day you come in here...you always tell the kids 'guys there's something that we're doing in here... and you ask yourself, and you can't think of how it relates to our Driving Question then you need to ask me.'"

But other tools in the teacher material she did not find as useful to use. Where IQWST considered the data to be a key resource for constructing understanding, Ms. Kay found the data problematic, "we're trying to get some data so we can come up with some evidence right? Inquiry right? [laughs] Kids get some evidence right? To develop some sort of conclusion, whoa." Ms. Kay had two methods of attempting to respond to students reasoning with data, first was to make sure the students followed the procedures.

> "I'm certain that I spent so much time there because I've had a disaster before where I said set it up. So you've wasted an entire class period where somebody has interpreted the directions as being this way, so we haven't had any consistency... I'm almost a hundred percent sure as to why I spent that time on the front end with set up... I mean clearly, we would do the same thing as it relates to setup."

But Ms. Kay recognized that students were not following the procedures carefully. And so, that leads to her second method of attempting to relate students experiences with the data to the laws she is trying to prove by using the vote, "Clearly there were some changes in data, so you go to the podium and majority wins, which was the rationale behind that last comment." The vote was Ms. Kay's pedagogical resource to demonstrate to the students her understanding of what the data from the mirror represented

> "I'm trying to make this look like what you [students] have. Let you know there is a pattern. You're not crazy, I'm not crazy, and this is gonna be the best way for me to point out this V pattern based upon what we see. So, that was really the rationale, bout how I, no thought process, I remember thinking of it on the spot. I'm gonna do a chart, lord I'm on tape, oh my god, what am I going to do? Ok, let's draw it out cause I mean I probably drew it six seconds before that."

One might think that Ms. Kay did not have the personal understanding of how the community of science analyzes data, but she immediately identified the contradiction between her practice, and the practice of science.

> "I had prepared to just do a traditional chart, cause you tell your kids you want to put your data in a chart. When you think of collecting data, that's [the vote] not even a traditional way that you would even collect data or even organize data. You teach them process skills, when you make observations during the investigations you're going to take this data, put it in a chart or a graph, you're going to interpret a chart or graph, so that was clearly a non traditional way. So, what I had prepared and what I did was just clearly not gonna work, I'm gonna draw something real quick, I just drew it to try to make sense of it. And, um, what probably prompt that on that spot was me going to see that hey, this data really isn't perfect."

Ms. Kay has the personal understanding of scientific practice, she identified the difference between the authentic practice of making data charts and graphs, but in her on the spot decision she decided these were not persuasive enough to prove to the students. So, she manipulated the chart to prove the pattern they were supposed to find.

Social and Socioscientific Commitments and Resources

From Ms. Kay's previous comments it is evident that tensions existed between the IQWST commitment to using the practices of science to construct understanding of models, and Ms. Kay's commitment to using practices to prove scientific laws. So, in the next section I explain the norms in the classroom that were consistent with Ms. Kay's goal to help students understand the content and see the value of science in their lives.

Social Norm Commitments. Ms. Kay described her goal to be a facilitator that guides students with the best possible instruction. And she also said that her commitment is to the black and white content because when it isn't "then it only pulls them so much further away from science and why they need it." And Ms. Kay wants her students to be successful in science class and she knows they can be "You know, I'm going to pull it out of my kids because I know its in you...but just in my mind I was going to guide them anyway." Because in Ms. Kay's classroom the valued content is the black and white knowledge, the term participation structure is a valued way of thinking and acting which is different from an IQWST way of thinking and acting if students were constructing knowledge and understanding. This structure was consistent with her commitments to the content being black and white because vocabulary is an easily identified form of understanding, and because vocabulary is a brief response Ms. Kay could quickly nominate students to provide the correct response and pull the right answer from her students.

Social Norm Resources. However, while she referenced the ways de-centered expert facilitates the discussion by pausing, reflecting, and giving students an opportunity to reflect, when students aren't reflecting on what they have learned she refers to the traditional facilitation she was trained to do and what she has learned from experience.

> "Because you're trained to believe that if they're not giving you what you ask, you help them out... I've just learned you know, you just kind of help them out, you assist them, you meet them where they are and then you gradually help them. How do you help them? By maybe having them pause or reflect on what they've said, of have them think about and then rephrase. But really, just giving them an opportunity to as opposed to taking over you know which is clearly how I started. Clearly, I mean without a doubt.

But she also mentions as a part of learning how to help students out, that the prompts in IQWST are helpful but kids have their own ideas that IQWST didn't prepare her for. And, when kids have other ideas that make the logic of the lesson difficult to complete, she again guides the students.

> "Cause you expect it as a teacher to work, they [IQWST] said it was going to work if I follow these procedures. They [students] didn't ask. Because you had the wonderful guide that it prompts you, but they [students] didn't say that. This is what I need them to say in order for this to be a smooth transition, so what do you do? You quickly guide them to what you want them to say. You basically make the sentence and let them fill in the blank."

So in effect she uses the term structure to distribute participation because this is consistent with her personal understanding of the black and white nature of science content which is easily defined with specific vocabulary terms in contrast to ways students might describe their own ideas. And she trades the students' making sense of the experiment, for the process of completing the lesson. In one sense she differed from IQWST because she believed the curriculum material would work, that it is a trusted resource. But when the educative material did not provide the necessary information she resorted to her past traditional training. And this is an important point because in contrast to Ms. Kay and Ms. Cee, Mr. Dee did not mention lack of support from the curriculum material due to his personal resources necessary to make his own sense of students' responses.

Socioscientific Norm Commitments. In the report participation structure Ms. Kay asked students for data, then explained to the students what the data should show. This process fits with the science practice in Ms. Kay's classroom because of her commitment to her role in the learning process. The socioscientific norm for this process determines what is considered appropriate in terms of expected contributions to knowledge, and who makes decisions about evidence.

> "And kind of what led me to the vote, well my thing is you tell kids. Kids are expecting, no matter what you tell them, they are expecting that when you do an investigation, it's going to come out right. 'You are the teacher and you told me that if I put, this half a potato in a bag on some wet moist paper towel, that I'm going to have some sprouts.' So and in a kids mind, it's always 'Oh yeah it didn't work. It never works.'"

She is describing here her thoughts about how participation in a science classroom is expected to be distributed. Students expect to do things that will turn out right, and when things do not go right the teacher's job is to figure out a way to make it appear right so students do not think science does not work. The socioscientific norm is consistent with her commitment to science content as something black and white and science practice as a process that works.

Socioscientific Norm Resources. Ms. Kay used the report structure as a pedagogical resource to model the practice of creating arguments from evidence.

> "They've engaged in an investigation, and I was just attempting to make sense of it, my collecting data and see if they can see some trends so that they can even realize that it was evidence, according to some claim. Taking a look as a class together."

While the practice of reasoning with evidence is important to both IQWST and Ms. Kay, she adapted the practice of validating the evidence with a vote. And, what also is important is that Ms. Kay states here that again, it is the teacher's responsibility to make sense of the data because Ms. Kay is committed to a process of science that works to prove the truth of the content. However, in terms of a mixture of traditional and IQWST practices, Ms. Kay's report structure is important because in contrast to Mr. Dee and Ms. Kay who did not attempt to model reasoning with evidence, Ms. Kay did attempt to establish the socioscientific norm that patterns in data are an important part of science. While Ms, Kay had the classroom management resources to distribute participation and nominate students to propose their own ideas and make sense of the data, Ms. Kay did not use this resource to respond to student reasoning.

So, she's committed to the "role as a teacher being a facilitator to make this effective." But when after an experiment and she has asked the kids where the evidence for the explanation comes from and the students have not made the connections she explains that she resorts to what she calls her traditional training.

> "Oh, Lord, we have done that, I mean in my mind, I'm thinking, we just done that, and they don't even remember why, what was the? They just thought we had mirrors and a meter stick it didn't even click. So initially after a hand didn't go up to say 'oh the mirror' I'm like, God, it didn't work. What? So, that's kind of why I keep 'talk to me guys, come on think, yeah you're right, think, think.' So clearly, just trying to help them make connections."

