DESIGNING PROFESSIONAL DEVELOPMENT TO INCREASE LOCAL CAPACITY TO SUSTAIN REFORM

By

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DEDICATION

This dissertation is dedicated to two groups: First, my family, Kathe, Anders, Sarah, and Morgan. Second, I dedicate this dissertation and my work to the teachers bent on changing students' lives in instructional settings that can be very challenging.

ACKNOWLEDGEMENTS

This dissertation is the result of an extended effort that has been facilitated by many people. I would like to take this opportunity to acknowledge some of the people that have influenced my thoughts and actions during the time I was engaged in the work this dissertation is based on. These people include my advisors, my research colleagues, the teachers that I have had the privilege of working with in Detroit, and my family.

At the heart of any dissertation process is the relationship between the graduate student and his or her advisor. In my case, I have been fortunate to have two advisors, Joe Krajcik and Barry Fishman, who have provided steadfast guidance and support for my efforts. You may, gentle reader, be surprised to hear that I am not the easiest advisee to have. I am afraid to say that curricular reforms of the 1970s (focusing on critical thinking) that punctuated my early education along with a healthy dose of skepticism in all things that could not be expressed mathematically inspired by the University of Maryland Physics Department have left me with a strong desire go about my own way and to not ask for help until I am satisfied that I really don't know what I'm doing. It is a credit to both Barry and Joe that they have been willing (and of course, able) to at least suggest ways that I could begin to pick up the pieces and continue to do productive work. They can rest assured that one day, I too will have me as a graduate student, and that I will get a chance to experience the frustration that I no doubt have caused them.

In addition to Joe and Barry, my time in the University of Michigan School of Education was influenced a great deal by my research colleagues. My research group, the Center for Highly Interactive Classrooms, Curricula, and Computing, and in Education (hice), included my graduate student classmates, the group's professors, and a variety of invaluable support staff members. I originally came to study in hice because of their commitment to a teaching approach called Project-Based Science (PBS), and I have enjoyed the fact that hice's approach of having its graduate students engage in many simultaneous, meaningful, research projects put PBS into action, and made my coursework as well as my support for teachers more meaningful. The conversations and meetings that I had in hice allowed me to understand the ideas held by young people who I am confident will one day be preeminent science education researchers.

A major component of my work and research in hice actually took place in schools and meeting rooms in Detroit. During the period between 2001 and 2007, I had the privilege of working with many highly talented teachers and district personnel, including Kolanda Colson, a teacher at Bates Middle School, Chevon Kay, a teacher at Beaubian Middle School, and Deborah Peek-Brown, the district instructional specialist who coordinate the LeTUS curriculum project. Both Kolanda and Chevon went beyond reasonable expectations by allowing me access to their classrooms at will as well as working closely with me to plan and enact LeTUS professional development activities. Before coming to Michigan, my experience in school reform was in a progressive suburban school district in Maryland. Working on professional development with Deborah Peek-Brown helped me to better understand the challenges reform advocates face in large urban school districts and the professional respect and dogged persistence that successful leaders and change agents must possess in order to help their teachers and students in meaningful ways.

I appreciate the fact that my family has made significant sacrifices for me to return to graduate school and also acknowledge their role in my success to this point. My wife Kathe faced the challenge of us both returning to school by maintaining high expectations in both her own research and in our household. Our children, Anders, Sarah, and Morgan have each pursued their own interests and in so doing have enriched our homelife. Throughout our graduate careers, Kathe's parents, Larry and Micke Schneider supported our family in many ways. It is true to say that without their help, we would not have made it Ann Arbor, been able to stay in Michigan as long as we did, or been able to leave Michigan to reach Rhode Island.

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Chapter 1
Introduction

Researchers are addressing current concerns about the quality of K-12 science education by developing curriculum materials they hope will enhance all students' understandings of critical scientific ideas and processes. These materials are innovative in part because they have been designed using what we have learned over the past three decades about how to support classroom teaching and learning. While our ability to design effective curriculum materials has grown, our understanding of how to implement curricular innovations so that they become institutionalized within school districts is still developing.

Efforts to implement innovative materials in the past have demonstrated this aspect of reform to be challenging and complex. Because these materials rely on nontraditional classroom practices, most teachers need opportunities to develop their own understanding of the principles that guided the design of the materials if they are going to adopt and use them successfully. This dissertation describes research directed at understanding teachers' uses of innovative curriculum materials as well as our efforts to provide professional development (PD) that can eventually be taken over at the district level to continue supporting teachers' understanding of the innovation and therefore sustain a change in the local educational culture. Before describing the studies that constitute this dissertation, I will first set the stage by explaining our current understanding of curricular reform, what we understand about scaling innovations, the role PD plays in this process, and the developmental context of my research.

The Challenge of Implementing Curricular Reform

The challenging conditions and poor student performance occurring in many American science classrooms warrant researchers' efforts to develop materials that will meet more students' needs and improve their understanding of science. There is general agreement on a growing need to improve the opportunities that students have to learn science (Committee on Prospering in the Global Economy of the 21st Century (CPGE), 2005). American science teachers often have difficulties providing students with intellectually rigorous experiences or sufficient opportunities for sensemaking (Weiss, Pasley, Smith, Banilower, & Heck, 2003).

Curriculum materials play a significant role in a teacher's capacity for instruction (Ball & Cohen, 1999). Historically, efforts to improve science teaching have often included efforts to provide teachers with high-quality curriculum materials and professional development (DeBoer, 1991; Welsch, 1979). Many of the science textbooks that are traditionally used by teachers lack critical supports necessary to help teachers focus instruction on key ideas in science while taking into account how students learn (Kesidou & Roseman, 2002).

To address these shortcomings, researchers are developing curriculum materials that address standards-based learning goals while providing classroom experiences that encourage students to intellectually engage with natural phenomena and participate in scientific inquiry (Krajcik, McNeill, & Reiser, 2008). When implemented effectively, materials of this type have been successful at supporting student learning, even in challenging educational contexts (Geier et al., 2008). To extend the reach of these materials so that they enhance the learning opportunities experienced by more students, we have to address the challenge of how to support their integration into the curricula of school districts on a large scale.

We already know that "scaling up" the use of challenging curriculum materials is not as simple as making them available through a commercial publisher and trusting market forces to lead to their adoption. Past efforts to reform science education by providing similar materials have generally not led to them being spontaneously adopted by a large number of districts nor has their initial use in "hothouse" classrooms been sustained after the external supports that are typically provided were removed (Cuban, 1993; Elmore, 1996; Fullan, 1991; Welch, 1979). Though research-based materials have proven effective at helping students learn, they are often implemented in the context of comprehensive support programs that include teacher PD opportunities provided by the curriculum developers as well as other supports (Blumenfeld, Fishman, Krajcik, Marx, & Soloway, 2000). Some of these supports are represented in Figure 1.1. To use new materials with their students, teacher often participate in a series of PD opportunities, have access to new instructional materials and classroom technologies, and rely on in-class support and coaching to implement new classroom practices (Blumenfeld et al., 2000; Penuel, Fishman, Yamaguchi, & Gallagher, 2007).

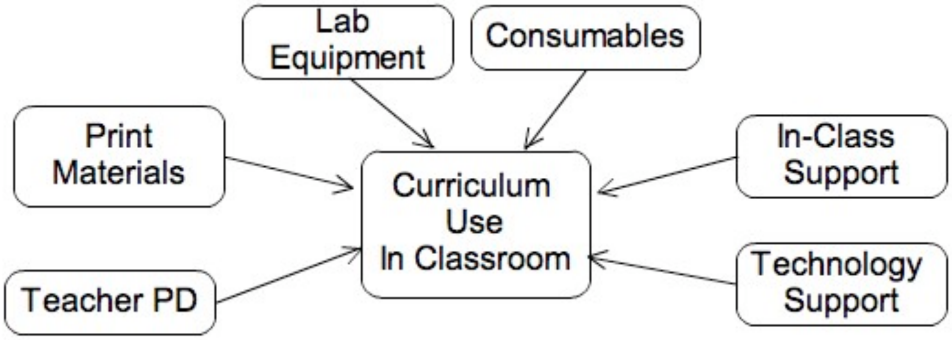

Figure 1.1. Classroom innovations often require several types of support.

The "chasm" between the highly supported classroom environments where these materials are tested and the more typical classrooms that do not have access to a high degree of external support has led some researchers to recognize the need to study the implementation process with an eye towards designing materials and support strategies that are capable of being scaled and sustained in more typical educational settings (Confrey, Castro-Filho, & Wilhelm, 2000; Fishman & Krajcik, 2003). Recently, there have been efforts to develop a theoretical foundation that would allow those concerned with this problem at the district level to organize their efforts.

A Theoretical Frame for Understanding Systemic Scalability

Efforts to theorize about how best to support districts' long-term efforts to adopt innovative curriculum materials are just beginning. In her synthesis of the literature pertaining to sustaining classroom innovations, Coburn (2003) identifies four dimensions in which change must occur if the use of an innovation such as high-quality curriculum materials can be “scaled up” and sustained within and across districts. These dimensions include the depth at which the innovation is being used, the degree that use of the innovation persists over time, the spread of the innovation among teachers, and the degree that ownership of the innovation shifts from external to internal stakeholders. The idea that the degree that an innovation is usable, and therefore scalable, by a district is multidimensional is consistent with those that point out that there should be a "good fit" between the innovation and a school's capabilities, their culture, and existing policies (Blumenfeld et al., 2000; Fishman & Krajcik, 2003). McDonald et al. (2006) point out that though "scaling up" in the end must be about measuring the spread of a proven innovation, it is necessary to build up to this level by studying the use of the innovation and its supports in a variety of contexts.

Though our efforts to build a theory of how to sustain innovations are just beginning, these early descriptions of how districts adopt and institutionalize innovative curriculum materials and how researchers might study this process provide useful guidance to those interested in facilitating and understanding the "scale-up" process at the district level. In this dissertation, I study how teachers use curriculum materials as well as how curriculum developers and district lead teachers provide PD to extend our understanding of the PD supports needed to scale and sustain innovative curriculum materials within a district.

The Role of PD in Implementing and Sustaining Curricular Reform

If teachers are to use unfamiliar curriculum materials effectively, they need opportunities to understand their intended use. A teacher's use of innovative curriculum materials is influenced by his or her understanding of the materials, their subject, their students, their attitudes about teaching and learning, as well as their beliefs and values (Davis & Krajcik, 2005; Roehrig, Kruse, & Kern, 2007; Richardson, 1996). Participation in curriculum-focused PD while they are beginning to use new instructional materials helps teachers use the materials effectively (Borko, 2004; Desimone, Porter, Garet, Yoon, & Birman, 2002; Kubitskey, 2006; Penuel et al., 2007; Supovitz & Turner, 2000). Past curriculum implementation studies have established that teachers need several enactment cycles to understand the features of complex curriculum materials (Blumenfeld et al., 2005; Kubitskey, 2006; Snyder, Bolin, & Zumwalt, 1992).

Coburn (2003) defines the sustainability of an innovation as the degree that its use persists in time and points out that if this is to occur, districts must eventually have the ability to take control, or ownership, over their use of an innovation. The temporary nature of external supports, teacher and administrator turnover, changing priorities, and competing programs increases the difficulty of sustaining the use of externally provided materials (Coburn, 2003; Fullan, 1991). Providing ongoing PD opportunities can help sustain innovations by providing learning opportunities for teachers with different levels of expertise with the materials (Fullan, 1991), provide a chance for teachers within a school or district to align their practices (Kubitskey, 2006), and foster local communities of practice where teachers can collaborate on refining their teaching and supporting newcomers (Lave & Wenger, 1991; Putnam & Borko, 1997; Supovitz, 2002).

It is reasonable to conclude that for new curriculum materials to have a lasting influence within a district, the challenge of how to provide teachers with the necessary supports, such as ongoing PD, will have to be addressed. Past efforts to build local PD capacity have included fostering a network regional PD providers (Penuel et al., 2007), creating a district-level cadre of teacher leaders (Corcoran, McVay, & Riordan, 2003) as well as developing local personnel at pilot schools to coordinate regional dissemination centers (Davila & Gomez, 1995). This research describes efforts by curriculum developers within a district-university partnership to address this need by examining the usability of their own PD and helping the district develop its capacity to support its teachers as it assumes more control over the use of innovative materials (Fishman et al., 2003). This research seeks to apply our current understanding of teacher learning and PD to build local PD capacity.

Context of this Research

For over a decade, researchers been developing curriculum materials that address both the instructional practices and key science ideas called for the national standards. Beginning in 1997, the Center for Highly Interactive Curriculum, Computing, and Classrooms at the University of Michigan (hice) and the Learning Sciences Group at Northwestern University collaborated with the Detroit and Chicago school districts to establish the Center for Learning Technologies in Urban Schools (LeTUS) and to provide the cities' middle school teachers with science curriculum materials that helped teachers facilitate extended investigations and use technology in their classrooms. (Blumenfeld et al., 2000; Fishman, Marx, Best, & Tal, 2003). Beginning in 2001, these groups began building on their success in LeTUS to develop the Investigating and Questioning Your World Through Science and Technology (IQWST) curriculum units. The IQWST curriculum combined a project-based approach with an emphasis on critical science learning goals and facilitating classroom inquiry to create a coherent and comprehensive sequence of units designed to span the middle school grades in the physical, biological, and earth sciences (Krajcik, McNeil, & Reiser, 2008).

Both the LeTUS and IQWST projects have provided an excellent setting to research possible support strategies for scaling and sustaining the use of reform-centered curriculum materials. Within the first five years of LeTUS, use of the curriculum materials was successfully scaled up to include over sixty teachers in thirty schools. Initially supported with in-class visits and monthly professional development workshops, the evolution of LeTUS over time provided a venue to investigate how the responsibility for providing professional development opportunities originally provided by university personnel could be met by district teacher leaders and the ownership on the overall program be adopted by district personnel. Instead of tailoring materials to the needs of specific school districts, the IQWST curriculum has been designed from the beginning for dissemination on a national scale. To that end, we have used its earliest field trials to examine our professional development program to identify salient features to be included in professional development support materials that can be used by districts to sustain the use of the IQWST materials in the future.

The Studies Comprising this Dissertation

This dissertation consists of three independent studies that examine aspects of helping local school organizations such as districts develop their capacity to sustain and scale-up teachers' effective use of reform-rich curriculum materials through PD.

To provide PD experiences that support curriculum materials being used effectively, it is important to understand how teachers are using the materials and how their practice effects what students learn. The first study in this dissertation uses a post-enactment survey to ask teachers about their enactment of one of the first IQWST units and relate aspects of their practice with what their students learned from the unit as indicated by their gains on pre- and post-tests. The effects on student learning of teachers' adaptations provide information that can be used to design PD experiences that support teachers' use of the materials (Fishman et al., 2003; Pinto, 2005).

As districts begin to take control over new innovations, curriculum developers will probably need to take an active role in supporting local efforts. Researchers are just beginning to apply knowledge of teacher learning to address the need to design PD programs that can be used effectively by external facilitators (Borko, 2004). One approach to preparing to meet this challenge is to critically analyze the PD opportunities led by the curriculum developers themselves in light of what we know about what teachers need to know in to use challenging materials and what constitutes effective PD. The second study of this dissertation using what we know about teacher knowledge and learning to investigate how a group of curriculum developers introduced their curriculum materials to a group of experienced teachers in a summer workshop. The study focuses on both the knowledge and strategies used by the curriculum developers in their workshop sessions. This knowledge can inform our decisions regarding what types of resources should be included in PD materials aimed at supporting external facilitators such as district lead teachers.

For the use of successful curriculum materials to persist, districts will need to provide ongoing PD. The final study in this dissertation describes our efforts within a mature district–university partnership to build the district's capacity for providing this support. In this effort, university researchers participated with district curriculum specialists in a workcircle to support district lead teachers as they plan and conduct PD around reform-based curriculum materials. Our approach was to help the teachers build on their classroom expertise by providing them with access to theoretical and research-based knowledge relevant to their work as professional developers.