So, in order to figure out what students are thinking Ms. Kay asks them "does that make sense" and when the students reply she can continue with the lesson. And while she is committed to helping the students make sense, her pedagogical resource is consistent with the socioscientific norm that distributes responsibility to the students for telling her when they do not understand, so she can continue to try to make the connection for the students between the process of experimenting and the laws of science that data is meant to prove.

Summary Ms. Kay

In the end I think Ms. Kay is a really interesting mixture of commitments to content and commitments to practice. She has a commitment to laws of science, in contrast to the IQWST commitment to models built upon the scientific laws. And therefore, this commitment to laws is reflected in her commitment to a scientific practice that should prove the laws.

With both her own commitment to the black and white content of science and the students' expectations that science works, the socioscientific norm that the teacher's role is to reveal the scientific truths to the students is consistent with the scientific practices Ms. Kay models. So she manipulates the practice of science with the vote, but she also realizes her students do not understand the law of reflection with the evidence and in the end uses the analogy with the road that is in effect similar to Mr. Dee's use of bouncing balls to explain scattering and reflection. So she sacrifices her commitment to process and practice of science in exchange for science content that is absolute and true. Although she is open to the view of science as building and revising models from evidence as IQWST intends, and at least in the interview she sees the usefulness of constructing and revising models, Ms. Kay often resorts to what she calls her traditional training to achieve her academic goals for the lesson.

Ms. Cee

Ms. Cee's enacted role as "the tour guide" is another interesting mixture of her commitment to an alternative vision of inquiry and limited personal resources necessary to sustain the IQWST vision of inquiry. She values the students' experiences with the activities in the IQWST curriculum and provides the explanations. She welcomes the opportunities for students to do science, do the experiments, but when it comes to analyzing the results, she does not model the practice of formulating patterns and explanations. Instead, she sees as her role the importance of providing the opportunities for students to explore and talk about their ideas, and then read to them the right knowledge in the form of explanations from the curriculum material.

Ms. Cee also expressed as her teaching goal a commitment to inquiry when she described her goal for science teaching.

> "Well definitely to ah create kind of mini scientists [laughs] I would say. I want kids to kind of learn that aspect of it more so than 'Ok, here's the worksheet. This is what's going to happen and do it.' I want them more inquiry based. Them to learn how to do it. Them to be able to come up with their own ideas. Do you give them a question? Ok."

So, where Mr. Dee and Ms. Kay expressed a commitment to inquiry practice that was concentrated on the content, Ms. Kay expressed a commitment concentrated on the process of science. For Ms. Cee, her goal is to transform her students into mini scientists by investigating phenomena just like scientists.

Content Commitment and Resources

Content Commitments. For an indicator of Ms. Kay's commitment to the nature of content best suited to the learning of science I go back to part of the previous quote, "here's the worksheet this is what's going to happen and do it." With this I think Ms. Kay is expressing her discontent with the traditional forms of school content found in worksheets, but at the same time she follows that with a preference for "Them to be able to come up with their own ideas." Students' coming up with their own ideas is not the same commitment to content found in IQWST where students validate accepted canonical science content, but does explain why of the three teachers she is most likely to have students propose alternative ideas in the class. However, unlike Mr. Dee and Ms. Kay, Ms. Cee does not have the same commitment to the explaining or proving the science content.

Content Resources. A number of indicators of Ms. Cee's limited personal content knowledge resources occurred during the viewing session. She expressed her struggle with making sense of the content and students' reasoning.

> "I think that the discussion part went fairly well. And I remember struggling with which is another thing that teachers should be prepared is, how to actually get to the point that they want to get at. And I struggled a lot with that with a couple of things. And I'm not sure why that was, whether it was because I wasn't quite sure where I was at. I thought I knew, and then all of a sudden when I got there, its like well, wait a minute I thought I knew this, I read this, I did this, um, but now I'm a little unsure on something."

And Ms. Cee commented on her own need to use more scientific terms while watching another clip about her explanation of scattering and reflection

> "I think this teacher needs to learn some more scientific terms. Willy nilly I'm telling ya. …Now see that wasn't good. I never really specifically explained to them, 'Ok, so that was scattering.' Now which one of those did we end up really doing? If I was a kid, I'd say 'ok, it's scattering, but if I had to come up and draw it again. If I had to come up there and draw that again which one of those four am I supposed to pick? Which one of those four was it supposed to be?' I think it's good I'm going to computers. [laughs] Anyway's no. Yeah, definitely needed to have more clarification on that."

This shows her own personal lack of knowledge about what scattering and reflection are, she expressed her own dissatisfaction with her use of "willy nilly" as a scientific term.. She also recognized now she had not responded to students' reasoning and clarified the scientific explanation. In addition after this particular lesson during a personal communication with me I had tried to explain to her what scattering actually was and she said she felt terrible about not clarifying the content and would make sure to go back and explain that the next day. There were many other additional instances throughout the unit when students proposed explanations that were actually more scientifically accurate, yet Ms. Cee continued to assert her own inaccurate explanation.

Practices Commitments and Resources

Practice Commitments. I asked her about the IQWST material itself, and this demonstrates her commitment to authentic practice which is students learning science by doing the science.

> "But, I do think that they have a good solid structure, and I like the way they [IQWST] interweave the different things like modeling, and data, and you know doing this along with the subject. I think that makes it a lot easier on the kids, because they don't even realize that they're also getting these other things like you know the driving question board, and they don't even realize they're getting that."

What is important and different from IQWST is Ms. Kay's comment that "the kids don't even realize." IQWST expects the teacher to model and coach students in these scientific practices. However, Ms. Cee believes students will learn simply by engaging in the process of completing the IQWST activities.

She also identified her commitment to the practice of learning science when she noted that her beginning of lesson 6 was not actually how she had intended.

> "Well in that particular clip I don't see any inquiry per say. Well maybe a little on the questioning, but not what I consider to be, I mean. I I just told them they were going to set this up, so I've set it up for them. I didn't ask them, 'if I wanted to do this, how would I set it up?' I didn't give them a goal, 'ok this is our purpose, now how are we going to set this up? How are we going to do it?' I got some materials here..."

I asked her about her decision to start this way and she asked me if something happened before this clip "Do you know if before we went to question board?" I told her she had not gone to the question board and this was how she began lesson 6. She noted she should have but then went on to express a commitment to the process of learning science through the experiment.

> "But still, the lesson is the lesson. The experiment is the experiment. Which if it be true inquiry it wouldn't be. Unless, I think I probably was trying to follow the

> format per se. Other than maybe not the driving question board, you know the lab part of it to the uh instructions. Knowing that we're trying to test this out."

What this quote explains is why Ms. Cee conducted the experiments with the mirrors and the paper back to back without discussing with the students the pattern that the mirror experiment was intended to produce. While she expressed a commitment to a community of practice where students test their own ideas, she believes the learning process is facilitated through following the format of the investigations. Ms. Cee's commitment to the practice of science is different from IQWST, Mr. Dee, and Ms. Kay who all in different ways expected the teacher to take an active role in helping students make sense of the process.

Practice Resources. To teach for understanding in the IQWST vision, a teacher needs to have the personal understanding of the scientific practice of inquiry, and Ms. Cee identified her own limited understanding of the nature of inquiry.

> "So if you wanted to make it a little bit more inquiry, a little bit more freedom in there, you can have guided inquiry. But, so another thing is, you're going to have to have a teacher who really understands what inquiry is. Which is a very difficult thing. And I can't tell you that I do completely either."

In part this may have explained why in the previous section Ms. Cee explained her valued way of acting as following the format of the experiment. But as a teacher committed to following the IQWST curriculum guide, in a way, the curriculum was a resource that actually hindered her own ability to respond to and support students' reasoning.

> "Because, that was another thing that would sometimes happen, is I would read the lesson, and then have it ready for the next day, and re read it in the morning and make my notes, but I never really looked at the goals, ok? I just kind of went along with the way it was written, and if I had a question I might, I would look at the background or maybe ask you."

She did not look at the final product intended by IQWST which was for the students to use evidence and construct understanding of the light model. Also, when she had a question she looked to the curriculum material rather than drawing on her own resources to adapt a new solution. So, my explanation for Ms. Cee's enacted teacher role is that she is committed to inquiry practice, but her personal knowledge resource of inquiry practice is limited and she values following the curriculum material as the way to lead her students through the process of science.

Social and Socioscientific Commitments and Resources

Social Norm Commitments. One day at the beginning of lesson 6 the following interaction occurred.

> Student: Are you a tour guide?
> Ms. Cee: And to the left we have the overhead. No, I'm not a tour guide. Yes, Yes I am. I'm a tour guide that is going to lead you through the exciting things of science.

This interaction illustrates in some ways the tension between Ms. Cee's commitment to learning as a process where students come up with their own ideas, and her need to be in control, which she describes as being a good director. She states here that she values directing students to a particular answer, in this case the "v" shape pattern.

> "So, I think it's really important if you're going to, like through the discussions, to know how to be a good director to where you want them to go. Um, as far as inquiry, I think they were kind of thinking a little bit along those lines, but it was still kind of, it's more on the end of your directed part of the inquiry."

In this quote Ms. Cee expresses her belief that the learning process needs to be directed by the teacher. Ms. Cee attempts to both direct the conversation, and encourages students to share their ideas, which is consistent in her participation structures because the students in comparison to Mr. Dee and Ms. Kay have more rights to initiate turns and new topics.

Social Norm Resources. Ms. Kay has identified her own limited ability to design something for her own students. And in fact later she herself picked up on in the video clip where she was reading from the teacher guide

> "Did that seem to flow? Do you remember? Did that seem to flow right in terms of the way it was on the overhead. I think it's really difficult. Or I think that by watching, if your just specifically looking at this, is the fact that I haven't done it before, and I think you see a lot in all of these clips, of just, even though I might have, read it, prepared it, it's just different because now I know that I'm in front of the camera and have to get it just right, and I get confused and, I'm trying to think of what I'm going to do. Like, I didn't like the part where I was just reading it out of there. To me, reading it out of there tells me, the teacher doesn't even have it, you know, she's just reading it out of there to. So I'm thinking maybe just practice it a little bit."

In effect this links back to her limited content resource, she has identified that 'just reading it' tells her the teacher does not have a deep personal understanding, and to compensate for that lack of teacher understanding participation is not distributed amongst the teacher and student but from the teacher guide to the students. She uses the teacher guide as her own personal resource because as Ms. Cee stated she gets lost in the content when discussing it and attempting to make sense of the students' reasoning. So, she uses the teacher guide because it is her anchor in the storm of student ideas.

The use of the teacher guide is also consistent with her resources for establishing her role as the social authority in the classroom. In contrast to Mr. Dee and Ms. Kay, Ms. Cee has not established a similar high degree of personal social authority so when she makes a claim, the claim is grounded in the IQWST material.

Socioscientific Norm Commitments. I already quoted Ms. Cee here for her commitment to inquiry, but I think this quote is important again because it illustrates one reason why she seems to use the move on participation structure with unresolved questions or answers, "Them to learn how to do it. Them to be able to come up with their own ideas." This is in a way similar to IQWST where students should produce their own ideas, and Ms. Cee adopts the sharing of student ideas. However, IQWST also intends for the classroom community to use scientific practices for validating data to decide upon one idea that best fits the evidence. In the next quote Ms. Cee described that she values students coming up with and sharing their ideas when I showed her the clip about the student talking about his homework and she suggested that he try the experiment again to test his mom's idea.

> "So we didn't really actually see where he did try it then. I think it would have been important then at that time to maybe, to figure out a way to try it. I think the best thing would have been to stop and say, 'Ok, well you've got materials here, go try it.' That was the perfect time for him to be able to get that straight in his mind. Because until he did, he wasn't going to, you know he'd always be thinking about that, I think. But, so that was kind of a missed opportunity I guess. To let him go and explore that...Actually that would have helped him get the lesson done I think a little bit better. And then maybe have him share with the group, or he could share with the whole class, say well you know I had this question about the reading last night, and so I just did it here and this is I what I found out."

When I first saw the interaction between Ms. Cee and the student about the homework I thought this was a resource issue because Ms. Cee was not personally capable of reasoning with that student's response. Instead after this comment I now think that when she asked the student if he had tried it but did not coach the student in ways to test the idea, Ms. Cee was simply acting out the socioscientific norm she valued, that science inquiry and science practice is a process of discovering and sharing individual ideas. However, I also think if she did have a better personal understanding of the content she would have also provided suggestions on how to test the student's idea.

In the next quote it is interesting to note that Ms. Cee expresses discontent with her own valued way of acting to support students in becoming mini scientists who come up with ideas and her actual use of the IQWST teacher guide as the tool to make sure the lesson ends right.

> "But, so I think that's basically why, because I wanted to make sure that they did get the correct concept. And I think that in my mind, I thought I was sure, but I was kind of self doubting there to make sure that I didn't mess it up, because earlier things I kind of had, that I was just going to read it from there, then I would know that that was."

As she says she had a commitment to getting it right, so at this point there is a difference it seems in what she values for thinking and acting in the classroom. She has said many times she values students coming up with their own ideas, but when it comes to her own personal thinking, she does not consider her own reasoning important, but instead she sees getting the curriculum material completed correctly as the valued way of acting. So her personal habit of mind of following the teacher guide to get it right leads to her reading to the class from the teacher guide. These tensions in her own commitments to two different socioscientific norms of everyone sharing ideas versus the one right idea from the teacher guide are consistent with her limited understanding of nature of scientific inquiry and the social resources to distribute participation so student not only share their ideas, but actually debate them.

Socioscientific Norm Resources. Now IQWST and Ms. Cee both identify the need for the teacher to in some ways direct the students in how to construct understanding, and one essential resource for that is to be able to respond to students' reasoning. I asked Ms. Cee how she could have responded after a student stated there were four theories about light scattering.

> "Well you could actually do a demonstration of it to see which one of them were correct. Or have each one explain, see because we just had them go up there and draw what their end result was, they didn't explain why they got that, or why they think the light did that. Why they thought that it went in that zig zag direction.

> Why they thought it went up, or over. They didn't tell us why they got that. They just drew it on the board."

So with that shows her limited personal resource understanding of the purpose for the experiments in IQWST. The students had already conducted the experiment, but Ms. Cee did not realize that the experiments provided data to analyze. Unlike Ms. Kay who tried very hard to analyze the data, and Mr. Dee who quickly produced analogies to explain the data, Ms. Cee directed students toward the words scattering and "v" shape with the tour guide participation structure.

In the following quote Ms. Cee recognizes the tension between her own commitments and her practice for directing students to the answer for deciding upon the correct theory.

> "I mean then I thought, 'Oh good we've got it.' Because scattering and I told them. But now, if I were to look at this, I'd say 'gee I really wonder, do they really? Or did they just, ok this is what you told me.'"

Looking back on the video clip, Ms. Cee recognized that in her classroom there was not a scientific norm of reasoning with evidence, instead the norm was to direct the students to the answer, and the students would use the terms Ms. Cee directed them to and accept that but not really come up their own ideas.

One reason for her moving on is her limited personal understanding of the science, one of the questions I asked her when she saw this clip of the four theories was where did the numbers go and why didn't she use the data that had been collected, "Why don't I go back, because I guess I'm not a strong data person." She talked about how previous materials had not required her to support student reasoning,

> "See because like, the math and science kits, you didn't really have to have the prep for those. You just, I mean they had the assignment, you come in, you did it. There wasn't the discussion questions in it. There wasn't the going back and making sense, they just put their answers in the journal, and then you corrected their answers in the journal."

And so since she had never been required to use data and reasoning with previous curriculum materials when she used the IQWST materials, she was not prepared to engage students in discussing and reasoning with their data.

> "There wasn't the discussion piece, and I think that was key. Because even I struggled with it to, but just kids being able to discuss it, and to think I didn't obviously think about using data. For them to think about the fact that that's a good way for them to prove their point, and for that to become natural, would have been, I mean it didn't happen, but now I look back on it, if I were to think of a goal for teaching it next year. A goal that I would have would be that my kids would be able to answer your question fairly fluently using their data that they got. That would be a success for me. As I look back at it now, before success was just trying to get through it."