The dissertation concludes by synthesizing the findings in each study to extend our understanding of how to support innovation with sustained PD. Beginning with Kubitskey's (2006) model for a program of PD workshops designed to sustain reform-centered curriculum materials within a district, I use results from each of my three studies to suggest ways to refine and extend this model in light of our understandings of teacher learning and PD. These refinements include leveraging the situated nature of teachers' knowledge and practice, refining the high-level consensus of what constitutes effective PD into useable design principles for PD, and taking seriously the need to shift ownership of innovations to the districts that decide to adopt them.

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Chapter 2
Comparing the Effect of Teachers' Adaptations of a Middle School Science Inquiry-Oriented Curriculum Unit on Student Learning

Introduction

The science learning goals specified in national standards documents (American Association for the Advancement of Science (AAAS), 1993; National Research Council (NRC), 1996) have provided an opportunity for researchers to focus their efforts to develop classroom resources that enhance student learning on key learning goals. In addition to establishing a coherent framework for the science topics at the different grade levels, these documents suggest that students should learn science by engaging in inquiry processes that allow them an active role in their own learning and reflect how knowledge is constructed within the various scientific communities.

Reviews of traditional textbooks have called into question the degree that these textbooks support students developing deep understandings of the learning goals identified in the national standards (Kesidou & Roseman, 2002). To provide more effective classroom materials, researchers at the Center for Highly Interactive Curriculum, Computing, and Classrooms at the University of Michigan (hice) and the Learning Sciences Group at Northwestern University developed the Investigating and Questioning Our World Through Science and Technology (IQWST) curriculum units (Krajcik, McNeill, &

Reiser, 2008; Krajcik, Reiser, Fortus, & Sutherland, 2008) . One of the first two units designed for IQWST is a middle school chemistry unit, "How Can I Make New Stuff from Old Stuff?" or the *Stuff* unit.

Early enactments of the *Stuff* unit in urban, suburban, and rural settings indicated that the curriculum helped teachers address their target learning goals successfully and supported student learning (McNeill et al., 2003). During these enactments, we observed teachers choosing to enact the unit's activities in different ways. This process of teacher adaptation, or transformation, is a common occurrence when teachers use innovative materials (Pinto, 2005), and an essential step if the materials are to be used long term in these classrooms (Blumenfeld, Fishman, Krajcik, Marx, & Soloway, 2000; M. Brown & Edelson, 2001; Fullan, 1991). Consequently, it is important to better understand how teachers' curricular adaptations affect student learning. In this study, we investigated how middle school teachers' self-efficacy, experience, and curricular adaptations of an inquiry-oriented science curriculum impacted student learning of key science learning goals.

Theoretical Framework

Role of Curriculum in Educational Reform

Over the last decade, researchers have worked to incorporate what we currently know about teaching and learning into curriculum materials they believe will prove effective. Effective curriculum materials must meet the follow criteria: (1) Their content primarily focuses on a coherent set of important, age-appropriate student learning goals (Roseman, J. E., Linn, M. C., & Koppal, M., 2008); (2) their instructional design effectively supports the attainment of the specified student learning goals; and (3) the teacher's guides support teachers in helping students attain these goals (Kesidou & Roseman, 2002). The first requirement reflects the need to focus on topics that help students learn fundamental scientific concepts, e.g. ideas expressed in either in the *National Science Education Standards* (NRC, 1996) or the *Benchmarks for Science Literacy* (AAAS, 1993). The second requirement specifies that the curriculum must provide support for instructional strategies that are consistent with what we know about how people learn, such as helping students to make sense of new experiences in light of what they already know, to share and refine their understandings, and to assume responsibility for their own learning (Bransford, 2000). The third requirement is that resources be provided for the teacher so that he or she can facilitate an effective learning environment and develop knowledge of students' commonly held ideas and expertise in assessing students' understanding and adapting instruction accordingly. Because of the deficiencies of the texts used in most classrooms, there is a dire need for more supportive science curricula (Kesidou & Roseman, 2002).

Factors Influencing How Teachers Utilize Classroom Innovation

In addition to trying to develop innovations that support student learning, researchers have recognized the importance of how teachers use these innovations with their students, and have turned their attention to teachers' adaptations of these materials. Analysis of past reform efforts indicated that in order for innovations to be sustained, teachers had to adapt them to meet local needs and conditions. In their review of past studies of teachers' adaptations of innovations, Pinto (2005) found that teachers' adaptations to innovations were influenced by their knowledge and beliefs about the subject they were teaching, their beliefs about their own identity and about teaching and learning, and the degree that the innovation was supported within their local contexts.

Teachers' beliefs about teaching and learning influence their use of new curriculum materials. Implementing classroom innovations often requires a teacher to change his or her practice and take on the unpleasant role of "novice" again (Fullan, 1991). A strong predictor of whether teachers can successfully meet this challenge is their sense of self-efficacy. Tschannen-Moran, Hoy, & Hoy (1998) define a teacher's self-efficacy as his or her belief in their ability to act in ways that successfully accomplish specific teaching goals. In their review of the use of the teacher efficacy construct, they found that it has been correlated with teachers' willingness to implement innovations. In other words, teachers who believe they are able to achieve specific teaching goals are more willing to try new innovations in their classroom.

Another factor that influences how innovations are enacted in classrooms is teachers' experience with the innovation. In past studies, we have seen that teachers continue to strengthen their use of reform-based curriculum materials through their second and third years using the units (Geier, 2005). Each time a teacher uses a particular innovation, we would expect an increase in both their understanding about how to use the innovation in his or her class, as well the effectiveness of their use of the innovative materials.

In addition, the local context can also have a significant impact on teachers' use of the curriculum. Our work with teachers occurs predominately in urban schools. Impoverished urban schools have been characterized as relying on a "pedagogy of poverty" in which students predominately engage in low level tasks (Haberman, 1991). Instructional innovations aimed at supporting complex scientific inquiry can be difficult to implement in such impoverished settings due to inadequate resources, insufficient time, large class sizes, teachers' low levels of science and computer knowledge, lack of training opportunities, high levels of teacher and student mobility, limited instructional freedom, lack of administration support, and unreliable internet connectivity (Songer, Lee, & Kam, 2002). Consequently, these contextual challenges can also impact the adaptations that teachers make to the curriculum.

Teachers' Curricular Adaptations

Although we see adaptation as essential for enacting units, some adaptations can diminish the intended function of the curricular unit. Pinto (2005) identified common themes from concurrent implementation studies of four classroom innovations. Each team of researchers saw their innovations being transformed by teachers. Sometimes these adaptations were benign and sometimes problematic. In all cases, the teachers tended to demote the goals of the innovation and adapt the innovation so its use more closely resembled familiar classroom practices. In order to provide opportunities for teachers to reflect on and refine their uses of innovations in subsequent professional development workshops, it is important to be able to share with them how specific transformations affect student learning. The transformations we are concerned with in this study include how much time teachers spend on the unit, the level of completion of the unit's activities, and whether the teachers had students actively experience the unit's investigations first hand or presented them as whole-class demonstrations.

When implementing a new curriculum or other classroom innovation, the teacher must decide how much time can be spent on the new unit. There has been considerable research on how time is spent in classrooms, and the effect of these practices on student learning. When using curriculum units designed to facilitate deep conceptual understanding, students need sufficient instructional time, i.e. time spent actively engaged in learning activities, to integrate their understandings. Reducing the amount of instructional time originally called for by the unit can reduce students' depth of understanding (Clark & Linn, 2003). However, previous research on the effects of the amount of time that teachers allocate for particular classroom activities on student learning has produced mixed results. Allocated time is not always spent on learning activities. Consequently, some studies suggested that while allocating more time for particular activities may have a small positive effect for low ability students, there is no overall effect on what students learn (Cotton, 1989). We are interested in whether the quantity of time teachers' spent on the *Stuff* unit affected student learning.

Teachers have to continually seek a balance between "covering" the topics they feel are important and ensuring that students' experiences are sufficient to develop deep understanding (Van den Akker, 1998). Teachers sometimes scale back student investigations, or decide to omit particular activities or portions of activities in the unit.

Adaptations such as this might limit students' opportunities to engage in inquiry practices, such as asking questions and talking with classmates to solve problems, or affect the coherence of unit overall (Schwartz, Fortus, Krajcik, & Reiser, 2008). Previous research has shown that teachers who frequently use inquiry-oriented teaching practices have a positive impact on science achievement. (Kahle, Meece, & Scantlebury, 2000). Consequently, we are interested in how the level of completion of a unit by a teacher influences student learning. In addition to considering how much of the curriculum they complete, it is also important to consider how they use the curriculum materials.

The tendency for teachers to transform innovative curriculum so that they resemble more traditional classroom practices suggests that how teachers choose to enact the unit might affect what students learn. The different ways that teachers manage classroom discourse have been called participation structures (Cazden, 1986) or activity structures (Fuson & Smith, 1998). These patterns of classroom discourse can vary in time scale and purpose, ranging from simple routines such as "initiation-reply-evaluation" (I-R-E) (Mehan, 1978, 1979) exchanges where students answer questions and receive immediate feedback to a sequence of project milestones used to facilitate open-ended classroom inquiry (Polman, 2004). The tendency toward transmissive classroom routines despite accepted evidence for the need for students to take a more active role in their learning is well known (Bean, 2001). In other words, whole class teacher-centered instruction often dominates classroom practice. We are interested in the relationship between teacher adaptations of the activity structures, such as completing the activities as teacher-centered demonstrations versus student-centered investigations, on student learning.

When teachers try to implement innovations such as standards-based curriculum units, there are many challenges. Teacher support structures are necessary for teachers as they implement reforms and refine their understandings (Fullan, 1991). Our own efforts at supporting systemic reform acknowledge and support teachers adapting innovative curriculum materials as they address the needs of their students, time constraints, and limitations in resources (Blumenfeld et al., 2000). One way that designers can support the adaptation process is by providing teachers with feedback on the effect their adaptations have on student learning and to provide opportunities in subsequent professional development efforts to reflect upon their practice and discuss enactment issues with colleagues and designers (Pinto, 2005). To do this, we need ways of determining how teachers' curricular adaptations influence what their students learn. In this study, we ask the following research questions:

1. How do teachers' responses on a post-enactment survey align with their enactment of curriculum materials?
2. How do teachers' curricular adaptations (the amount of time on the unit, the level of completion of the unit, and the activity structures), teacher self-efficacy, and teacher experience enacting the unit influence student learning of target science learning goals?

Method

In order to address our research questions, we used data from the enactment of the *Stuff* unit during the 2003-2004 school year. In this section, we begin by describing the *Stuff* unit in more detail. Then we discuss the participants and data sources that we used to address our research questions. Finally, we describe our procedure for analyzing the videotapes, test data and teacher survey data.

Description of Stuff Unit

The IQWST curriculum units were designed to address the need for curriculum materials that support learning goals expressed in the national standards documents and to support classroom inquiry (Krajcik et al., 2008; Reiser, Krajcik, Moje, & Marx, 2003). Aimed at middle school science classrooms, each IQWST unit includes a teacher's guide and student activity books that contain investigation sheets for each activity and reader passages that correspond to each lesson. The units' activities engage students in inquiry activities with relevant phenomena and support teachers in facilitating discussions that allow students opportunities to understand how their experiences relate to the units' learning goals. Each unit also includes supports for inquiry practices such as using evidence to construct scientific explanations and creating representations or models of phenomena.

The *Stuff* unit introduces students to the concepts of characteristic properties, substances, chemical reactions, the conservation of mass, as well as how the particulate nature of matter explains these macroscopic phenomena (McNeill, Harris, Heitzman, Lizotte, & Sutherland, 2004). The unit consists of 16 lessons, some of which contain several different activities. Some of the activities are identified as "optional," in order to provide teachers guidance in their adaptations of the completion of the unit. We felt that if teachers did need to cut activities in the unit because of time limitations that the optional activities could be removed and the students would still have opportunities to adequately support their learning of each of the target learning goals. For example, Lesson 13, "Does mass change in a chemical reaction?", includes three activities. Activity 13A is an optional activity that has students investigate whether the mass changes when they create "gloop." Activity 13.1 has students observing the reaction of Alka Seltzer in water in open and closed systems. Activity 13.2 has student redesign the 13.1 experiments so that mass will stay the same during the reaction. If all the "optional" activities are used, the unit is designed to take 33-35 school days, but if only the "core" activities are used, the unit should take only 26-28 school days.

Participants

The 2003-2004 enactment of the *Stuff* unit included five different districts and 24 different teachers. All teachers volunteered to using the curriculum materials. The teachers using the *Stuff* unit for the second time were volunteers from an earlier trial, but were not otherwise different from the teachers using the materials for the first time. We only included those teachers in the study from whom we received data from the required sources, student pre and posttest data and the teacher curriculum survey. This limited our analysis to 19 teachers (see Table 2.1).

Table 2.1:
Participants from the 2003-2004 School Year

Site	Urban A	Town B	Urban C	Suburb D	Rural E	Total
Schools	7	1	2	2	3	15
Teachers	8	3	2	3	3	19
Classrooms	30	5	4	13	13	65
Students	983	79	105	280	269	1716

Eight of the teachers were in public middle schools in a large urban area in the Midwest (Urban A). The majority of students in this school district were African American and come from lower to lower-middle income families. Three of the teachers taught in an independent school in a large college town in the Midwest (Town B). The majority of these students were Caucasian and from middle to upper-middle income families. Two of the teachers taught in a second large urban area in the Midwest (Urban C). The student population in this school district was 49.8% African American, 38% Hispanic, 8.8% Caucasian, and 3.2% Asian. Three of the teachers taught in a suburb of the second large urban area (Suburb D). The student population in this school district was ethnically diverse (approximately 42% Caucasian, 44% African American, 10% Hispanic and 4% Asian). Finally the last three teachers taught in a rural area in the south (Rural E). These schools had diverse populations each with a majority of African American students.

Measures

To answer our research questions, we needed to examine both teachers' enactment as well as their responses to our survey. To determine how teachers' survey responses might relate to classroom practice, we examined a selection of videotaped lessons from a subset of the respondents. To determine how teachers' practices might influence student learning, we measured student learning using pre/post tests and related these results to their teachers' responses to a survey about their enactment. In this section, we describe our use of video to characterize teachers' use of curriculum materials, our conceptual model, and our measures of each of the variables included in our model.

Description of video. To understand how teachers' survey responses corresponded to their actual classroom practice, we compared teacher responses with our own observations for a subset of lessons and teachers where video recordings were available. Due to the limited number of videotaped lessons available, our selection of teachers was neither representative nor random. The four teachers we videotaped taught in three different schools in the Urban A school district. These four teachers were selected to be observed, because of their proximity to the researchers and their willingness to be videotaped. We reviewed their enactments of five *Stuff* activities to determine the duration, activity structure, and level of completion, and compared our observations with the teachers' survey responses. Table 2.2 summarizes the number of hours of videotape reviewed for the four teachers.

Table 2.2:
Hours of video examined for each activity.

Activity	Description	Tchr D (hrs)	Tchr B (hrs)	Tchr H (hrs)	Tchr E (hrs)
Lesson 8	Does Acid Rain Make New Substances?				
8.1	After reading about the discoloration of the Statue of Liberty, students see a demonstration of burning magnesium and use the properties of the reactants and products to explain whether a chemical reaction has occurred.	1	2	2	2
8.2	Students study a model of the Statue of Liberty by investigating the effect of vinegar vapor on pennies.	2	1	3	1
Lesson 10	Do I Always Make New Substances?				
10.1	After hypothesizing whether or not the bubbles always indicate that a chemical reaction is occurring, students investigate whether boiling and condensing water is a chemical reaction	2	2	1	1
10.2	Students investigate whether creating a mixture such as "Kool-Aid" involves a chemical reaction.	2	1	0	0
Lesson 12	How Can I Make Soap From Fat?				
12.1	Students return to materials they described in the first learning set to create soap from fat. After they create their cake of soap, they read about the history of soap making to discuss the following day.	3	2	2	1

Our conceptual model. To investigate the influence of teachers' adaptations on students' learning during the *Stuff* unit, we compared measures of student learning with factors that may influence teachers' adaptations of the materials and the adaptation practices themselves. A conceptual model of our study including all of the measures that we investigated is shown in Figure 2.1. We describe each of these measures in more detail below.