So for Ms. Cee there were a number of personal resources that were limited. One, the norms for reasoning with evidence did not occur to Ms. Cee because she was a weak data person. Also, her previous teaching experiences with science kits had not asked her to have discussions with students and reason with data. Finally, there is Ms. Cee's sense of success, success comes with simply getting through the lesson.

In part the tensions in Ms. Cee's commitments to socioscientific norms and the participation structures used in her classroom are due to her own personal relationship with the science content. In terms of her commitment to the learning process Ms. Kay uses the teacher guide because the IQWST curriculum tells her and so she does what the curriculum says,

> And I think it says in there to tell students this, [laughs] You know, yeah ok, so I'm forty five years old, Ok, it says tell students, well I'm going to make sure I tell students that instead of you know rephrasing. It probably would have been better to rephrase it in my own words.

So in terms of the socioscientific norms of what counts as explanations in science, there is a difference here in how Ms. Cee perceives her role from IQWST, Mr. Dee, and Ms. Kay's vision of the teacher role. Where IQWST, Mr. Dee, and Ms. Kay all expected the teacher to be an expert in one way or another, Ms. Cee states here that when the curriculum says to "tell students" she hears that as a voice of authority and simply proclaims the content of science because she is less sure of her own personal understanding of the science and her need to be in control of the classroom.

Summary Ms. Cee

There are interesting tensions between Ms. Cee and IQWST in both the commitments and resources for inquiry practice which leads to the mixture of Ms. Cee's discovery oriented inquiry practice and IQWST. Ms. Cee is committed to aiding students in coming up with their own ideas, yet at the same time values the correct answer. Whereas IQWST recognizes that students coming up with their own ideas is problematic and difficult, and therefore the teacher plays an important role in scaffolding student experiences and reasoning to construct the understanding of scientific models. IQWST intended the curriculum materials to be a resource that teachers could use to scaffold student reasoning and building arguments from evidence, but also recognized that the teacher plays a crucial role in responding to student ideas. Ms. Cee however, has limited personal resources and finds it difficult to enact her valued way of teaching and at the same time reason with students' ideas in order to direct them toward the canonical science knowledge.

Discussion

From the sociocultural point of view it is important to understand how teachers make sense of their local community of practice and the community of practice envisioned in reform-based curriculum materials such as IQWST (Keys & Bryan, 2001). Within this local context are important relationships between teachers, students, and the ideas of what it means to know and understand science (Remillard, 1999). In this chapter I attempted to explain how the three teachers' commitments and resources toward science as inquiry, the learning process, and their resources to enact their commitments produced unique communities of authentic science classroom practice.

Mr. Dee is committed to a learning process that conflicts with the IQWST vision. As a result, Mr. Dee is not tied to the IQWST tasks, but is willing to appropriate some tasks that provide experiences with data, but equally ready willing and able to invent his own tasks to explain science content.

Ms. Kay both appropriates the IQWST tasks and invents alternative practices to complete the tasks. Similar to Ms. Cee she trusts the IQWST material to provide her with resources to complete the process of science, but in the end sees the need to alter the reasoning practices and so invents representations of data that prove the science content.

Ms. Cee appropriates the IQWST curriculum tasks because she trusts the process of science designed in the IQWST curriculum materials. And when the process breaks down, she continues to move on both because she is committed to the idea that the experiment is the process, and she doesn't have the personal understanding to reason with students' ideas.

In the end all three teachers through their commitments to valued ways of scientific thinking, the purpose of learning, and their personal resources to understand both the IQWST tasks and students' encounters with the tasks design three unique communities of classroom science. In the final chapter I will discuss some implications of this study.

Chapter 7

On the agenda of IQWST and other current science education reform efforts is an attempt to achieve the types of fundamental reforms in science teaching and learning that require changes in views of knowledge, and also changes in teacher and student classroom roles. Throughout this long history of attempts to reform teaching practices, studies have shown that what often occurs is a mixture of old and new practices (Cohen, 1988; Cuban, 1993). I set out in this study to describe and understand how three teachers designed their own classroom communities of science practice with IQWST materials. I presented an argument that all three teachers designed a curriculum that was in each case a unique mixture of traditional and IQWST academic tasks and instructional practices. First I will summarize my description and explanation of the three cases. Then, I will discuss three implications for the design of inquiry-based curriculum materials.

Conclusion

The IQWST curriculum materials are designed with a number of curriculum design principles that situate student learning in the context of the authentic scientific practices of building arguments from evidence and model-based reasoning. There are intended to be opportunities for the teacher and students to interact with both the people in the classroom and the cognitive tools of science which include the key ideas and practices. This process of learning the content of science and the practices of science is meant to be scaffold by both the teacher and the IQWST materials. What I have found in this study is that the teachers' curriculum designs were unique mixtures of practice due to a complex relationship between the teachers' personal commitments to curriculum design and their personal resources to enact that design.

I have presented a model of Mr. Dee's community of classroom practice in which he enacts the teacher role of the nature guy role. In this role Mr. Dee situates science content and practice in the context of explaining the relationship between students' experiences and the scientific laws that explain those experiences. He does this by establishing connections between students' personal experiences and intuitively appealing models to represent the scientific laws. He distributes the participation in the classroom community by allowing students the opportunities to express their ideas if they choose, and asking students to make predictions based on their understanding of science laws, but does not require students to share their ideas for the explanation of those laws.

In Ms. Kay's classroom she enacted the teacher role of the gatekeeper. As the gatekeeper there was a fundamental difference between Ms. Kay's commitment to curriculum design and the IQWST principles. IQWST acknowledge that learning science is a process of enculturation into a scientific community of practice with habits of mind that are different from everyday life, whereas Ms. Kay sees inquiry as a method of teaching to help students see the natural connections between science and their everyday habits of mind. In addition Ms. Kay is committed to a body of black and white science knowledge versus the IQWST commitment that knowledge is constructed by the community of scientists.

What this leads to is a context where science activity is framed by the problem of proving science. In Ms. Kay's classroom students learn to participate in a community that is not natural but different from the real world of scientists. In this community Ms. Kay was responsible for the thinking and reasoning to make sense of the experiences in such a way that would make sense to the students.

In Ms. Cee's classroom with her enacted role of the tour guide the learning of science was situated in the context of completing the tasks for the purpose of individuals expressing their own ideas. Ms. Cee has a commitment to inquiry that in some ways is similar to IQWST because her stated goal is to teach students to be mini scientists and so she values the curriculum goal of teaching her students the cultural ideas and practices valued by scientists. However, she does not have a personal knowledge of the content and practice of science, and as a result she relies on the IQWST curriculum materials to resolve the inevitable knowledge claims that arise in the context of students' attempts to make sense of experiences. Therefore, when the IQWST materials fall short and she wants to make sure that the lesson gets done right, she directs students to producing the names for key ideas and reads answers from the teacher guide. So for Ms. Cee, the flaws in the IQWST design are more evident because she is unable to draw on the personal resources that Mr. Dee and Ms. Kay draw on to pull off their visions of communities of science practice.

Implications

After completing this study I have three particular questions of interest that have implications for the design of inquiry-based educative curriculum materials. One question is what is, or should be the nature of school science activity? Two, what is the role of professional development used to support the use of IQWST curriculum materials? And, three what is the nature of "educative" curriculum material?

Nature of Authentic Science Community

IQWST has modeled the design principles after a vision of authentic, or paradigmatic, practice of science embodied in science education reform documents. However, Mr.

Dee's use of coordination of intuitively appealing models and student experiences raises an interesting question about the nature of the pedagogical structure for teaching and learning science. In addition to invitations to do inquiry as scientists, Schwab (1962) also proposed that narratives of inquiry were a potential method to teach science. More recent scholars (Bruner, 1996; Wong, 1996) have made arguments that learning science is not the same as learning to be a scientist, and that narratives as a mode of thinking are equally valuable ways to organize knowledge.

Mr. Dee has a wealth of knowledge of personal experiences, stories, and demonstrations that he can draw on to represent the content. So, when he interacts with a curriculum like IQWST, he draws from it what he sees valuable and when he has to make on the spot decisions he decides to use ways to represent the content rather than the social practices of an inquiry community that constructs the content. This raises the question for IQWST and other curriculum developers what is are appropriate practices of authentic science for classrooms? What are the appropriate curriculum aims and intents?

In addition to the issue of what nature of practice, narrative or paradigmatic, is an appropriate method to structure the content and practices of the curriculum, there is the question of within the current school context what personal resources do teachers need to distribute participation in authentic communities of science practice? In the classroom teachers are enacting roles at the nexus of multiple communities with interests and expectations for what happens in classrooms (Carlone, 2003). The type of roles that IQWST asks teachers to enact places distinctive demands on teachers that opens up uncertainty in the classroom, increases the difficulty of student work, and invites interactions that enhance teachers' dependence on the students (Cohen, 1988). While I do not doubt that Mr. Dee has the content knowledge, pedagogical content knowledge, and classroom management resources necessary to take on the distinctive demands that IQWST places on teachers, I do wonder, what additional personal resources are needed to take on the distinctive demands when teachers distribute more participation in the practice of science amongst the students?

The nature of professional development.

Professional development is an important aspect of systemic efforts to reform science education, and curriculum materials are one of a number of important aspects including professional development, and more time for teachers to learn from peers (Bransford et al., 2000). Important aspects of teacher learning that might improve the nature of professional development include teacher's prior beliefs and experiences, learning to teach new standards is difficult and takes time, content knowledge is key to learning how to teach subject matter, knowledge of children's ideas and thinking is critical for teaching for understanding, opportunities for analysis and reflection are central to learning to teach (Darling-Hammond & Ball, 1998). My study has revealed a number of insights into the three teachers' knowledge and beliefs about science teaching and learning.

Ms. Kay has been a long time participant with IQWST and previous curriculum development projects (LeTUS) with a professional development model that includes activities ranging from a 2-week summer institute, weekend work sessions, and classroom support from both university personnel and online support (Blumenfeld et al., 2000; Fishman, Marx, Best, & Tal, 2003). For the pilot study she did not have professional development for the light unit. However following the pilot enactment she had six professional development workshops before the interview, many of which were focused specifically on the scientific practice of modeling. And yet, she had not until my interview realized how the ray diagram model was revised in the light unit. Add to that her comments about science knowledge being black and white, and her personal experiences that you have to tell the students, I wonder what Ms. Kay has learned from the professional development? She also did say that she values the professional development and if it wasn't for the IQWST and LeTUS projects she would have left teaching.

And Ms. Cee participated in the same professional development opportunities prior to the second enactment of the light unit which I also observed and talked with her many times about her content and pedagogical knowledge and practices, yet in my interview with her following the second enactment Ms. Cee was surprised to think that evidence could be used to help students reason and compare their ideas, and she was surprised to realize that her students had not actually learned the ideas she was reading from the teacher guide.

But in person and watching their own practice Ms. Cee and Ms. Kay were quick to see issues in their practice, the content itself, and their students' understanding, so it leads me to wonder if teacher learning is situated in the context of their own classroom practice (Putnam & Borko, 2000), what is effective professional development? How can my interviews be used as case-based learning experiences for teachers?

One promising avenue for helping teachers develop the content knowledge of science needed in the context of IQWST is lesson study (Fernandez, 2005). Lesson study is a practice where teachers learn about teaching by jointly developing and examining actual classroom lessons. This practice easily could occur within the context of the IQWST professional development workshops. For example, in the summer workshops the teachers might plan a particular benchmark lesson together, videotape that lesson, and then share their video during a weekend work session. My experience with Ms. Cee and Ms. Kay during the viewing session indicates the potential value of including lesson study as one component of professional development, but as Fernandez notes while there is growing interest in the potential of lesson study there is much to be investigated about the opportunity to learn science content for teaching.

The Design of Educative Curriculum Materials

IQWST curriculum materials are designed to be educative so that they support teachers in learning the content and practices of science necessary to enact the inquiry-based reform ideals (Davis & Krajcik, 2005). Ms. Kay and Ms. Cee both talked about the challenges and problems in their practice as they attempted to reason with students' ideas and how they looked to the teacher guide for help but it was not there. And a particular issue of curriculum design that has often been discussed is finding the delicate balance between too much or not enough information for teachers (Davis & Krajcik, 2005; Remillard, 2005).

Remillard (1999) noted that often curriculum texts attempt to tell teachers what to do and in effect talk through the teacher to the students. And sometimes the language in the IQWST materials does say "tell students…" but both Ms. Kay and Ms. Cee noted that this support does not work for them in different ways. Ms. Kay struggled to determine how to lead students to the content ideas when the students were not replying with the anticipated student responses in the IQWST teacher guide. And Ms. Cee, commented that when the teacher guide said to tell the students something, she trusted the material and did not take the time to understand the ideas herself. So for Ms. Kay and Ms. Cee who were definitely participating with and drawing on the curriculum materials for support, which particular aspects of the IQWST educative curriculum material design heuristics were or were not particularly useful? How effective are these design heuristics?

Next Steps

In my work with inquiry-based curriculum materials design and enactment my research has shown that in addition to the difference in the order of experiences, patterns, and explanations, the practices of finding patterns is missing as well. When scientific inquiry is used as an instructional tool, inquiry should include the practices of science that include using mathematics to identify patterns in charts and graphs, and the textual literacy strategies to find scientific explanations from text resources. As my research continues I hope to identify and illustrate instructional strategies that coordinate the knowledge and practice of science.

The difference between traditional and inquiry-based discourse can be identified according to two aspects, the structure of the discourse and the embedded habits of mind associated with a discourse. In traditional instructional discourse structure, the topic is nominated by the teacher and the teacher's purpose for asking questions is to evaluate students' knowledge of the topic. In inquiry-based classrooms teachers need to learn new roles that change the structure of the discourse and distribute the participation as the classroom becomes a community of practice where teacher and students participate more equally.

In addition to the structure of the discourse, the habits of mind that underlie the discourse are also evident. Traditional discourse habits of mind are based on the assumption that the student is passive and knowledge is simply transmitted from the teacher to the student. Inquiry-based discourse habits of mind assume that students are active constructors of knowledge, and that the role of the teacher is to model for students the social and intellectual practices of the discipline. I hope to continue to study ways to support both practicing and pre-service teachers in learning how to take on classroom roles to support more authentic forms of practice.

APPENDICES

APPENDIX A: Classroom Event Coding Scheme

Type of Event	**Description of Event**
Formulating and Asking Questions (FAQ)	Any time generating questions, hypothesis, or identifying variables.
Data Gathering (DG)	Working with experiments setting up materials, making and recording measurements.
Formulating Patterns and Explanations (FPE)	Reading and constructing tables and graphs, identifying patterns, making claims about patterns.
Connecting Patterns and Explanations (CE)	Constructing, using, evaluating, or revising models.
Non IQWST	Taking attendance, checking homework, including additional experiences not in the IQWST curriculum.
Other IQWST	Non inquiry practices when the teacher introduces scientific content knowledge.

APPENDIX B: EPE Table Lesson 6

Observations or experiences (examples, phenomena, data)	**Patterns (laws, generalizations, graphs, tables, categories)**	**Explanations (models, theories)**
1. DQB 2. eyes fooled 3. Images (in mirror, in water, in TV screens, in windows, in Sides of Cars, in smooth I-pod, in polished wood floor) 4. No Image (in paper, unpolished wood floor, walls, cars, water, in scratched I-pod) 5. Data from mirror experiment (Activity 6.1 Data Table) 6. Data from Paper and mirror experiment (Activity 6.2 Data Table) 7. transparency of paper and I pod 8. Other experiences	9. Can see image in some things 10. Can not see image in some things 11. DQB Why can I see myself in a mirror but not paper? 12. Math pattern (Activity 6.1 Bar Graph) peak detector reading at same position light source 13. Math Pattern Reflection "V" angle incidence equals angle reflection 14. Math Pattern (Activity 6.2 Bar Graph) from paper light detector reading roughly same at all positions 15. Pattern – Scattering light bounces randomly equal 16. Pattern some surfaces rough scatter light to eye and smooth reflect light to eye 17. Other patterns	18. DQB Ray Model of Vision a) Light source b) Light spreads out from source in straight lines **c) Light bounces off object (revised in lesson 6)** **d) Light enters eye (revised scattered or reflected)** 19. Other explanations

Application: Model-based Reasoning – using models/theories to explain experiences

Inquiry: Finding and Explaining Patterns in Experience

APPENDIX C: IQWST Inquiry Practices Coding Scheme

IQWST Learning Progression Inquiry Practices for 6th Grade (Fortus et al., 2006)

Learning Progression for five scientific practices: design of investigations, data analysis and interpretation, explanation and argumentation, modeling, and systems thinking.