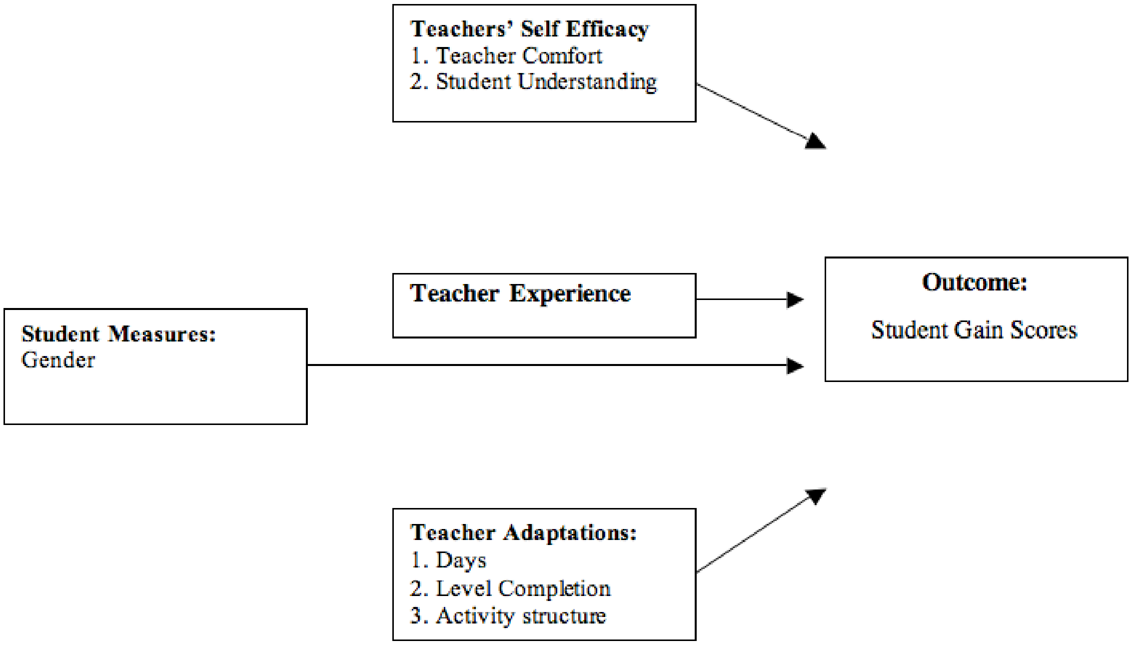

Figure 2.1. Conceptual Model

Description of pre/post test. To measure student learning for all teachers, the same test was administered to students before and after the *Stuff* unit. The test consisted of 15 multiple-choice items and 4 open-ended items for a total of 30 points. The test items were aligned with the unit's learning goals and learning tasks (Krajcik, McNeill & Reiser, 2008). All open-ended items were scored using specific rubrics created to address the particular inquiry practice and content area (see McNeill & Krajcik, 2007 for description of rubrics and coding). One rater scored the students' open-ended responses. We then randomly sampled 20% of the tests, which were scored by a second independent rater. Our estimates of inter-rater reliability were calculated by percent agreements. Our inter-rater agreement was above 96% for each of the four open-ended test items.

Only students who completed both the pretest and posttest were included in our analysis, because we were interested in how students' science achievement changed over time. Due to the high absenteeism in the urban schools, only 1234 students completed both the pre and posttest. In order to examine whether the students who only completed the pretest or only completed the posttest were different than the students who completed both the pre and posttest, we conducted a missing data analysis. We compared the students' pretest scores for those students who also completed the posttest to those students who did not complete the posttest for each of the nineteen teachers. Sixteen of the nineteen teachers did not have a significant difference for the two groups. For the three teachers that did have a significant difference (Teachers B, O and P), their students who were not missing the posttest had significantly higher pretest scores than those students who were missing the posttest. We also compared the students' posttest scores for those students who completed the pretest to those students who did not complete the pretest for each of the nineteen teachers. Fifteen of the nineteen teachers did not have a significant difference for the two groups. For the four teachers who did have a significant difference (Teachers N, R, P, and Q), the students who were not missing the pretest had higher posttest scores than those students who were missing the pretest. This suggests that the students who were in school for both the pre and the posttest were higher science achievers than those students who were absent on one of the test administration days for some of the teachers. Yet for the majority of the teachers those students who were absent one test day were not significantly different. Nonetheless, one limitation of this study is that we were unable to collect pre and posttest data from all of the students.

In order to assess student learning over the unit, we used students' gain scores. We calculated the gain scores by subtracting the pretest score from the posttest score. We used this measure as the outcome for our model. On the test, students also indicated their gender, which we also included in the model. Unfortunately, our agreement with the schools did not allow us to collect other demography data from the students so were not able to include race or other measures in our study.

Description of survey. To gauge how teachers assessed and adapted the *Stuff* unit, each teacher was asked to complete a survey after they finished their enactment. The survey consisted of 16 pages, one for each of the unit's lessons, which could include more than one activity (For a sample survey page, see Appendix 1.1). Since we were interested in the teachers' appraisals of their efficacy using the unit, they were asked to indicate their comfort-level with each activity and their students' understanding of each activity. To get feedback on their adaptation strategies, teachers were asked to indicate whether each activity was done by students or as a teacher demonstration, its level of completion, and how many days were spent on each lesson. To determine each teacher's experience with the unit, we used our records of previous enactments.

To analyze the survey responses, we first converted each teacher's checkmarks on the survey form to numerical codes and transferred them to a cumulative table. Table 2.3 summarizes how numbers were assigned to the teachers' responses.

Table 2.3:
Numerical assignments for teachers' survey responses.

Variable	Survey Item	Numerical Assignment
Self-Efficacy	Teacher Comfort Level	1 – low; 2 – medium; 3 – high
Self-Efficacy	Student Understanding	1 – low; 2 – medium; 3 – high
Experience	Experience	0 – first use of unit; 1 – second use of unit.
Teacher Adaptation	Activity Structure	1 – teacher demo; 2 – student investigation; 3 - both
Teacher Adaptation	Level Completion	0 - not used; .5 - partially completed; 1 - completed
Teacher Adaptation	Days Spent on Lesson	Total number of days spent teaching the unit

After tabulating teachers' responses, we reduced each teacher's responses to a single number for each of the variables listed above. For the teachers' self-efficacy, we averaged their responses for their own comfort level and their students' understanding for each activity across the entire unit. Each teacher's experience with the unit was coded as either the first or second use of the materials. In order to summarize the activity structures teachers used during the unit, we averaged their scores across all of the activities in the unit. For their level of activity completion, we totaled their scores across the unit and divided this total by the number of "core" or not optional activities so that teachers who enacted the core activities along with one or more optional activities would have a score greater than one. The total number of days each teacher allocated to the unit was found by adding the days he or she indicated were spent on each lesson.

Analytic Method

We analyzed both the teachers' enactments to determine how the their practice related to their reports of their practice on our survey as well as how their survey results related to their students' achievement. Each of these steps is described below.

Enactment analysis. To answer how teachers' survey responses represented how they enacted the *Stuff* materials, a small sample of videotaped lessons were reviewed. Teachers' survey responses for activity structure and level of completion were compared with their videotaped enactments for the four teachers where videotape data was available.

HLM analysis. Determining the impact of teacher adaptations on student learning is a complex issue. Because each teacher's efforts affect each of his or her students, learning by individual students in the same class is not independent. On the other hand, considering the class mean as the outcome variable loses the individual variability of student learning. Neither approach would allow us to disentangle individual and group effects on student learning. In our analysis of the survey and test data, we needed to consider this grouping or nesting of students and any differential effects across teachers. Multi-level modeling recognizes the dependence and grouping of data leading to more correct estimation of effects and variance. We used Hierarchical Linear Modeling (HLM) in a two-level format to investigate the effect of factors that affect teachers' adaptations and teachers' adaptation strategies on student learning (Raudenbush & Bryk, 2001). Our use of HLM consisted of three steps. First, we created a fully unconditional model (FUM), then we created a level 1 or within-teacher model to examine the effect of student level variables, and finally we created a level 2 or between-teacher model to examine the effect of teacher level variables.

Fully Unconditional Model. HLM analysis begins with a fully unconditional model, which consists only of the outcome variable and no independent variables. The fully unconditional model provides the results of partitioning the outcome variance into within-group ($\sigma2$) and between-group ($\tau00$) components, testing whether the between group component is significantly different from zero. In our model we used student gain scores, to determine whether there were differences in student learning across the nineteen teachers. From these measures we computed the intraclass correlation coefficient (ICC), ρ, which is the proportion of variation in the student gain scores that is due to differences among teachers.

Within-Teacher Model. Next, we investigated the student-level measures that could account for the variation within teachers. We entered gender as a fixed effect. This meant that the effect of gender did not vary depending on what teacher a student had. The following is the equation for our level-1 model:

$$\text{Gain Score}_{ij}=\beta_{0j} + \beta_{1j}(\text{Gender}_{ij}-\text{Gender}_{..}) + r_{ij}$$

In this equation, β_{0j} represents the intercept or the gain score when all other variables equal zero, β1j represents the effect of gender on student gain scores and, and rij represents the error term.

After running the within-teacher model, we determined how much of the total unexplained individual-level variance for student gain scores was explained by the addition of our level-1 variable.

Between-Teacher Model. Lastly, we ran a between-teacher model. This allowed us to model student learning with our teacher-level measures to explain the between-teacher variation in our outcome variable. More specifically, we determined if student learning was impacted by teacher self-efficacy, experience, and curricular adaptations. We tested the six teacher level variables that we described above: teacher comfort level, teacher evaluation of student understanding, teacher experience enacting the unit, the number of days allocated to the unit, the level of completion of the unit's activities, and the teachers' activity structure, (i.e. whole-class demonstration versus student investigation). We removed any variables that were not significant.

The relatively small number of teachers in the study limited our model. As a general rule, you need ten cases at a level (either level 1 or level 2) for each significant variable included in a model (Raudenbush & Bryk, 2001). Since we only had nineteen teachers in our study to include in the level 2 model, it was not surprising that we ended up with a model that included only two significant teacher practices. In our testing of the various models, we found two models that each included two significant variables. One model included teacher experience and level of completion and the second model included teacher experience and activity structure. Since the second model including teacher experience and activity structure had lower significant levels, we used it as our final model. We hypothesize that if we had a larger sample of teachers, all three variables, teacher experience, level of completion and activity structure, would significantly influence student learning. The following is our equation for the level-2 model for student gain scores:

$$\beta_{0j} = \gamma_{00} + \gamma_{01}(\text{Activity structure}) + \gamma_{02}(\text{Teacher Experience}) + \mu_{0j}$$

In this equation, γ_{00} represents the intercept, γ_{01} represents the effect of activity structure, γ_{02} represents the effect of teacher experience, and μ_{0j} represents the error term. Teachers' activity structures (i.e. whole-class demonstration versus student investigation) and level of experience were used to model the intercept. None of the other teacher-level measures, days spent on the unit, student understanding, teacher comfort level or level of completion, were significant. Consequently, we removed them from our final level-2 models.

As with the within-teacher model, we can determine how much of the total unexplained individual-level and teacher-level variance of our outcome has been explained by the addition of our level-2 variables.

Results

In this section, we begin by presenting the descriptive statistics for the results of the teacher survey and the results from the students' pre and posttest to provide an overview of the data. Then we present the results from comparing the teacher survey data with the video analysis. Finally, we present the results from the HLM model.

Descriptive Statistics

Before creating our HLM model, we first examined whether there were differences in student learning and teacher adaptations across the 19 teachers. Table 2.4 summarizes the descriptive statistics for all of the variables included in our study.

Table 2.4:
Descriptive Statistics (n=1234)

	Mean/% (Standard Deviation)
Student Variables	
Gender[a]	50.00
Test Gain Score	7.49 (5.23)
Teacher Variables	
Self-Efficacy – Teacher Comfort Level	2.55 (0.34)
Self-Efficacy – Student Understanding	2.39 (0.44)
Experience[b]	27.00
Teacher Adaptation - Days	31.17 (6.97)
Teacher Adaptation – Activity structure	1.93 (0.14)
Teacher Adaptation – Level Completion	0.94 (0.16)

Percentage of female compared to males
Percentage of teachers who have done the unit before compared to those who have not

Fifty percent of the students in the sample are male and fifty percent are female. We only included students in the analysis who completed both the pre and posttest. We computed each student's gain score by subtracting the pretest score from the posttest score. On average, students gained 7.49 points from the pre to posttest though the gain scores ranged from –13.36 to 22.80.

For the teacher variables, we see a range of scores for both the teacher adaptation variables and the efficacy variables. For teachers' activity structure the average score was 1.93. Remember a score of 1 means that a teacher completed all activities as a demonstration, a score of 2 means that students completed all activities, and a score of 3 means that all activities were both demonstrated by the teacher and completed by the students. This suggests that for most lessons teachers had students complete the activities, but some were on average only completed as demonstrations. The average level of completion was 0.94 suggesting that typically teachers were completing a little less than the recommended core activities within the unit. Remember that we coded teachers' completion as 0 for not using the activity, 0.5 for partially completing the activity and 1 for fully completion of the activity. On average, teachers spent 31.17 days on the unit. Twenty-seven percent of the teachers previously enacted the unit. Teacher's average comfort level was a 2.55, which is between medium and high. Finally, teachers' perception of student understanding was 2.39, which is also between medium and high.

Student Assessment Data

Since we are interested in whether there is differential learning by teacher, we examined the effect size of student learning by teacher[1]. Figure 2.3 shows the effect sizes for the nineteen teachers.

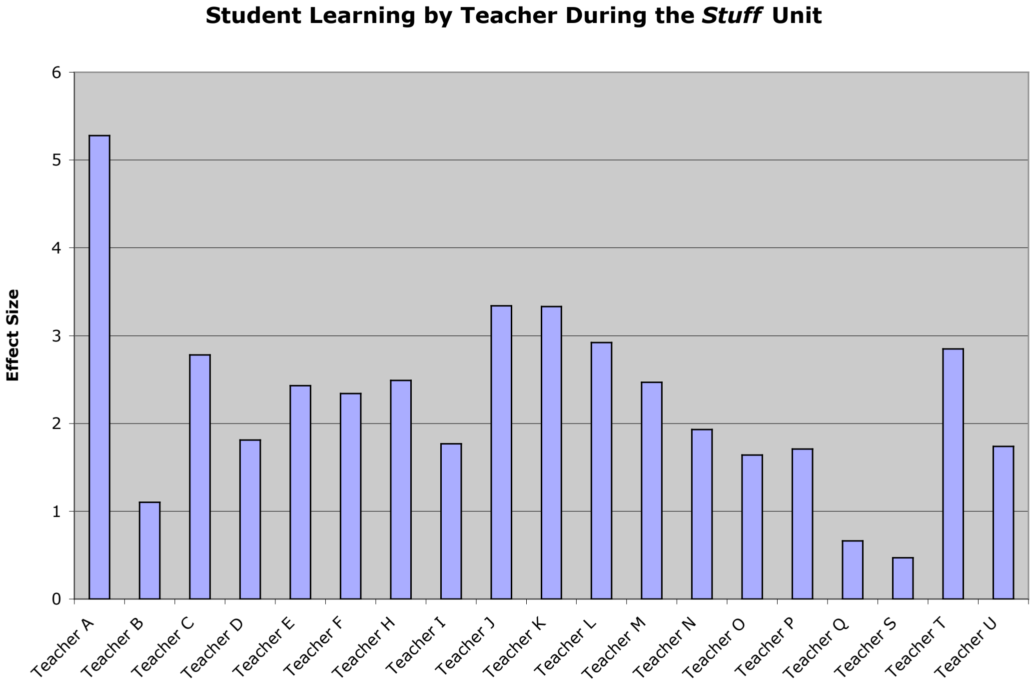

Figure 2.2. Effect size by Teacher

Across the nineteen teachers, there is a wide range of effect sizes from 0.47 to 5.27. We tested whether there was a significant teacher effect by performing an ANCOVA on students' posttest scores with the pretest scores as the covariate. There was a significant teacher effect with the learning gains of some teachers being greater than other teachers, F (18, 1215) = 9.062, $p < .001$. There was also a significant interaction between the

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[1] ^{c}Effect Size: Calculated by dividing the difference between posttest and pretest mean scores by the pretest standard deviation

teacher and students' pretest scores, $F\ (18, 1215) = 2.868$, $p < .001$, suggesting that the effect of a students' pretest on their posttest varied by teacher.