Note: * Indicates Light Unit Primary Emphasis Modeling and Secondary Emphasis DGOA

Formulating and Asking Questions (FAQ)

1. Generate questions
2. Hypothesis and formulate predictions
3. Identify Variables (independent and dependent)
4. Control variables

Data Gathering (DG)

5. Decide if need instruments*
6. Select appropriate instruments*
7. Use appropriate units*
8. Record data orderly manner*
9. Evaluate data*

Formulating Patterns and *Explanations* (FPE)

10. Read & construct tables*
11. Read & construct graphs*
12. Identify patterns*
13. Identify data ranges*
14. Compare two groups of data*
15. *Simple claim requires one piece of evidence*
16. *Sufficient and appropriate evidence*
17. *Variation in data – reliability*
18. *Differentiate – Opinion, Empirical, inference, evidence*
19. *Multiple interpretation data*
20. *Reason include Scientific Principle*

Connecting Patterns and Explanations (CE)

21. Construct models to explain or understand*
22. Use models to predict, explain, or test*
23. Evaluate models*
24. Revise models*

APPENDIX D: Viewing Session Interview Questions

How long have you been teaching?

Where have you taught?

What subject(s) have you taught?

What grade level(s) have you taught?

What are your college degree(s)?

What is/are your teaching certification(s)?

What are your goals for science teaching?

What should good science teachers know and be able to do?

I'm going to show you some video clips from lesson 6. My purpose here is try to figure out how to write curriculum that is clear and compatible with teachers' classroom needs and perspectives. I've been comparing what happened in the three classrooms with the IQWST curriculum, and I've been developing a story based on three research questions that I am interested in. As you watch the video clips I'd like to you to think about these three questions and tell your story as it relates to these three questions.

1) What does inquiry look like in this classroom? Describe what you think the inquiry feature or practices were in this clip?

2) How did you balance your teacher roles as the authority responsible for managing a classroom and the inquiry norms to help students find answers to questions in the data? In other words how did you balance the norms for investigating science and with the inquiry norm of encouraging students' generating and resolving different science ideas?

3) What were your particular teaching strengths and weaknesses and beliefs about inquiry that influence your interactions with your students?

REFERENCES

Akerson, V. L., & Hanuscin, D. L. (2007). Teaching nature of science through inquiry: Results of a 3-year professional development program. *Journal of Research in Science Teaching, 44*(5), 653-680.

American Association for the Advancement of Science. (1989). *Science for all Americans*. Washington, DC: American Association for the Advancement of Science.

American Association for the Advancement of Science. (1993). *Benchmarks for science literacy*. New York: Oxford University Press.

Anderson, C. W. (2003a). How can schools support teaching for understanding in mathematics and science. In A. Gamoran (Ed.), *Transforming teaching in math and science: How schools and districts can support change* (pp. 3-21). New York: Teachers College Press.

Anderson, C. W. (2003b). *Teaching science for motivation and understanding*, from http://www.msu.edu/~andya/TEScience/Assets/Files/TSMU.pdf

Ball, D. L., & Cohen, D. K. (1996). Reform by the book: What is-or might be-the role of curriculum materials in teacher learning and instructional reform? *Educational Researcher, 25*(9), 6-8, 14.

Bereiter, C. (1994). Constructivism, socioculturalism, and popper's world 3. *Educational Researcher, 23*(7), 21-23.

Blumenfeld, P. C., Fishman, B. J., Krajcik, J., Marx, R. W., & Soloway, E. (2000). Creating usable innovations in systemic reform: Scaling up technology-embedded project-based science in urban schools. *Educational Psychologist, 35*(3), 149-164.

Blumenfeld, P. C., Soloway, E., Marx, R. W., Krajcik, J. S., Guzdial, M., & Palinscar, A. (1991). Motivating project-based learning: Sustaining the doing, supporting the learning. *Educational Psychologist, 26*(3 & 4), 369-398.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (Eds.). (2000). *How people learn: Brain, mind, experience, and school*. Washington, D.C.: National Academy Press.

Brickhouse, N. W. (1990). Teachers' beliefs about the nature of science and their relationship to classroom practice. *Journal of Teacher Education, 41*(3), 53-63.

Brickhouse, N. W. (2001). Embodying science: A feminist perspective on learning. *Journal of Research in Science Teaching, 38*(3), 282-295.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher, 18*(1), 32-42.

Brown, M., & Edelson, D. C. (2001). *Teaching by design: Curriculum design as a lens on instructional practice.* Paper presented at the Annual Meeting of the American Educational Research Association, Seattle, WA.

Bruner, J. (1996). *The culture of education.* Cambridge, Massachusetts: Harvard University Press.

Carlone, H. B. (2003). Innovative science within and against a culture of "Achievement". *Science Education, 87*(3), 307-328.

Carlsen, W. S. (1997). Never ask a question if you don't know the answer: The tension in teaching between modeling scientific argument and maintaining law and order. *Journal of Classroom Interaction, 32*, 14-23.

Cazden, C. B. (1986). Classroom discourse. In M. C. Wittrock (Ed.), *Handbook of research on teaching* (3rd ed., pp. 432-463). New York: Macmillan.

Cazden, C. B. (2001). *Classroom discourse: The language of teaching and learning* (2nd ed.). Portsmouth, NH: Heinemann.

Chin, C. (2007). Teacher questioning in science classrooms: Approaches that stimulate productive thinking. *Journal of Research in Science Teaching, 44*(6), 815-843.

Cobb, P., Confrey, J., diSessa, A., Lehrer, R., & Schauble, L. (2003). Design experiments in educational research. *Educational Researcher, 32*(1), 9-13.

Cobb, P., Stephan, M., McClain, K., & Gravemeijer, K. (2001). Participating in classroom mathematical practices. *The Journal of the Learning Sciences, 10*(1/2), 113-163.

Cobb, P., Yackel, E., & Wood, T. (1989). Young children's emotional acts while engaged in mathematical problem solving. In D. B. McLeod & V. M. Adams (Eds.), *Affect and mathematical problem solving: A new perspective* (pp. 117-148). New York: Springer-Verlag.

Cohen, D. K. (1988). Teaching practice: Plus que ca change... In P. Jackson (Ed.), *Contributing to educational change: Perspectives on research and practice* (pp. 27-84). Berkeley: McCutchen.

Cohen, D. K. (1990). A revolution in one classroom: The case of Mrs. Oublier. *Educational Evaluation and Policy Analysis, 12*(3), 327-345.

Cohen, D. K., & Ball, D. L. (1999). *Instruction, capacity, and improvement*: Consortium for Policy Research in Education University of Pennsylvania.

Collins, A., Brown, J. S., & Newman, S. E. (1989). Cognitive apprenticeship: Teaching the crafts of reading, writing, and mathematics. In L. B. Resnick (Ed.), *Knowing,* *learning, and instruction: Essays in honor of Robert Glaser* (pp. 453-494). Hillsdale, NJ: Lawrence Elrbaum Associates.

Cook-Gumperz, J., & Gumperz, J. J. (1982). Communicative competence in educational perspective. In L. C. Wilkinson (Ed.), *Communicating in the classroom* (pp. 13-24). New York: Academic Press.

Crawford, B. (2000). Embracing the essence of inquiry: New roles for science teachers. *Journal of Research in Science Teaching, 37*(9), 916-937.