This analysis suggests that something is occurring in each of these classrooms that is influencing student learning. These differences could be caused by a variety of factors such as the school culture, parental influence, or different resources. We also believe that the differences in teachers' enactments are influencing student learning based on prior research (Kahle et al., 2000). Our hypothesis is that some of this difference in student learning is the result of teacher adaptations, experience and efficacy.

Enactment Analysis

In order to evaluate the validity of the self-report survey data, teachers' adaptations of lessons 8, 10 and 12 were reviewed from videotapes. The results, sorted by each teacher's effect size, are summarized in Table 2.5. For each activity, an objective measure of the degree that the activity was completed was computed by dividing the number of activity elements observed (AEs_{OB}) divided by the total number called for in the *Stuff* teacher's guide (AEs_{TG}) is recorded for each teacher, along with the average level of completion of the activities indicated on their survey. The teachers' activity structure for each activity (Demonstration, Student Investigation, or Both) observed in the videotapes was also recorded, along with teachers' survey responses for how they adapted each activity.

Table 2.5:
Observed activity elements.

	Observed Activity Elements (AE)	Tchr B	Tchr H	Tchr D	Tchr E
	Teacher Effect Sizes	1.10	1.77	1.81	2.43
Less 8	Does Acid Rain Make New Substances?				
Act 8.1	*Students observe a demonstration of burning magnesium and use the properties of the reactants and products to explain whether a chemical reaction has occurred.*				
	Level of completion from video (AE_{OB}/AE_{TG})	0.6	0.7	0.7	0.8
	Level of completion from survey (1=fully completed, 0.5 = partial, 0 = not used)	1	1	1	1
	T Demo = 1 / Student Inv = 2 / Both = 3 (video)	1	2	2	1
	T Demo = 1 / Student Inv = 2 / Both = 3 (survey)	3	3	2	2
Act 8.2	*Students study Acid Rain by investigating the effect of vinegar vapor on pennies.*				
	Level of completion (video) (AE_{OB}/AE_{TG})	0.3	0.6	0.6	0.4
	Level of completion (survey) (1=fully completed, 0.5 = partial, 0 = not used)	0.5	1	1	1
	T Demo = 1 / Student Inv = 2 / Both = 3 (video)	1	3	2	3
	T Demo = 1 / Student Inv = 2 / Both = 3 (survey)	2	3	2	2
Less 10	Do I Always Make New Substances?				
Act 10.1	*Students investigate whether boiling and condensing water is a chemical reaction*				
	Level of completion (video) (AE_{OB}/AE_{TG})	0.3	0.4	0.7	0.6
	Level of completion (survey) (1=fully completed, 0.5 = partial, 0 = not used)	0.5	0.5	1	0.5
	T Demo = 1 / Student Inv = 2 / Both = 3 (video)	1	1	2	1
	T Demo = 1 / Student Inv = 2 / Both = 3 (survey)	3	1	2	1
Less 12	How Can I Make Soap From Fat?				
Act 12.1	*Students return to materials they described in the first learning set to create soap from fat.*				
	Level of completion (video) (AE_{OB}/AE_{TG})	0.8	0.6	0.8	0.6
	Level of completion (survey) (1=fully completed, 0.5 = partial, 0 = not used)	1	1	1	1
	T Demo = 1 / Student Inv = 2 / Both = 3 (video)	3	2	3	2
	T Demo = 1 / Student Inv = 2 / Both = 3 (survey)	3	2	2	2

To determine how teachers' responses on the survey might represent their enactment of the opportunities to learn provided in the *Stuff* curriculum materials, the fraction of AEs observed, the level of completion indicated by each teacher on the survey, the activity structures observed, and the activity structures indicated by teachers on the survey were averaged for each teacher across the reviewed activities.

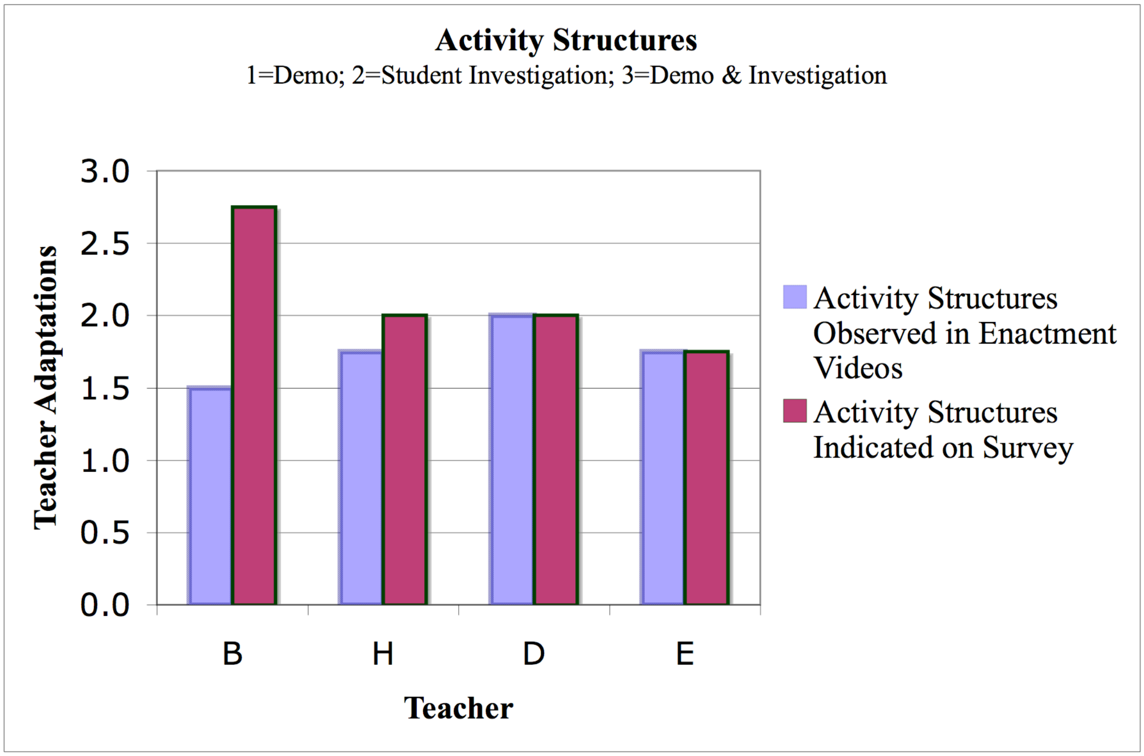

Figure 2.3. Activity Structures

Figure 2.3 compares four teachers' activity structures observed in videotapes of selected activities with their survey responses about how they enacted the same lessons. These comparisons are arranged in order of effect sizes, with the leftmost teacher having a lowest effect size (1.10), the middle two teachers having similar effect sizes (1.77,1.81), and the rightmost teacher having a higher effect size (2.43). The graph shows that the survey responses belonging to the three teachers with the highest effect sizes were very similar to the assessments of their enactments from the videotapes. These teachers' average activity structure scores were between 1.75 and 2.00, suggesting they generally provided students opportunities to conduct the investigations called for in the unit. Though the fourth teacher's survey suggested that students also had these opportunities, examination of the videotaped activities indicated that the teacher relied more on demonstration and direct instruction to address the unit's topics.

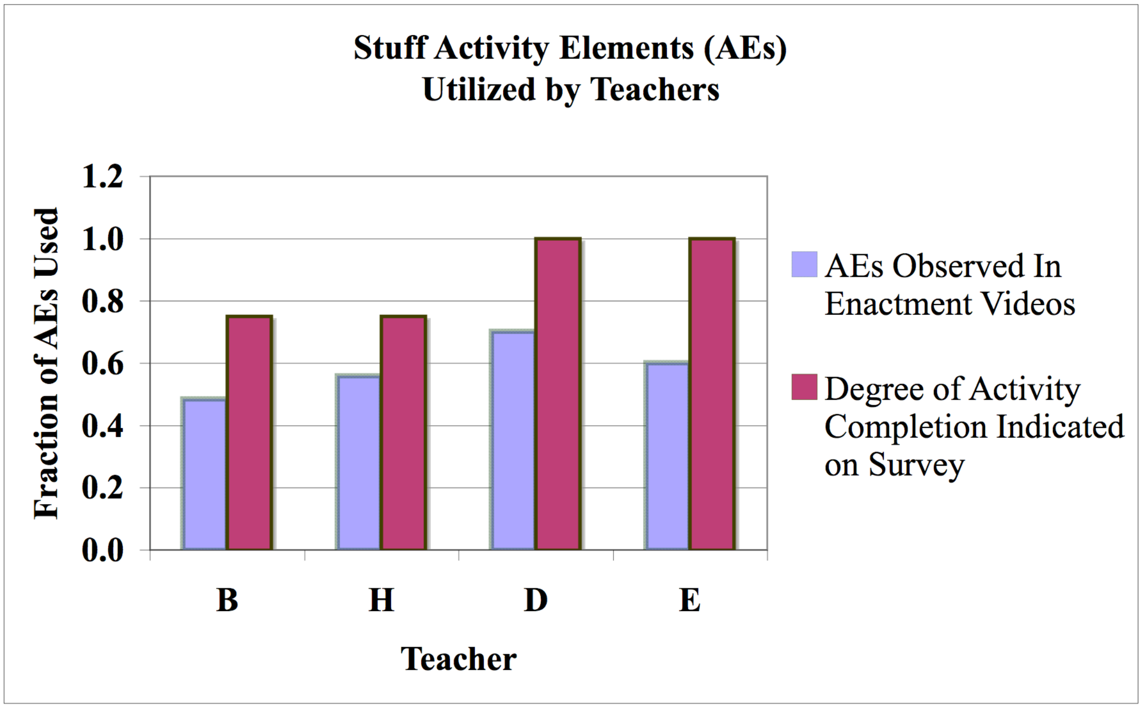

Figure 2.4. Level of completion

Figure 2.4 compares the proportion of the learning opportunities called for in the *Stuff* materials experienced by students the in four teachers' classrooms that were videotaped with the level of completion of each *Stuff* activity reported by the teachers for the videotaped lessons. As in the previous graph, the comparisons are arranged from lowest to highest effect size. The graph suggests that although each of the teachers overestimated the extent that his or her enactment contained the activities suggested by the curriculum materials, the teachers with higher effect sizes enacted more of the activities as indicated.

HLM Analysis

Fully unconditional model. We began our HLM analysis by examining the fully unconditional model, which partitions the total variance in students' gain scores into its within- and between-teacher components. Table 2.6 provides the results from the unconditional model.

Table 2.6
Unconditional Model of Student Learning
(n = 1234 students, N = 19 teachers)

	Student Gain Scores
Tau (τ)	0.384
Sigma-squared (σ^2)	0.646
Lambda-reliability (λ)	0.967
Intraclass Correlation (ICC)[a]	0.373
Adjusted-ICC[b]	0.380

[a] ICC = $\tau/(\tau + \sigma^2)$

[b] Adjusted ICC = $\tau/(\tau + (\lambda\sigma^2)$

Lambda is the pooled reliability estimate across all the teachers for estimating our outcome variable, student gain scores. Since the reliability estimate is high, 0.967, we are comfortable using the adjusted intraclass correlation (ICC). The adjusted ICC tells us that 38% of the variance in student gain scores lies among teachers. There was a significant difference in student gains between teachers, $\chi^2 = 693.85$, $df = 18$, $p < .001$. Consequently, this supports our decision to use multilevel methods.

Within-teacher model. The within-teacher model explores whether gender is associated with student learning. We included gender as fixed effect, which means that the effect of gender did not vary depending on the teacher. Table 2.7 provides the results from our within-teacher model.

Table 2.7:
Within-Teacher Model of Student Gain Scores
(n = 1234 students, N = 19 teachers)

	Student Gain Scores
Random Effects	
Intercept (β_0)	-0.012
Fixed Effects	
Gender[a]	0.104*
Variance Components for Random Effects	
Intercept variance (β_0)	0.383***

~ < .1; * p < .05; ** p < .01; *** p < .001
[a] Females compared to males

A student's gender does significantly influence their gain scores. On average, a female's gain score increases 0.104 standard deviations more than a male. Although adding gender does significantly influence student learning, it explains a very small percentage of the individual-level variance in student learning, less than 1%[2]. Unfortunately, we do not have access to other student level variables to include in the model. The intercept variance at the bottom of Table 2.7 suggests that there is still significant between-teacher variability. This provides support that there are contextual factors or characteristics of the

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[2] From the Fully Unconditional Model, we found that the amount of variance at the individual level was 0.64575. After taking into account our predictor variables in our within-teacher model, the within teacher variance is 0.64359. Therefore, the proportion of the individual-level variance that has been explained by our individual-level predictors is (0.64575 – 0.64359)/ 0.64575, which equals 0.0033. This means that our within teacher model explains 0.33% of the variance in student learning.

teachers that influence student learning. In order to further unpack the role of teacher characteristics, we need to add level 2 predictors to our HLM model.

Between-Teacher HLM model

Table 2.8 presents the results from our complete HLM model including both Level 1 and Level 2 predictors. Although we tested numerous teacher level characteristics in our model, we only kept in the model those measurements that were significant.

Between-teacher model. The first set of results under intercept in Table 2.8 is for our model in terms of the intercept as the outcome. These results tell us whether any of the teacher characteristics influence student learning.

Table 2.8:
Between-Teacher Model of Student Learning
(n - 1234 students, N = 19 teachers)

	Student Gain Scores
Random Effects	
Intercept (β_0)	
Base	-0.234
Activity structure	1.869~
Experience with Unit	0.715**
Fixed Effects	
Gender[a]	0.105*
Variance Components for Random Effects	
Intercept Variance (β_0)	0.258***

~ < .1; * p < .05; ** p < .01; *** p < .001
[a] Females compared to males

Teachers' activity structures (i.e. demo versus student investigation) have a marginally significant effect and a teacher's experience with the unit has a significant effect on student learning. Holding all other variables constant, as a teacher's activity structure increases by 1 point (i.e. goes from all lessons completed as demo to all lessons completed by students), students gain scores increase by 1.869 standard deviations. This is a very large increase in students' gain scores and suggests that having students actively complete the activities is important for students understanding of the key learning goals. On average, a teacher with experience teaching the unit has student gain scores of 0.715 standard deviations higher than a teacher who is completing the unit for the first time. This suggests the importance of having experience with reform based curriculum units.

Neither the number of days spent on the unit, teacher comfort level, teachers' report of their students understanding, nor level of completion significantly influenced student learning. As we mentioned before, since our data includes only 19 teachers we would expect to only have at most two significant variables in our model. Our model is not powerful enough to detect significant effects of more variables. Other variables, particularly level of completion, which was significant by itself or in combination with teacher experience, could be important predictors of student learning if we had a more powerful model. Our model does not suggest that these other variables are not important; rather it provides support that both teacher experience and activity structure are particularly important for student learning.