Cronin-Jones, L. L. (1991). Science teacher beliefs and their influence on curriculum implementation: Two case studies. *Journal of Research in Science Teaching, 28*(3), 235-250.

Cuban, L. (1993). *How teachers taught: Constancy and change in American classrooms 1890-1980* (2nd ed.). New York: Teachers College Press.

Dagher, Z. R., Brickhouse, N. W., Shipman, H., Letts, W. J., & Sturt, C. (2004). How some college students represent their understandings of the nature of scientific theories. *International Journal of Science Education, 26*(6), 735-755.

Darling-Hammond, L., & Ball, D. L. (1998). *Teaching for high standards: What policy makers need to know and be able to do*. Philadelphia: Consortium for Policy Research in Education.

Davis, E. A., & Krajcik, J. S. (2005). Designing educative curriculum materials to promote teacher learning. *Educational Researcher, 34*(3), 3-14.

DeBoer, G. E. (1991). *A history of ideas in science education: Implications for practice*. New York, NY: Teachers College Press.

DeBoer, G. E. (2002). Student-centered teaching in a standards-based world: Finding a sensible balance. *Science & Education, 11*, 405-417.

Doyle, W., & Carter, K. (1984). Academic tasks in classrooms. *Curriculum Inquiry, 14*(2), 129-149.

Driver, R., Asoko, H., Leach, J., Mortimer, E., & Scott, P. (1994). Constructing scientific knowledge in the classroom. *Educational Researcher, 23*(7), 5-12.

Driver, R., Newton, P., & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. *Science Education, 84*, 287-312.

Duschl, R. A. (1990). *Restructuring science education: The important of theories and their development*. New York: Teachers College Press.

Duschl, R. A., Schweingruber, H. A., & Shouse, A. W. (Eds.). (2007). *Taking science to school: Learning and teaching science in grades K-8*. Washington, D.C.: National Academies Press.

Edelson, D. C. (2001). Learning-for-use: A framework for the design of technology-supported inquiry activities. *Journal of Research in Science Teaching, 38*(3), 355-385.

Engle, R. A., & Conant, F. R. (2002). Guiding principles for fostering productive disciplinary engagement: Explaining an emergent argument in a community of learners classroom. *Cognition and Instruction, 20*(4), 399-483.

Erickson, F. (1982). Classroom discourse as improvisation: Relationships between academic task structure and social participation structure in lessons. In L. C. Wilkinson (Ed.), *Communicating in the classroom* (pp. 153-181). New York: Academic Press.

Erickson, F. (1986). Qualitative methods in research on teaching. In M. C. Witrock (Ed.), *Handbook of research on teaching* (3rd ed., pp. 119-161). New York: McMillan.

Erickson, F. (2006). Definition and analysis of data from videotape: Some research procedures and their rationales. In P. Elmore (Ed.), *Handbook of complementary methods in education research* (pp. 177-191). Mahwah, NJ: LEA.

Erickson, F., & Shultz, J. (1981). When is a context? Some issues and methods in the analysis of social competence. In J. L. Green & C. Wallat (Eds.), *Ethnography and language in educational settings* (pp. 147-160). Norwood, NJ: Ablex Publishing Corporation.

Fernandez, C. (2005). Lesson Study: A means for elementary teachers to develop the knowledge of mathematics needed for reform-minded teaching? *Mathematical Thinking and Learning, 7*(4), 265-289.

Fishman, B. J., Marx, R. W., Best, S., & Tal, R. T. (2003). Linking teacher and student learning to improve professional development in systemic reform. *Teaching and Teacher Education, 19*, 643-658.

Floden, R. E., & Buchman, M. (1993). Between routines and anarchy: preparing teachers for uncertainty. *Oxford Review of Education, 19*(3), 373-382.

Florio-Ruane, S. (1987). Sociolinguistics for educational researchers. *American Educational Research Journal, 24*(2), 185-197.

Fortus, D., Hug, B., Krajcik, J. S., Kuhn, L., McNeill, K. L., Reiser, B., et al. (2006). *Sequencing and supporting complex scientific inquiry practices in instructional materials for middle school students.* Paper presented at the Annual meeting of the National Association for Research in Science Teaching, San Francisco.

Fortus, D., Nordine, J., Rozelle, J., Schwartz, C., Weisman, A., & Grueber, D. J. (2005). Seeing the light: Can I believe my eyes? : Unpublished IQWST Unit.

Freebody, P. (2003). *Qualitative research in education: Interaction and practice*. London: Sage.

Gallagher, J. J. (1991). Prospective and practicing secondary school science teachers' knowledge and beliefs about the philosophy of science. *Science Education, 75*(1), 121-133.

Gearing, F., & Epstein, P. (1982). Learning to wait: An ethnographic probe into the operations of an item of hidden curriculum. In G. Spindler (Ed.), *Doing the ethnography of schooling: Educational anthropology in action* (pp. 240-267). New York: Holt, Rinehart and Winston.

Gee, J. P. (2004). Discourse analysis: What makes it critical? In R. Rogers (Ed.), *An introduction to critical discourse analysis in education*. Mahweh, NJ: Lawrence Erlbaum Associates.

Gee, J. P., & Green, J. (1998). Discourse analysis, learning, and social practice: A methodological study. *Review of Research in Education, 23*, 119-169.

Gilbert, J. K., & Boulter, C. J. (1998). Learning science through models and modeling. In B. J. Fraser & K. G. Tobin (Eds.), *International Handbook of Science Education* (pp. 53-66): Kluwer Academic Press.

Good, R., & Shymansky, J. (2001). Nature-of-science literacy in *Benchmarks* and *Standards*: Post-modern/relativist or modern/realist? *Science & Education, 10*, 173-185.

Haigh, M., France, B., & Forret, M. (2005). Is 'doing science' in New Zealand classrooms an expression of scientific inquiry? *International Journal of Science Education, 27*(2), 215-226.

Hatch, J. A. (2002). *Doing qualitative research in educational settings*. Albany: SUNY Press.

Herrenkohl, L. R., & Guerra, M. R. (1998). Participant structures, scientific discourse, and student engagement in fourth grade. *Cognition and Instruction, 16*(4), 431-473.

Herrenkohl, L. R., Palinscar, A. S., DeWater, L. S., & Kawasaki, K. (1999). Developing scientific communities in classrooms: A sociocognitive approach. *The Journal of the Learning Sciences, 8*(3&4), 451-493.

Hogan, K., & Corey, C. (2001). Viewing classrooms as cultural contexts for fostering science literacy. *Anthropology & Education Quarterly, 32*(2), 214-243.

Hogan, K., & Maglienti, M. (2001). Comparing the epistemological underpinnings of students' and scientists' reasoning about conclusions. *Journal of Research in Science Teaching, 38*(6), 663-687.

Hymes, D. (1972). Models of the interaction of language and social life. In J. Gumperz & D. Hymes (Eds.), *Directions in sociolinguistics: The ethnography of communication*. New York: Holt, Rinehart & Winston.

Kelly, G. J., & Crawford, T. (1997). An ethnographic investigation of the discourse processes of school science. *Science Education, 81*, 533-559.

Keys, C. W., & Bryan, L. A. (2001). Co-constructing inquiry-based science with teachers: Essential research for lasting reform. *Journal of Research in Science Teaching, 38*(6), 631-645.

Krajcik, J., Blumenfeld, P., Marx, R., & Soloway, E. (2000). Instructional, curricular, and technological supports for inquiry in science classrooms. In J. Minstrell & E. v. Zee (Eds.), *Inquiring into inquiry learning and teaching in science* (pp. 283-315). Washington D.C.: AAAS.

Krajcik, J., McNeill, K. L., & Reiser, B. J. (2008). Learning-goals-driven design model: Developing curriculum materials that align with national standards and incorporate project-based pedagogy. *Science Education, 92*(1), 1-32.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. New York: Cambridge University Press.

Lehrer, R., & Schauble, L. (2000). Developing model-based reasoning in mathematics and science. *Journal of Applied Developmental Psychology, 21*(1), 39-48.

Lemke, J. L. (1990). *Talking science: Language, learning, and values*. Norwood, NJ: Ablex Publishing.

Magnusson, S. J., Palinscar, A. S., & Templin, M. (2004). Community, culture, and conversation in inquiry-based science instruction. In L. B. Flick & N. G. Lederman (Eds.), *Scientific inquiry and nature of science* (pp. 131-155). Netherlands: Kluwer Academic Publishers.

McComas, W. F., Almazroa, H., & Clough, M. P. (1998). The nature of science in science education: An introduction. *Science & Education, 7*, 511-532.

McGinn, M. K., & Roth, W. M. (1999). Preparing students for competent scientific practice: Implications of recent research in science and technology studies. *Educational Researcher, 28*(3), 14-24.

Mehan, H. (1979). *Learning lessons: Social organization in the classroom*. Cambridge, MA: Harvard University Press.

Merriam, S. B. (1988). *Case study research in education: A qualitative approach.* San Francisco: Jossey-Bass Inc.

Minstrell, J. A. (1992). Teaching science for understanding. In M. K. Pearsall (Ed.), *Relevant research. Scope, sequence, and coordination of secondary school science. Vol II.* (pp. 237-251). Washington, DC: National Science Teachers Association.

Moje, E. B. (1995). Talking about science: An interpretation of the effects of teacher talk in a high school science classroom. *Journal of Research in Science Teaching, 32*(4), 349-371.

Munby, H., Cunningham, M., & Lock, C. (2000). School science culture: A case study of barriers to developing professional knowledge. *Science Education, 84*, 193-211.

National Research Council. (1996). *National science education standards.* Washington, DC: National Academy Press.

National Research Council. (2000). *Inquiry and the national science education standards.* Washington, DC: National Academy Press.

Ochs, E. (1979). Transcription as theory. In E. Ochs & B. B. Schieffelin (Eds.), *Developmental pragmatics* (pp. 43-72). New York: Academic Press.

O'Connor, M. C., & Michaels, S. (1996). Shifting participant frameworks: orchestrating thinking practices in group discussion. In D. Hicks (Ed.), *Discourse learning and schooling* (pp. 63-103). New York: Cambridge University Press.

Osborne, J., Collins, S., Ratcliffe, M., Millar, R., & Duschl, R. (2003). What "Ideas-about-science" should be taught in school science? A Delphi study of the expert community. *Journal of Research in Science Teaching, 40*(7), 692-720.

Page, R. (1999). The uncertain value of school knowledge: Biology at Westridge High. *Teachers College Record, 100*(3), 554-601.

Pajares, M. F. (1992). Teachers' beliefs and educational research: Cleaning up a messy construct. *Review of Educational Research, 62*(3), 307-332.

Philips, S. U. (1972). Participant structures and communicative competence: Warm springs children in community and classroom. In C. B. Cazden, V. P. John & D. Hymes (Eds.), *Functions of language in the classroom.* Prospect Heights, IL: Waveland Press, Inc.

Pickering, A. (1995). *The mangle of practice: Time, agency, and science.* Chicago: The University of Chicago Press.

Powell, A. G., Farrar, E., & Cohen, D. K. (1985). Origins. In *The shopping mall high school: Winners and losers in the educational marketplace* (pp. 233-308). Boston: Houghton Mifflin Co.

Putnam, R. T., & Borko, H. (2000). What do new views of knowledge and thinking have to say about research on teacher learning? *Educational Researcher, 29*(3), 4-15.

Reiser, B. J., Krajcik, J., Moje, E., & Marx, R. (2003). *Design strategies for developing science instructional materials.* Paper presented at the Annual Meeting of the National Association of Research in Science Teaching, Philadelphia, PA.

Remillard, J. T. (1999). Curriculum materials in mathematics education reform: A framework for examining teacher's curriculum development. *Curriculum Inquiry, 29*(3), 315-342.

Remillard, J. T. (2005). Examining key concepts in research on teachers' use of mathematics curricula. *Review of Educational Research, 75*(2), 211-246.

Resnick, L. B. (1987). The 1987 presidential address: Learning in school and out. *Educational Researcher, 16*(9), 13-20+54.

Roehrig, G. H., Kruse, R. A., & Kern, A. (2007). Teacher and school characteristics and their influence on curriculum implementation. *Journal of Research in Science Teaching, 44*(7), 883-907.

Roehrig, G. H., & Luft, J. A. (2004). Constraints experienced by beginning secondary science teachers in implementing scientific inquiry lessons. *International Journal of Science Education, 26*(1), 3-24.

Roth, K. J. (1991). Learning to be comfortable in the neighborhoods of science: An analysis of three approaches to elementary science teaching. In S. A. Jagusch (Ed.), *Vital Connections: Children, science, and books*. Portsmouth, NH: Heinemann.

Sandoval, W. A., & Reiser, B. J. (2004). Explanation-driven inquiry: Integrating conceptual and epistemic scaffold for scientific inquiry. *Science Education, 88*, 345-372.

Schneider, R. M., Krajcik, J., & Blumenfeld, P. (2005). Enacting reform-based science materials: The range of teacher enactments in reform classrooms. *Journal of Research in Science Teaching, 42*(3), 283-312.

Schneider, R. M., & Krajcik, J. s. (2002). Supporting science teacher learning: the role of educative curriculum materials. *Journal of Science Teacher Education, 13*(3), 221-245.

Schwab, J. J. (1962). The teaching of science as enquiry. In *The teaching of science* (pp. 1-103). Cambridge, MA: Harvard University Press.

Schwab, J. J. (1978). Education and the structure of the disciplines. In I. Westbury & N. J. Wilkof (Eds.), *Science, curriculum, and liberal education: Selected essays* (pp. 229-272). Chicago: University of Chicago Press.

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review, 57*(1), 1-22.

Singer, J., Marx, R. W., Krajcik, J., & Chambers, J. C. (2000). Constructing extended inquiry projects: Curriculum materials for science education reform. *Educational Psychologist, 35*(3), 165-178.

Smith, D. C., & Anderson, C. W. (1999). Appropriating scientific practices and discourses with future elementary teachers. *Journal of Research in Science Teaching, 36*(7), 755-776.

Tabak, I., & Baumgartner, E. (2004). The teacher as partner: Exploring participant structures, symmetry, and identity work in scaffolding. *Cognition and Instruction, 22*(4), 393-429.

Tobin, K., & McRobbie, C. J. (1996). Cultural myths as constraints to the enacted science curriculum. *Science Education, 80*(2), 223-241.

Weiss, I. R., Pasley, J. D., Smith, P. S., Banilower, E. R., & Heck, D. J. (2003). *Looking inside the classroom: A study of K-12 mathematics and science education in the united states.* Chapel Hill, NC: Horizon Research, Inc.

Wells, G. (1995). Language and the inquiry-oriented classroom. *Curriculum Inquiry, 25*(3), 233-269.

White, B., & Frederiksen, J. (1998). Inquiry, modeling, and metacognition: Making science accessible to all students. *Cognition and Instruction, 16*(1), 3-18.

Wiggins, G., & McTighe, J. (1998). *Understanding by Design.* Alexandria: Association for Supervision and Curriculum Development.

Wilson, S. M., & Berne, J. (1999). Teacher learning and the acquisition of professional knowledge: An examination of research on contemporary professional development. *Review of Research in Education, 24*, 173-209.

Windschitl, M., Thompson, J., & Braaten, M. (2008, in press). Beyond the scientific method: Model-based inquiry as a new paradigm of preference for school science investigations. *Science Education*, 1-27.

Wong, E. D. (1996). Students' scientific explanations and the contexts in which they occur. *The Elementary School Journal, 96*(5), 495-509.

Yerrick, R. K., Pedersen, J. E., & Arnason, J. (1998). "We're just spectators": A case study of science teaching, epistemology, and classroom management. *Science Education, 82*, 619-648.

Yin, R. K. (2006). Case study methods. In J. L. Green, G. Camilli & P. B. Elmore (Eds.), *Complementary methods for research in education* (3rd ed., pp. 111-122). Mahwah, NJ: Lawrence Erlbaum Associates.