For average student learning between teachers, our model explains 33% of the variance.[3] By including only two variables in our model about teacher adaptations and experience, we explained a considerable percentage of the between teacher variation. Furthermore, we obtained the measure of teacher adaptation through a simple teacher survey of how they enacted the curriculum. Yet the variance component at the bottom of Table 2.8 shows that the between teacher variances is still significant. This means that we have not explained away all of the between teacher variance for student learning. There are other measures, such as the degree that teachers supported students' sensemaking, that were not included in our model that may further explain why student learning varies with different teachers.

Discussion

Alignment of teachers' survey responses with their enactment. In addition to modeling the effect of teachers' practices on what students learned during the *Stuff* unit, we were interested in how teachers' responses to a survey about their enactments compared to our observations of videotapes of their lessons. The limited availability of videotaped lessons led us to focus on four teachers from three schools in the one of our urban districts.

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[3] To calculate the proportion of the between-level variance that we explained in our model we used the following equation: $(\tau_{withinmodel} - \tau_{betweenmodel})/\tau_{withinmodel}$. In this case (0.38257-0.25814)/ 0.38257 = 0.3252.

When we reviewed two teacher adaptations that were addressed in the survey, activity structure and level of lesson completion, and our results were mixed. The teachers accurately represented how they enacted the lessons that we reviewed, i.e. demo or student activity. Though the teachers all overestimated the degree of completion for each activity, their enactments seemed to roughly parallel their responses on the survey. Though teacher self-reports of curriculum enactment have been criticized in the past (Snyder, Bolin, & Zumwalt, 1992), these results suggests that in the absence of the ability to directly observe teachers' enactments, using this type of survey can reflect some aspects of their use of the curriculum materials accurately.

Effect of teachers' curricular adaptations on student learning. We used teachers' responses on a post-enactment survey and pre/post test measures of student learning to determine whether teachers' adaptations to the *Stuff* curriculum unit explained differences in what their students learned.

We found the differences in student learning gains between teachers to be significant. Between-teacher variation accounted for 38% of the variance in student gain scores. Of the six teacher variables that we considered, only two of the variables, activity structure and teacher experience were found to be significant. Students who completed the activities had greater student gains then students in classrooms where the teacher completed the activities as demonstrations. Furthermore, experienced teachers had students with larger test gains. Our final model, which included the effects of activity structure and experience, explained 33% of the between-teacher variation in student learning gains. This result is consistent with previous studies documenting the importance of having students actively engage in making sense of their classroom experiences (Kahle et al., 2000) and the importance of teacher experience in enacting reform based curriculum (Geier, 2005). These results suggest that HLM analysis of survey data can contribute important knowledge about the impact of teacher adaptations of curriculum materials, which can be used by researchers as they bring their innovations to scale.

The relatively low number of teachers in our study for HLM limited the power of our model. We would expect other adaptation measures to be strong predictors of student learning, but their effects were not significant here. Specifically, we would expect that the level of completion of the unit and measures of teacher efficacy to influence student learning. Our model does not suggest that these measures are unimportant, rather it just suggests that teacher experience and activity structure are particularly important. Furthermore, as we discussed previously there are limitations in using survey data to measure teacher enactment. The survey did not provide a variety of details about the enactments such as any measure of the quality of instructional practices being used in the classroom. Future research needs to continue to explore what other characteristics in teachers' enactment cause the significant variation in student learning between teachers. Yet the importance of both students conducting activities and investigations as well as teacher experience in enacting inquiry-oriented curriculum are essential fundamental findings that should be kept in mind during future curriculum development and support.

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Chapter 3
Learning from Professional Development Institutes to Develop Facilitator Materials

Introduction

Classroom teachers continue to strive to improve their students' learning opportunities and researchers continue to develop curriculum materials they hope will support these efforts on a wide scale. Studies of past reform efforts suggest that if curricular resources are to contribute to improving student learning, providing teachers with sustained opportunities for professional development is critical for the reforms to become part of a school's or a district's culture (Snyder et al., 1992; Supovitz, 2007; Tyack & Cuban, 1997). In recent years, researchers have documented the effectiveness of professional development as a source of teacher learning (Borko, 2004), have added to our understanding of how teachers learn to use innovative curriculum materials from these experiences (Kubitskey, 2006), and have begun to investigate how professional development can help foster implementation of reforms (Penuel, Fishman, Yamaguchi, & L. P. Gallagher, 2007). Up to this point, however, little work has been done to understand how to design professional development experiences that can be facilitated by local personnel to scale and sustain the use of reform-rich curriculum (Borko, 2004).

One approach to preparing to meet this challenge is to critically analyze the professional development opportunities facilitated by curriculum developers themselves. Curriculum developers are often involved in supporting teachers' initial enactments of new materials. Though curriculum developers have a deep understanding of the materials as well as strong views about what constitutes the materials' essential features (Fishman, Fogleman, Kubitskey, et al., 2003), we do not know how this understanding influences their design of PD experiences and how they develop their capacity to design and facilitate PD that effectively supports their materials.

This study examines how a group of curriculum developers introduced their curriculum materials to a group of veteran teachers by examining how they planned and enacted an introductory professional development institute. The study focuses on the topics curriculum developers chose to address as well as the instructional strategies they relied upon during the institute. This knowledge can inform our decisions how we design and facilitate PD in the future as well as what types of supports will be needed to eventually transfer ownership of PD to external facilitators such as district lead teachers.

To capture the curriculum developers' capacity to provide PD supporting their units, both their plans and their enactment of the institute will be analyzed and compared. Our current understanding is that expert teachers use plans and instructional materials as a frame to support an interactive unfolding of the enacted curriculum (Brown & Edelson, 2001; Cohen & Ball, 1999; Remillard, 2005) and adapt their plans to address their students' needs (Remillard, 2005; Sawyer, 2004; Borko, Bellamy, & Sanders, 1992). In the case of curriculum developers leading professional development sessions to introduce their materials to teachers, my hypothesis is that their rich understanding of the design rationale, goals, and features of the materials comprise the expertise necessary to assess and address the needs of the participating teachers. In other words, the effort put forth to develop high-quality reform-rich curriculum materials should contribute to curriculum developers having the pedagogical content knowledge (Shulman, 1986) to conduct PD around their curriculum materials effectively. If this hypothesis is valid, I would expect to see the curriculum developers use PD strategies that modeled the type of interactions that they want teachers to use in their classes and adjust what they had planned during their enactment to meet their perceptions of teachers' needs while remaining consistent with their own priorities for the institute.

To understand how the curriculum developers represented their materials, I examine four half-day sessions that occurred within a week-long introductory professional development institute. These sessions were chosen because they were facilitated by curriculum developers and were focused on three of the four units that comprised the year-long curriculum. Videotapes and materials were analyzed in three stages to inform the findings. In the first stage, I examine the developers' planning meetings and written plans to determine their learning goals and priorities for the institute. In the second stage, I examine how the institute sessions were enacted. In the third and final stage, I compare the curriculum developers' plans with their enactment of four PD sessions.

To explore this issue, the following questions are examined:

a. What did the curriculum developers set out to convey about their units in an introductory institute?

b. What knowledge and strategies did curriculum developers use to represent key aspects of curriculum materials that address important science learning goals and inquiry practices to teachers in an introductory professional development institute?

c. How did the knowledge included and the professional development strategies used during the professional development compare to what the curriculum designers originally planned would occur, and how do these differences indicate why developers made these adjustments?

Theoretical Frame

When teachers are introduced to innovative curriculum materials, the designers hope that they will use the materials as they were intended and that students will learn successfully. To that end, professional development facilitators -- curriculum developers, professional developers, and teacher leaders -- design learning opportunities that help teachers understand the goals, resources, and instructional strategies that characterize the materials. The PD design process should take into account teachers' beliefs about how students learn, teachers' prior teaching practices, how teachers learn, how they typically use curriculum materials, what teachers need to know in order to use the new materials effectively, and what instructional strategies characterize effective professional development. In this section, I summarize what we know about each of these aspects and describe how I applied these understandings to examine the content and strategies used in professional development institutes.

Traditional Teaching Practices

Despite recent advances in our understanding of effective science teaching and learning, what is happening in typical science classrooms has not changed to reflect what we have learned. Many teachers, under pressure to cover a curriculum that is a "mile wide and an inch deep," still tend to rely on a "motivate, inform, and assess" instructional cycle that emphasizes students recalling facts instead of developing deep understandings of key concepts (Duschl, Schweingruber, & Shouse, 2007). Such teaching practices endure in part because they are so familiar to students, teachers, and parents, comprising what Tyack & Cuban (1997) called the "grammar of school."

How Teachers Use Reform-Rich Curriculum Materials

When designing learning experiences that prepare teachers to use new curriculum materials for the first time, it is also important to take into account what we know about how teachers use reform-rich curriculum materials and how these materials align with their current teaching practices. At the heart of classroom instruction are the interactions between students, curriculum resources, and the teacher. What students learn depends in part on their teacher's capacity to use the available curriculum resources effectively (Brown & Edelson, 2001; Cohen & Ball, 1999). Teachers' uses of curriculum materials are influenced by their knowledge and beliefs about teaching and learning, and their understanding of the material's intent and features (Pinto, 2005). There is evidence that given appropriate supports, teachers are able to use reform-rich materials to change their classroom practices, though many struggle with the more challenging elements such as facilitating student investigations and moderating classroom discussions to promote dialog among students (Schneider, Krajcik, & Blumenfeld, 2005).

How Teachers Learn

Davis & Krajcik (2005) summarize our knowledge of teacher learning as follows:

> "Teacher learning involves developing and integrating one's knowledge base about content, teaching, and learning; becoming able to apply that knowledge in real time to make instructional decisions; participating in the discourse of teaching; and becoming enculturated into (and engaging in) a range of teacher practices. Teacher learning is situated in teachers' practice -- including classroom instruction and also planning, lesson modification, assessment, collaboration with colleagues and communication with parents."

If teachers are to use curricular innovations successfully, they need opportunities to make sense of how their students are supposed to experience these innovations. There is evidence that teachers learn a great deal from enacting new materials with their students and their participation in ongoing professional development (Fishman, Marx, Best, & Tal, 2003; Kubitskey, 2006; Penuel et al., 2007; Richardson, 1996). In order to help teachers use materials that call for significant changes in these established classroom practices, PD opportunities should include experiences that help them understand these new practices in the context of using the materials with their students and provide them with opportunities to discuss their understandings with other practitioners. (Kolodner, 2002; Putnam & Borko, 1997).

What Teachers Need to Know to Use Curriculum Material Effectively

What do teachers need to learn in order to enact reform-rich curriculum materials for the first time? If teachers are expected to be able to adapt their use of the materials to their local conditions and to the needs of their students, then their introductory professional development should prepare them to use the materials in ways that remain congruent to the intent of the materials (Blumenfeld et al., 2006). Davis and Krajcik (2005) suggest several types of knowledge that can enhance teachers' ability to adapt curriculum materials to meet their students' needs. These knowledge types can be used to distinguish the types of knowledge conveyed in professional development institutes. These include:

1. Subject matter knowledge (SMK) - The concepts, facts, and disciplinary practices related to the subject dealt with in the curriculum materials.
2. Pedagogical content knowledge (PCK) - Information that helps teachers anticipate and interpret what learners may think about or do in response to the activities in the unit, what understandings they may hold on to, and how to respond to those ideas during instruction.
3. Curricular knowledge (CurrK) - Knowledge of the curriculum materials, including their philosophical underpinnings, the learning principles that guided the design of the materials, the learning goals, the instructional strategies the materials are designed to support, as well as the conceptual and procedural connections within and across different instructional units.
4. Representations of the curriculum being used as intended. Examples of how representations, analogies, models, or diagrams described in the curriculum materials

might look like when they are enacted and examples of student work and how they might be assessed.

Effective Professional Development Strategies

In addition to considering the content of introductory institutes, professional development facilitators must decide on appropriate professional development strategies and activities. There is general agreement that professional development should enhance teacher content and/or pedagogical knowledge, provide opportunities for collegial collaboration, be sustained over time, and be supported with adequate resources (Butler, 1992; Clewell, de Cohen, Campbell, & Perlman, 2004). Though much has been written on the characteristics of effective professional development, there is little understanding beyond these high-level guidelines about the effects of specific professional development activities and strategies (Guskey, 2003).

Efforts to learn more about the effects of specific professional development strategies have begun. Structured discussions around rich instructional cases can increase teachers' pedagogical content knowledge of unfamiliar science concepts (Heller, Daehler, Shinohara, & Kaskiwitz, 2004). Video-recordings of enactments of curriculum materials have been used to help teachers deepen their understanding of the features of specific curriculum materials as they begin using them (Fishman, 2002). Other institute strategies that have proven to influence teacher learning include examination of student work, model teaching, and peer exchange (Butler, 1992; Desimone, Porter, Garet, Yoon, & Birman, 2002; Kubitskey & Fishman, 2007) and lesson study (Lewis, Perry, & Murata, 2006). Though this work is just beginning, these strategies provide a framework for describing how curriculum developers plan and conduct professional development, and how precious institute time is being spent.

Methods

To analyze professional development designed and enacted to help teachers understand and enact curriculum materials, it is important to understand the context of the institute sessions as well as the methods used to study them. I first describe the context of the institute. The developmental context includes the unique characteristics of the curriculum materials represented in the professional development as well as the characteristics of the participating teachers. Next I describe the various sources of data. I conclude this section by explaining how I coded the various data to address the research questions.

Development Context

To provide more effective classroom materials, researchers at the Center for Highly Interactive Curricula, Computing, and Classrooms at the University of Michigan (hi-ce) and the Learning Sciences Group at Northwestern University developed the Investigating and Questioning Your World Through Science and Technology (IQWST) curriculum units (Krajcik, McNeil, & Reiser, 2008; Reiser, Krajcik, Moje, & Marx, 2003).

The IQWST curriculum units are designed to address the need for curriculum materials that support learning goals expressed in the national standards and to support classroom inquiry (Krajcik, McNeil, & Reiser, 2008; Kesidou & Roseman, 2002). Aimed at middle school science classrooms, each IQWST unit includes a teacher's guide that describes a sequence of instructional activities and student activity books that contain activity sheets for each of the unit's investigations as well as reading passages that reinforce each lesson's concepts. The units' activities are designed to address key learning goals in each science discipline, such as the behavior of light, by having students experience phenomena and engage in inquiry practices such as constructing scientific models that explain their observations (Krajcik et al., 2008). In addition to detailed descriptions of each lesson, the teacher's guide includes background information on each inquiry practice as well as a variety of pedagogical features of the IQWST materials such as facilitating classroom discussion and students' literacy skills.

Each of the IQWST units is part of a coherent sequence, and focuses on topics from physics, chemistry, biology or earth science. The units are coordinated both within and across each academic year in such a way that concepts and science practices introduced in earlier units are sometimes applied or extended in one or more subsequent units. For example, in the sixth grade, students learn about scientific models and develop models of how we see in the physics unit. In the next unit dealing with chemistry, students develop a model of matter that can answer the question "How can I smell things from a distance?" Each unit is designed to take six to ten weeks to complete, and uses a "Driving Question" to provide students with a meaningful context for engaging in various scientific practices and developing deep understandings of the unit's learning goals (Blumenfeld, Fishman, J.

Krajcik, Marx, & Soloway, 2000; Krajcik et al., 2008). The topics, driving questions, and scientific practices addressed in the sixth grade IQWST units are shown in Table 3.1.

Table 3.1
Sixth Grade IQWST Scope and Sequence

	PHYSICS	CHEMISTRY	BIOLOGY	EARTH SCIENCE
6th Grade	Light & its interaction with matter	Particle nature of matter & phase changes	Survival: From organisms to ecosystems	Water & rock cycles
Driving Question	Seeing the Light: When Can I Believe My Eyes?	How Can I Smell Things From a Distance?	Where Have All the Creatures Gone?	How Does Water Shape Our World?
Learning Goals	Light and its Interaction with Matter	Particulate nature of matter and phase changes	Survival: From organisms to ecosystems	Water and rock cycles
Scientific Practices	Developing and Applying Scientific Models Data Gathering, Organization, and Analysis (DGOA)	Developing and Applying Scientific Models	Constructing Scientific Explanations	Developing and Applying Scientific Models Designing Investigations

In addition to addressing key science ideas and practices, IQWST units provide extensive support for teachers for enacting each unit. The units are both highly specified, i.e. their purpose and content are explicitly described in the teacher's materials, and highly developed, i.e. include extensive student materials that support each learning activity (Cohen & Ball, 1999). In addition, each unit is designed to be *educative* for teachers (Ball & Cohen, 1996; Davis & Krajcik, 2005), providing opportunities for teachers to learn about new teaching practices, aspects of subject matter knowledge needed to teach the units, and common student understandings as they enact each unit. Though the IQWST units span grades 6-8, this study focuses on events related to the initial enactment of the four sixth grade units by seven teachers. In addition to the physics and chemistry units already mentioned, the sixth grade IQWST curriculum includes a biology unit, "Where Have All the Creatures Gone?," which introduces the ideas of structure, function, and natural selection, and an earth science unit, "How Does Water Shape Our World?," which focuses on the water and rock cycles.

Participants

Participants in this study included the team of researchers and curriculum developers that planned and enacted the institute as well as the teachers that participated in the institute. The planning team included two or three members of each unit's development team, as well as three researchers interested in supporting the IQWST professional development across the units. Each of the curriculum developers had extensive experience with their particular unit as well as extensive backgrounds providing professional development to teachers enacting reform-rich curriculum materials. The researchers not connected with a specific IQWST unit had extensive experience planning and conducting curriculum-aligned professional development in the context of other projects.

Seven teachers and one district curriculum specialist participated in the institute. Of these participants, five were from urban schools, one from a rural school, and two were from suburban school districts. All but two of teachers had more than ten years teaching experience, and all but two had taken a science course for college credit in the previous five years. Two of the teachers had previous experience with the IQWST materials, one having piloted the chemistry unit and one the physics unit. The teachers' certification and teaching experience are summarized in Table 3.2. The curriculum specialist represented a large urban district, had extensive experience with both IQWST and other reform-based units, and was responsible for supporting her district's teachers who were not able to attend the summer institute.

Table 3.2.
Teacher Certification and Experience

Teacher	Middle Schools Certification	School Context	Teaching Experience	Last Science Course	Prior Experience w/ IQWST?
Ms. West	Science, Math	Rural	11-15 yrs	11-20 yrs ago	Yes
Ms. Taylor	Science	Urban Charter	3-5 yrs	Within last 5 yrs	No
Ms. Hall	English, Science	Suburban Town	11-15 yrs	6-10 yrs ago	Yes
Ms. Heart	Math	Urban	26 or more yrs	Within last 5 yrs	No
Ms. Lewis	Science	Urban	16 – 20 yrs	Within last 5 yrs	No
Ms. Martin	None	Urban Parochial	11 – 15 yrs	Within last 5 yrs	No
Mr. North	Science, Math	Suburban Town	6 – 10 yrs	Within last 5 yrs	No

Sources of Data

In order to identify the institute goals and what the curriculum developers taught during first IQWST professional development institute, I reviewed planning documents as well as video-recordings of the enactment of the institute sessions. The institute's goals were determined collaboratively by the curriculum developers that were leading the different institute sessions during bi-weekly video conferences held in the six months leading up to the institute. In addition to the curriculum developers, two researchers with experience in coordinating, planning, and conducting professional development facilitated and kept minutes for each of the meetings.

Researchers and curriculum developers used a wiki to collect and share their plans for the institute. Wikis are websites hosted on a central server whose pages are editable by each anyone with access to the site. Since wikis maintain a revision history for each page, it was possible to determine what resources were modified during the planning process. As the curriculum developers planned their sessions and shared these plans with the rest of the institute planning team, we refined the learning goals, the institute timetable, the focal points, and the plans for each institute session and maintained our plans at http://www.iqwstpd.wikispaces.com. Table 3.3 summarizes the type and number of documents produced by the group during the planning period for the institute, as well as the number of times each document was revised by the planning team. Notes were taken during each meeting of the planning team on the wiki site. These meetings typically took place by videoconference, and lasted approximately ninety minutes. Notes from each meeting were posted on the team's wiki in the days following the meeting. The group maintained pages that included a list of general teacher learning goals, a timetable for the institute, as well as detailed lesson plans for the institute sessions that the curriculum developers were planning to conduct.

Table 3.3
IQWST PD Planning Documents

Document Name or Type	Number of Documents	Number of Revisions
Meeting Notes Pages	19	0
Teacher Learning Goals	1	10
Institute Timetable	1	17
Session Plan Pages	6	54

In addition to the institute plans, I also collected data to document what occurred during the enactment of the institute. The institute was held in late summer on the campus of the University of Michigan, and lasted from Monday morning to Friday at noon, for a total of thirty-six hours. Except for the first and last days, which consisted of several shorter sessions, each institute day was divided into a morning and an afternoon session lasting approximately three hours. Because it would be the first unit used by the teachers during the year, each of the morning sessions focused on the IQWST Physics unit, while the IQWST units that occurred later in school year where introduced during single afternoon sessions. The professional development timetable is included as Appendix 3.3.

The enactment of the institute was monitored and assessed using a variety of data sources. All sessions were videotaped using a camera that was directed at the general location of the facilitator for the entire session. For this study, approximately twelve hours of videotape corresponding to a running record of two complete days of the institute were digitized and transcribed. The sessions analyzed were chosen because they, unlike the first day's introductory sessions, were planned and facilitated by the curriculum developers and focused on specific IQWST units and scientific practices. In addition to the session plans posted online, last-minute changes to the plans as well as the presentation slides were also collected for each session. The session plans and transcripts of the session videotapes were also used to compare the enacted sessions with what was originally planned for each session. At the end of each day, teachers completed an online questionnaire that asked them to reflect on the day's sessions.

Analytic Method

I analyzed how the IQWST curriculum developers represented their material to teachers and compared what was enacted to what was originally planned in three steps. First, I looked to the curriculum developers' planning meetings to identify their planning priorities. These planning priorities and our knowledge of what teachers need to know to use reform-rich materials effectively were then used to describe the four three-hour professional development sessions. Finally, I compared the enacted sessions with what the curriculum developers had originally planned to describe their adaptations. I describe each of these three steps in detail below.

Understanding Developers' Planning Priorities

In order to plan a week-long introduction to a year-long curriculum with several features that potentially require teachers to change how they teach, the curriculum developers had to decide which aspects of the materials they would focus teachers' attention on. To identify their planning priorities, I summarized minutes from each planning videoconference by identifying the topics that were discussed at each meeting. I determined the developers' priorities and concerns that influenced their planning by determining the frequency each topic recurred during the series of planning meetings.

Describing the Types of Knowledge and PD Strategies Used in the Institute

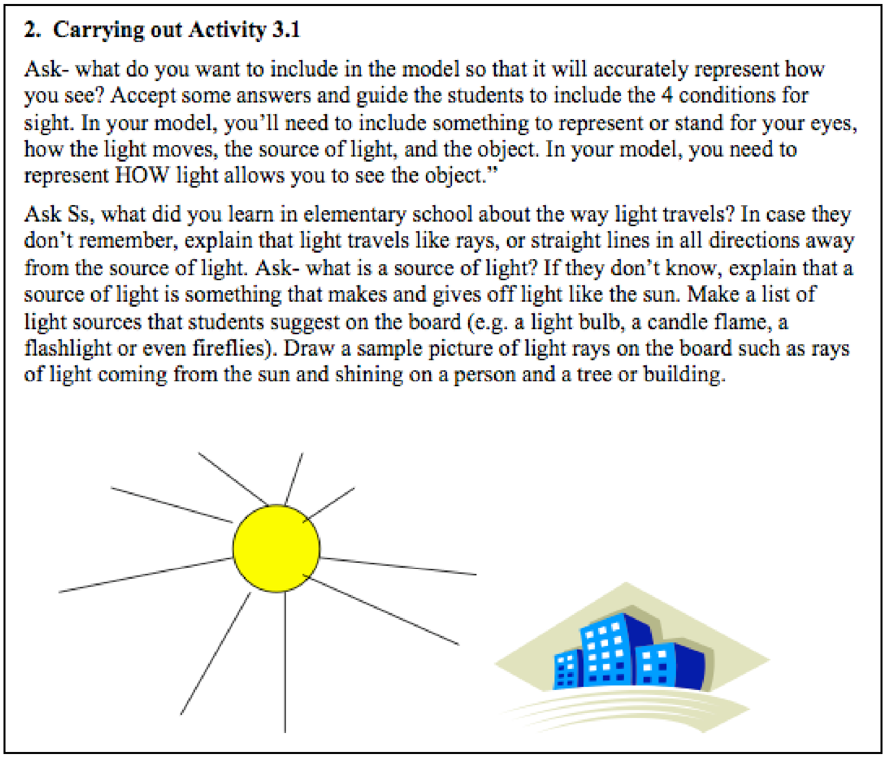
I used our current understanding of what teachers need to understand about reform-rich curriculum materials in order to use them effectively and the curriculum developers' planning priorities to examine the enactment of four three-hour sessions occurring on the second and third day of the institute. I began by developing a list of knowledge types based on Davis & Krajcik's (2005) summary of what teachers need to know in order to enact inquiry-rich curriculum materials effectively. This initial list included subject matter knowledge (SMK), curricular knowledge (CurrK), and pedagogical content knowledge (PCK). Within each of these broad types of knowledge, I identified more specific topics based on the priorities the curriculum leaders expressed in their planning discussions and in their institute plans. Finally, I identified subtopics within each topic that I observed as I watched the session video recordings. For each type of knowledge, I decided on a criterion to use to determine its presence based on commonly held definitions. These codes, their definitions, coding criterion, general examples are shown in Table 3.4.

Table 3.4
Definition of Knowledge Types

Knowledge Type/Topics	**Working Definition, Coding Criteria, and Example Codes**
Subject Matter Knowledge	Working Definition: The concepts, facts, and disciplinary practices (CFPs) which are either prerequisite or background knowledge related to a curriculum topic. Coding Criterion: Topic mainly about concept(s) related to a science topic or inquiry practice *beyond information \ already included in the curriculum's Teacher's Guide*. Example Code: SMK.Physics.Shadows was used to describe the umbra and prenumbra, terms used to delineate different regions of shadows from non-point sources of light.
Pedagogical Content Knowledge	"Information that helps teachers anticipate and interpret what learners may think about or do in response to the activities in the unit, what understandings they may hold on to, and how to respond to those ideas during instruction." (Davis & Krajcik, 2005) Coding Criterion: Topic provided information to teachers about students' probable understandings and ways to address these. Example Code: PCK.Scientific Models.Matter was used to describe students' common ideas how odors travel across a room.
Curricular Knowledge	"Knowledge of the curriculum materials, including their learning goals, the instructional strategies the materials are designed to support, the learning principles that underlie these strategies, as well as the conceptual and procedural connections within and across different instructional units." (Davis & Krajcik, 2005) Coding Criterion: Topic focused on learning goals, strategies, or materials included in the curriculum resources. Example Codes: CurrK.Physics.Light was used to represent the characteristics of how light behaves that were developed in the Physics unit. CurrK.Inquiry.Scientific Modeling was used to describe the curriculum features that supported students constructing their own scientific models.
Practitioner Knowledge	Knowledge about teaching held by teachers that is often integrated, detailed, and concrete. (Hiebert, Gallimore, & Stigler, 2002) Coding Criterion: Strategies or information shared by teachers on topics related to using the CMs. Example Code: PracK.Discussions was used to represent advice that teachers shared about how they facilitated discussions in their own classrooms.

For example, one of the topics discussed by the curriculum developers during several planning meetings was the need to support teachers' understandings of classroom inquiry. Davis & Krajcik (2005) suggest that teachers need to have a deep understanding of the specific features of curriculum materials in order to enact them effectively, so one type of knowledge that I expected to see represented by the institute leaders was curricular knowledge, i.e. knowledge of strategies and resources described by the curriculum materials supporting inquiry.

The IQWST units support classroom inquiry with activities that call for students to refine their understandings of learning goals by engaging in scientific practices such as creating scientific models. I expected the curriculum developers to convey knowledge about classroom inquiry, and within this topic, the subtopic of scientific modeling. The following transcript excerpt is an example of a video segment that was coded as curricular knowledge dealing with the topic of inquiry and the subtopic of scientific modeling. The passage was considered curricular knowledge because the facilitator used a representation called for in the teacher's guide for the unit, i.e. introducing the idea of creating a model of the behavior of light with a familiar representation of light. The description of this activity from the Teacher's Guide is shown in Figure 3.1.



2. Carrying out Activity 3.1

Ask- what do you want to include in the model so that it will accurately represent how you see? Accept some answers and guide the students to include the 4 conditions for sight. In your model, you'll need to include something to represent or stand for your eyes, how the light moves, the source of light, and the object. In your model, you need to represent HOW light allows you to see the object."

Ask Ss, what did you learn in elementary school about the way light travels? In case they don't remember, explain that light travels like rays, or straight lines in all directions away from the source of light. Ask- what is a source of light? If they don't know, explain that a source of light is something that makes and gives off light like the sun. Make a list of light sources that students suggest on the board (e.g. a light bulb, a candle flame, a flashlight or even fireflies). Draw a sample picture of light rays on the board such as rays of light coming from the sun and shining on a person and a tree or building.

Figure 3.1. Description of ray light model from Physics Teacher's Guide

The facilitator represented this knowledge during the session, as indicated by the following transcript excerpt:

> (Facilitator starts discussion by illuminating a blank transparency with the projector.)
>
> Facilitator (F): What is the one of the most basic or common ways that you see light represented, you probably saw this (assuming you're sixth graders again) in elementary school, what are some ways that you might have seen the sun represented? What are some ways that we've seen the sun represented?
>
> Teachers: A circle with lines or rays coming from the circle.
>
> (Facilitator draws circle on transparency.)
>
> F: Okay, we have our sun. And you say we need what coming out of it?
>
> Ts: Rays.
>
> (Facilitator also draws a house and a tree.)
>
> F: Okay, here is a very simple drawing. Are there ways you can think of this drawing as a model? What could this drawing help us do or understand?
>
> T: How the sun shines on the trees.

F: Now how does that help you? How does this model tell you that the sun is shining on the trees?

T: Because the lines that you have there tell me that the sun is shining near the trees.

F: Are there other things that this model tells you about how the sun is shining?

T: It says that the sun is above the trees.

F: So it says something about the sun's location.

One difficulty in trying to identify types of knowledge represented in curriculum materials designed to be comprehensive resources for teachers is the problem of overlapping knowledge types. When the knowledge that is necessary to teach a particular scientific concept (SMK or PCK) is represented in the curriculum materials, it can also be considered Curricular Knowledge. Though it would be possible to code each segment as an example of both knowledge types, I chose to not do this because it would make it more difficult to represent how institute time was used. By assigning a single knowledge type to each segment of the institute, it was possible to analyze what types of knowledge facilitators chose to spend their institute time representing, and shed light on the topics they considered most important to address. To address the difficulty of overlapping codes, related knowledge types were eventually consolidated to form knowledge categories. These knowledge categories are shown in Table 3.8 and explained in more detail later in this section.

In addition to identifying types of knowledge addressed in the institute sessions, I also looked at what strategies were used by the curriculum developers during each session. I began by using our understanding about how teachers learn from professional development and what comprises effective institute-based professional development experiences to develop a list of professional development strategies. For example, Butler (1992) suggests that modeling new teaching strategies is key to helping teachers understand how they might use them in their own classrooms. One professional development strategy that I looked for in the institute plans and enactment was episodes of model teaching, i.e. times when the facilitator enacted activity segments as called for the unit's teacher's guide. Table 3.5 shows the professional development strategies observed in the institute plans and enactment.

Table 3.5
Professional Development Strategies

Strategy	Operational Definition	Enactment Example
Sharing Institute Plans	Facilitators (Fs) describe and explain institute plans.	F explains changes to session's agenda due to time constraints.
Facilitator-Led Discussion	Verbal exchanges that are mostly characterized by Fs asking questions for Ts to answer.	F asking Ts questions to activate their prior knowledge of the particle model of matter.
Teacher-Led Discussion	Verbal exchanges that are mostly characterized by Ts asking each other questions.	T sharing video of discussion occurring in her classroom.
Examining Student Work	Ts examine and discuss student work samples from unit activities.	F presents a series of slides showing students' models of how odors travel across a room.
Assessing Student Work	Ts examine and assess student work samples from unit activities.	Ts assess student models of how we see.
Presenting Information	Fs presenting information directly to teachers.	Fs summarizing the misconceptions about light typically held by students.
Teachers Using Curriculum Materials	Ts using materials as teachers.	Ts use CMs to plan and investigation activity.
Reflecting on Peer Enactment	Ts examine and discuss peer enactment	Ts watch and discuss video recordings of a classroom discussion.
Teachers Acting as Students	Ts completing activities as Ss.	Ts collecting data on how light reflects off a mirror.
Model Teaching	Fs enacting unit activities in a manner that represents how Ts might use the CMs.	Fs leading a discussion with the Ts as called for in the unit's Teacher's Guide.

Analyzing the Use of Institute Time

To understand how time was spent during the institute sessions, I used the Transana (Woods & Fassnacht, n.d.) video analysis program to identify the purpose of video segments of each session. The process I used to prepare each session's videotapes for analysis is represented in Figure 3.2.

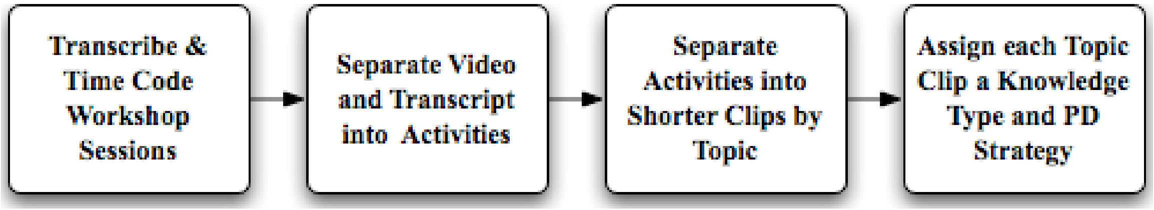


Figure 3.2. Steps for Preparing Video for Analysis

After converting the session videotapes into computer-based video files, I transcribed each video file within Transana, transcribing facilitator and teacher dialog and designating "time codes" where the session leaders transitioned between activities. Each activity dealt with a different topic, used a different instructional strategy, or was led by a different facilitator. After transcribing and time-coding the video files corresponding to each institute session, I divided each session's video and its corresponding transcript into its component activities using the previously assigned time codes. Finally, I divided each activity's video and transcript into smaller segments that each focused on a single topic. For each of these topic-specific segments, I assigned a knowledge type and an instructional strategy.

Comparing the Planned and Enacted Institute Sessions

One goal of an introductory curriculum institute is to represent the intent and features of the materials in a way that reinforces participating teachers' confidence in their ability to use the materials. As the curriculum developers led their particular sessions, one would expect them to follow their plans. I hypothesize that when they deviated from their plans, it was to address teachers' concerns and answer their questions. If this is the case, then these differences between what was planned and what was enacted represent knowledge that the curriculum developers judged necessary to provide for the teachers as they informally assessed the teachers' understandings during the institute sessions. These in-action decisions would be reflected in how the developers utilized the institute time.

To analyze how time was used in the institute sessions and compare it with what the curriculum developers originally planned, I needed to determine how the different types of knowledge were represented across the various sessions. The analytical sequence that I used to compare the planned and enacted institutes on the basis of time is illustrated in Figure 3.3. I used a four-stage sequence to analyze data from both the enactment and the institute plans. These stages include *determining time durations*, *aggregating time for each knowledge type and PD strategy*, *consolidating data into useful categories,* and finally *comparing enacted and planned time*. Each of these stages is explained in detail below.

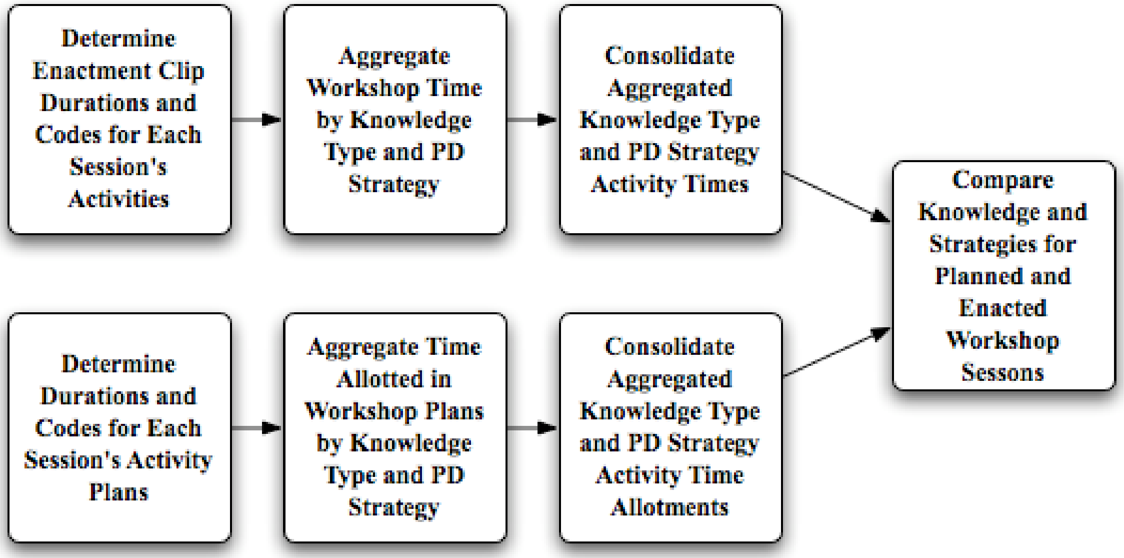


Figure 3.3. Analysis sequence for comparing planned with enacted PD sessions.

Determining Enactment Segment Durations and Codes For Each Session's Activities: The procedure that I used to divide the institute sessions into its component segments and code each segment based the type of knowledge it contained and PD strategy is described above. Once the codes were assigned to each segment, I assembled this data so that it could be manipulated and compared by exporting each segment's name, start time, end time, duration in seconds, knowledge type, and PD strategy from the Transana database so that it could be imported into a spreadsheet. By repeating this process for each enacted session, I was able to assemble a single table that contained the codes and start/stop times for all of the sessions that I reviewed.

Aggregating Time by Knowledge Type and PD Strategy: Once the data for all the segments was assembled, I used another spreadsheet to calculate the amount of session time duration dedicated to each knowledge type and PD strategy. Once each segment's duration was assigned to a specific knowledge type and PD strategy, these durations could be totaled for each session and for the two days of the institute examined. Unlike the enactment segments, the session plans sometimes specified an approximate duration at the activity level (with each activity consisting of multiple instructional steps) without specifying a planned duration for each step within the activity. To determine the duration of time *planned* for each knowledge type and PD strategy, each step in each activity was coded for a single knowledge type and PD strategy, and the time allocated to the activity was divided among the different knowledge types and PD strategies represented in the plans.

Consolidating Aggregated Knowledge Type and PD Strategy Activity Times by Establishing Knowledge Categories: Once the total time spent (and originally planned) for each of the twenty-eight knowledge types and fifteen PD strategies was tallied, they were consolidated. This consolidation addressed two difficulties. The first, discussed earlier, was the problem that some knowledge represented by the curriculum developers could be coded as more than one type of knowledge, e.g. a description of student ideas included in a teacher's guide could be coded as either PCK or Curricular Knowledge. The second problem was that different knowledge types and PD strategies were at such a fine grain that it sometimes made it difficult to see patterns in how time was distributed so that it could be related to the curriculum developers' original intentions or concerns. For example, knowledge about using literacy resources or student materials could both be considered knowledge related to using the curriculum materials. To address these problems, the aggregated times for each knowledge type and PD strategy were consolidated into broader knowledge and PD strategy categories. These categories were based on the developers' initial priorities for the institute, and are consequently summarized in the next section.

Comparing Knowledge and Strategies for Planned and Enacted Institute Sessions: Once times for the knowledge and PD strategies were assembled for the session plans and enactment segments, these were compared on a series of charts. These charts described how time was planned and utilized by knowledge category across the two institute days, and how different PD strategies were employed for each knowledge category.

Results

Before designing supports for external agents to provide professional development that sustains curriculum implementation, it is reasonable to examine the experiences planned and enacted by the curriculum developers themselves. This study asked three questions in order to learn more about the design of professional development institutes designed to introduce teachers to new materials. The first question focused on the curriculum developers' priorities for the institute, the second question looked at what the curriculum developers taught and how they taught it. The third question looked at how the curriculum developers' enactments of their institute sessions compared to their plans. The results that inform these questions are described below.

Understanding Developers' Planning Priorities

The goals and priorities the curriculum developers took into account while planning the institute were expressed in their bi-weekly meetings. Minutes from the nineteen meetings were analyzed to determine what topics were being discussed. Table 3.6 represents the topics of discussion and the frequencies these topics were discussed.

Table 3.6
Topics discussed by institute planning team.

Topic	Description	Number of Discussions
Institute timetable	Identified important institute topics across the IQWST units. Negotiated importance of these topics and allocated time during week-long institute.	8
Alignment of unit sessions	Coordinated how topics such as the science practices would be addressed across sessions.	8
IQWST pedagogy	Decided that institute should focus mainly on facilitating classroom discussions.	8
IQWST scientific practices	Decided to focus on scientific modeling and DGOA.	7
Institute logistics	Coordination materials and facilities.	6
Institute evaluation	Developed plans for how institute would be assessed.	5
Institute learning goals	Sessions should help teachers feel comfortable with curriculum materials, especially for physics unit.	3
Content of general IQWST sessions	How and when IQWST principles should be introduced at institute.	2
Addressing teachers' concerns about using materials	Need to address teachers concerns, e.g. need to score student work.	2
Other topics	Various topics discussed only once.	5

The institute planners were concerned with the challenge of representing the year-long IQWST curriculum in the limited time available in the summer institute. The three topics discussed most often dealt with this issue. The institute schedule was adjusted several times to reach consensus on the topics that would be addressed and the time each topic would be allocated. Each developer agreed that given the limited time available, they would focus their sessions on activities from their curriculum they felt were critical for teachers to experience in order to understand their units. The developers also decided to reinforce two scientific practices, scientific modeling and DGOA, by addressing each practice in both a morning physics session and in the following afternoon session that would introduce a subsequent IQWST unit. A third scientific practice, designing investigations, would be addressed separately in the afternoon session introducing the Earth Science unit because this unit's scientific investigations called for students to apply the other scientific practices. The developers also decided that though there were several pedagogical features of the IQWST units that might challenge the teachers, they would focus their attention on one pedagogical feature that they felt presented the biggest challenge for teachers implementing inquiry-rich units, fostering effective student-centered classroom discussions.

Describing the Knowledge and PD Strategies Used in the Institute Sessions

After examining the plans and meeting notes to determine the curriculum developers' priorities, I examined the four institute sessions to determine what knowledge was represented to the teachers and what PD strategies were used. A representation of how a single institute activity in which the facilitator modeled an IQWST lesson on creating a scientific model for the behavior of light was coded for knowledge type and PD strategy is shown in Figure 3.4.

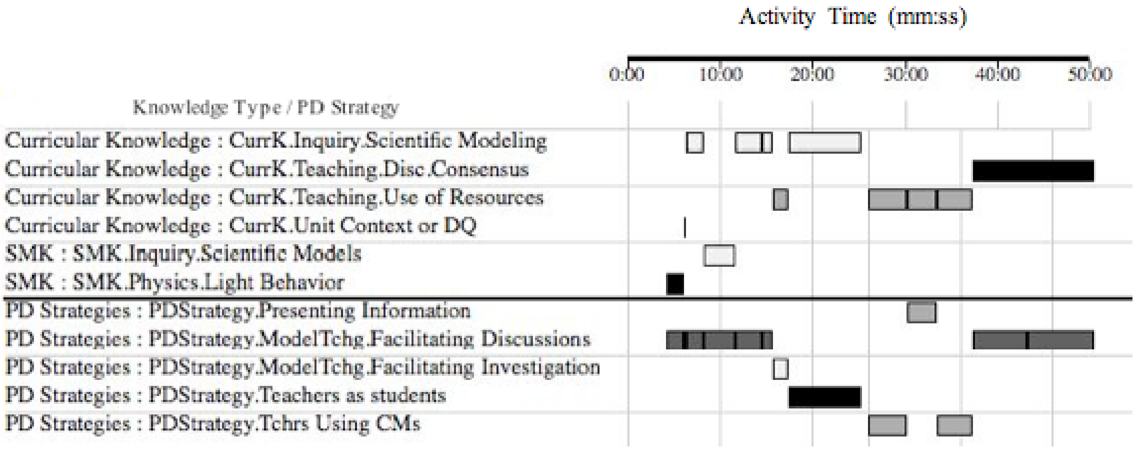


Figure 3.4. Knowledge type and PD strategy sequence for one institute activity.

The duration of the activity represented in Figure 3.4 was fifty minutes. Within this time, several different types of knowledge including knowledge about scientific modeling, facilitating discussions, and using curriculum resources was addressed using PD strategies ranging from model teaching to having the teachers using the curriculum materials both as teachers (discussing issues related to teaching the lesson) and students (engaging in activities as their students would). Appendix 3.4 shows the coded transcript for each segment of this activity.

Over the course of the two institute days, the sessions were divided into over one hundred fifty video and transcript segments. The average duration of each segment was around four minutes. How each session was broken down is summarized in Table 3.7.

Table 3.7
Summary of segments created from institute videotapes.

Session	Duration (min)	Number of Segments (segments)	Average Time/Segment (min/segment)
Day 2 AM - Physics	163	46	4
Day 2 PM - Chemistry	164	55	3
Day 3 AM - Physics	115	18	6
Day 3 PM – Earth Science	166	36	5
Total	607	155	4

What knowledge was represented during the institute sessions?

After each video segment was assigned a single knowledge type and PD strategy, the session time dedicated to each knowledge type was aggregated. Figure 3.5 shows how the time in each institute session was spent in terms of the knowledge types that were addressed in each session.

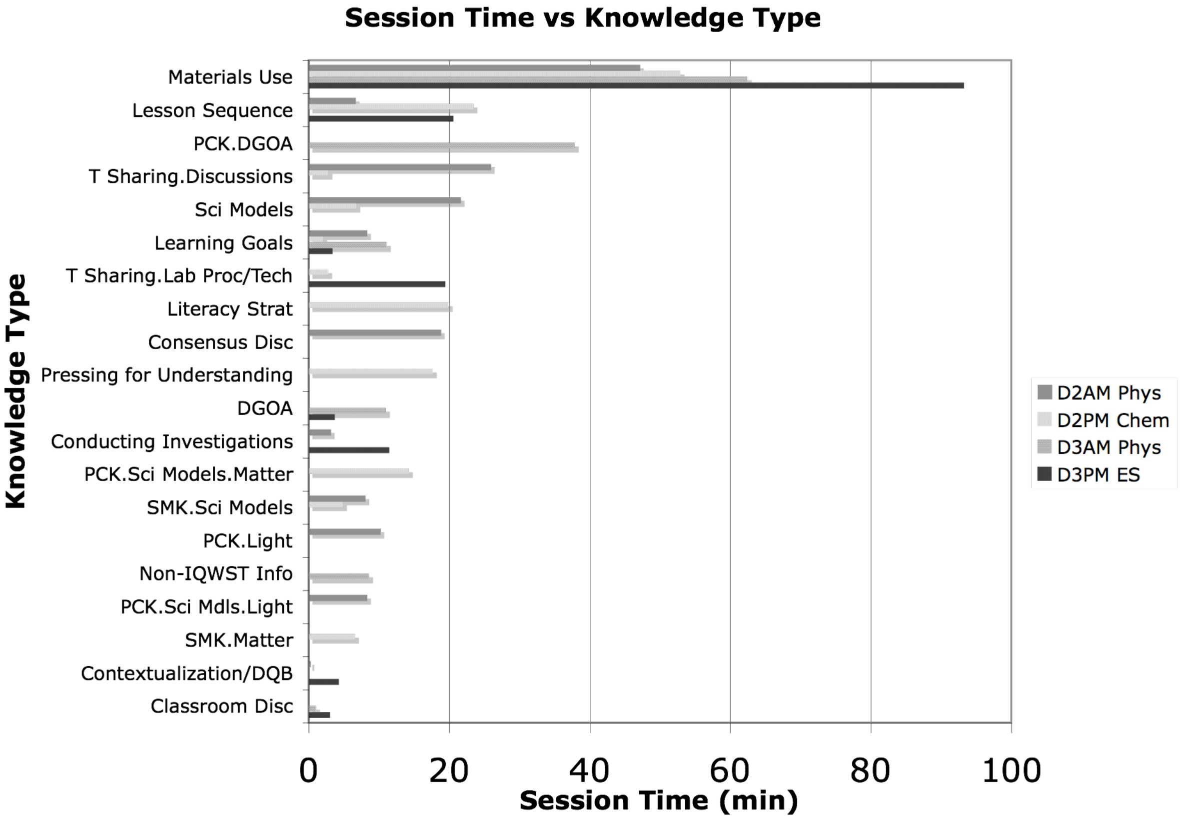


Figure 3.5. Session Time vs. Knowledge Type for each institute session.

Figure 3.5 indicates that most of each session's time was spent addressing how the curriculum material were intended to be used with students. Teachers also had opportunities to deepen their understanding of scientific practices such as scientific modeling and DGOA. By summing the times for each knowledge type across the four sessions, we get a representation of how the teachers experienced the curriculum in the institute.

The total institute time spent on each knowledge type is shown in Figure 3.6. This graph shows that almost half of the institute time was spent on helping teachers understand and use the curriculum materials themselves. The remaining time was split into several different knowledge types that could be considered critical to understanding the IQWST units. In addition to how teachers should use the materials, the rationale behind how the lessons were sequenced (Lesson Sequence), how to facilitate student data analysis and discussion (PCK.DGOA; T.Sharing.Discussions), scientific models (Sci Models) and each unit's learning goals (Learning Goals) were addressed. This graph shows that the time dedicated to specific topics such as the importance of contextualizing the lessons using a driving question board (Contextualization/DQB) and pedagogical content knowledge relevant to the physics unit (PCK.Sci Models, PCK Light) *beyond what was explained in the teacher's guide* received little reinforcement during this portion of the introductory institute.

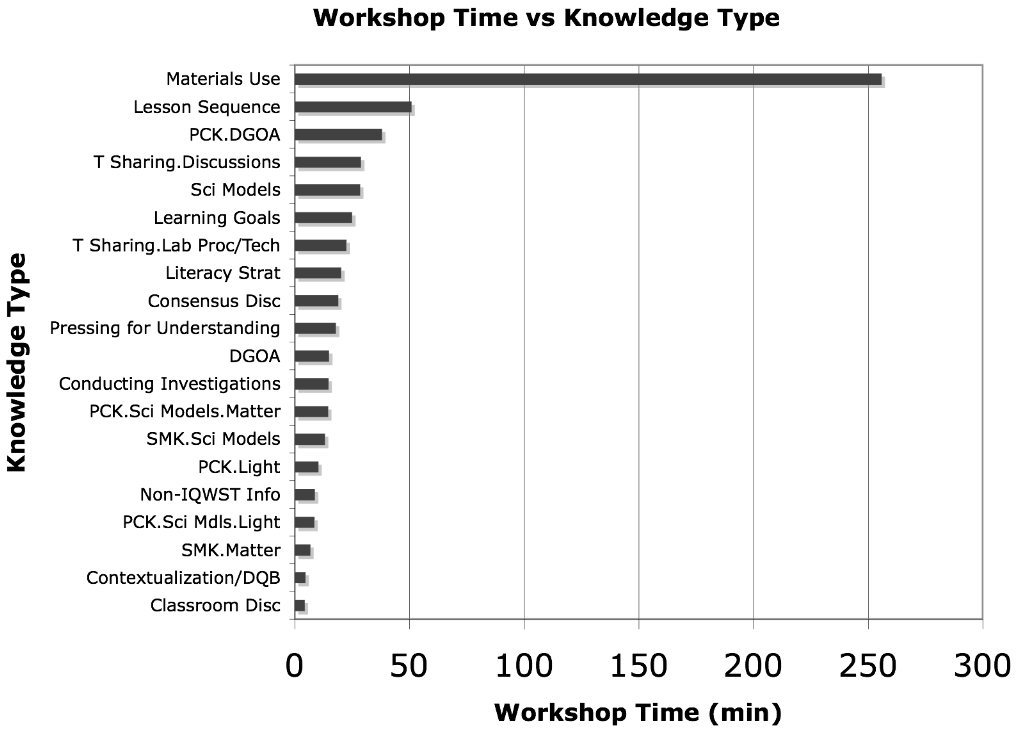


Figure 3.6. Institute Time vs. Knowledge Type across all sessions.

What PD strategies did the curriculum developers use during the institute sessions?

The teaching strategies used by the curriculum developers were also coded and aggregated for each session. Figure 3.7 shows how much time was dedicated to each strategy in each of the four sessions examined. In each of the sessions, approximately one hour was spent in discussions where the curriculum developers posed questions, represented, and synthesized teachers' comments (Fac Led Disc). Facilitators used a variety of other strategies, including having teachers engage in unit activities as their students would (Using CMs as Ss), presenting information in short mini-lectures (Presenting Info), model teaching (Mdl Tch), and providing time for teachers to exchange ideas (Tchr Peer Exchange). Very little time was used for other strategies such as having teachers use the curriculum materials to plan instruction (Using CMs as Ts) or examining and/or assessing student work samples (Exam Stu Wk).

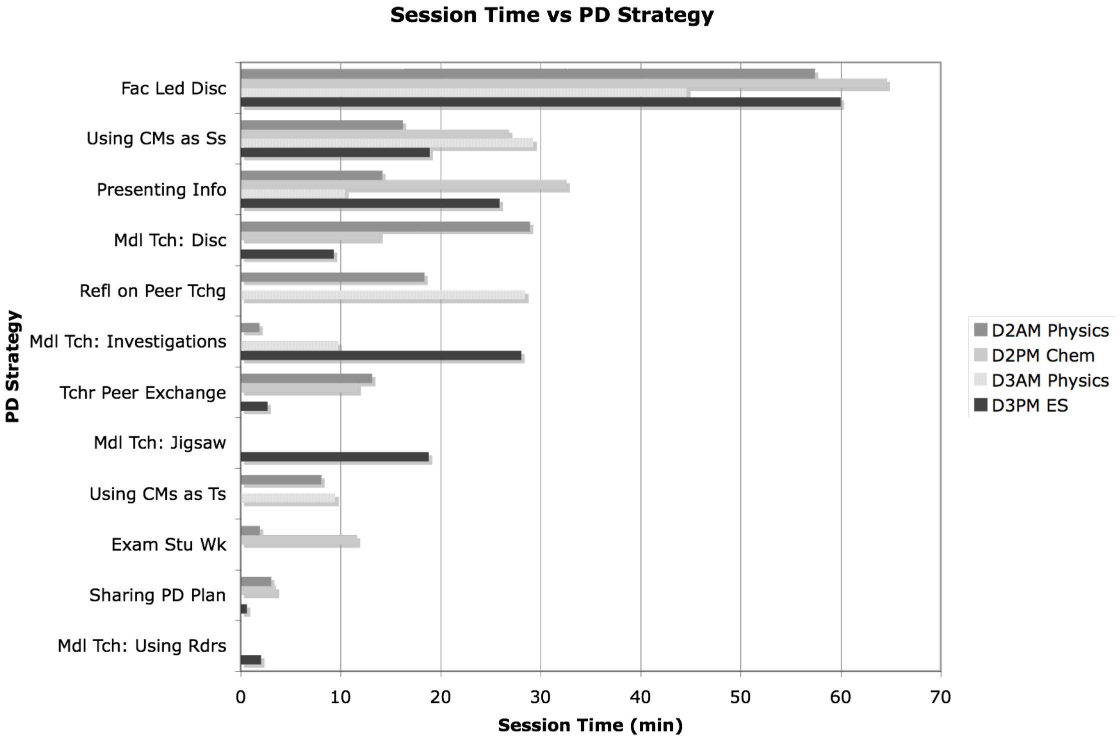


Figure 3.7. Session Time vs. PD Strategy for each institute session.

To examine how time was spent over these two days, the times spent using each PD strategy were summed across all the sessions. Figure 3.8 shows that over the approximately 600 minutes of institute time examined, teachers were actively engaged with the materials in a variety of ways for over 500 minutes, or about 83% of the time. Most of the remaining time, roughly 80 minutes, was spent with teachers listening as the facilitators presented information at various times during each session.

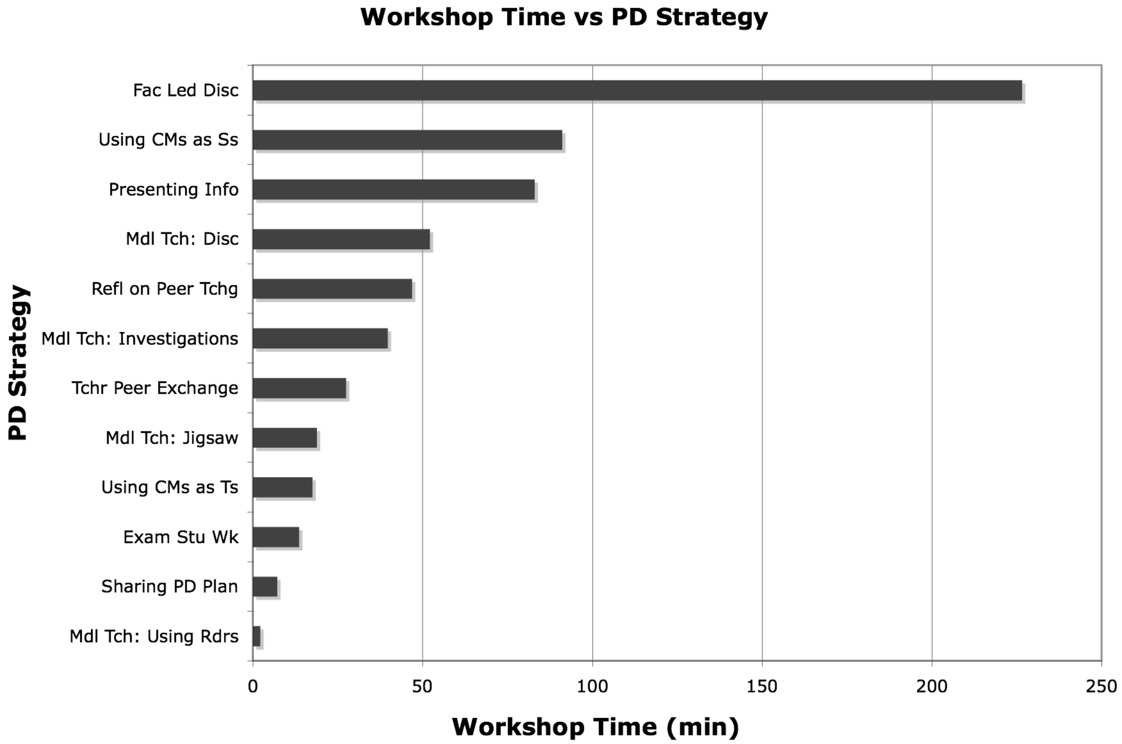


Figure 3.8. Institute Time vs. PD Strategy

Comparing the Planned and Enacted Institute Sessions

I compared the planned and enacted sessions in three steps. I first consolidated the twenty-eight knowledge *types* into four knowledge *categories* corresponding to the priorities the curriculum developers identified in their planning discussions. I then compared the time allocated in the plans with the time spent in the enactment for both the knowledge categories and the strategies used. Finally, I combined the knowledge and strategy results in order to describe *how* the curriculum developers represented the knowledge to the teachers during the sessions.

Consolidating Aggregated Knowledge and PD Strategy Activity Times

To represent the knowledge and strategies the curriculum developers used to introduce their units during the institute, I looked at how they allocated time based on their original priorities in planning the institute sessions. Based on their planning discussions, the curriculum developers were concerned with increasing teachers' comfort with key aspects of the IQWST. To do this, they chose to focus their sessions on helping teachers understand the IQWST learning goals as well as some of the critical pedagogical elements used in each of the IQWST units, experience critical lessons in each unit, and engage in some of the IQWST scientific practices. Table 3.8 shows the knowledge categories as well as their constituent knowledge types.

Table 3.8
Consolidation of observed types of knowledge into knowledge categories.

Knowledge Category	Facilitators' Priorities for Institute	Component Knowledge Types
IQWST Learning Goals	Help teachers understand and feel comfortable teaching IQWST, e.g. understanding concepts and student ideas related to IQWST topics.	SMK.Chemistry.Matter SMK.Physics.Light Behavior SMK.Physics.Shadows CurrK.Teaching.Lesson Sequencing CurrK.Context of Unit in Year CurrK.Design Principles. Accurate Science PCK.Physics.Light Behavior PCK.Chemistry.Matter CurrK.Unit Learning Goals
Scientific Practices	Prepare teachers to help students with inquiry skills used throughout IQWST units, e.g. scientific modeling, DGOA, and designing investigations.	SMK.Inquiry.Scientific Models CD - PCK.Inquiry.DGOA CD - PCK.Inquiry.DGOA.Limitations of Pictures CD - PCK.Inquiry.Scientific Models.Light CD - PCK.Inquiry.Scientific Models.Matter CD - PCK.Inquiry.DGOA CD - PCK.Inquiry.DGOA.Limitations of Pictures CD - CurrK.Inquiry.Conducting Investigations CD - CurrK.Inquiry.DGOA CD - CurrK.Inquiry.Scientific Modeling
IQWST Pedagogy	Introduce teachers to challenging IQWST instructional practices, e.g. facilitating classroom discussions.	CD - CurrK.Teaching.Disc CD - CurrK.Teaching.Disc.Consensus CD - CurrK.Teaching.Disc.Press for U'standing CD - CurrK.Teaching.Jigsaw CD - CurrK.Teaching.Literacy Strategies CD - CurrK.Unit Context or DQ CD - PracK.Lab Procedures/Techniques CD - PracK.Facilitating S Blogging CD - PracK.Facilitating Discussions
Experiencing IQWST Activities	Have teachers engage with IQWST materials as both students and teachers.	CD - CurrK.Teaching.Use of Resources

A graph of how time was allocated in each session is shown in Figure 3.9. This graph suggests that each session provided teachers with time to experience curriculum activities, with time roughly split among the other priorities of the facilitators. In the

Earth Science session, teachers spent a large amount of time designing and conducting their own stream table investigations called for by the curriculum.

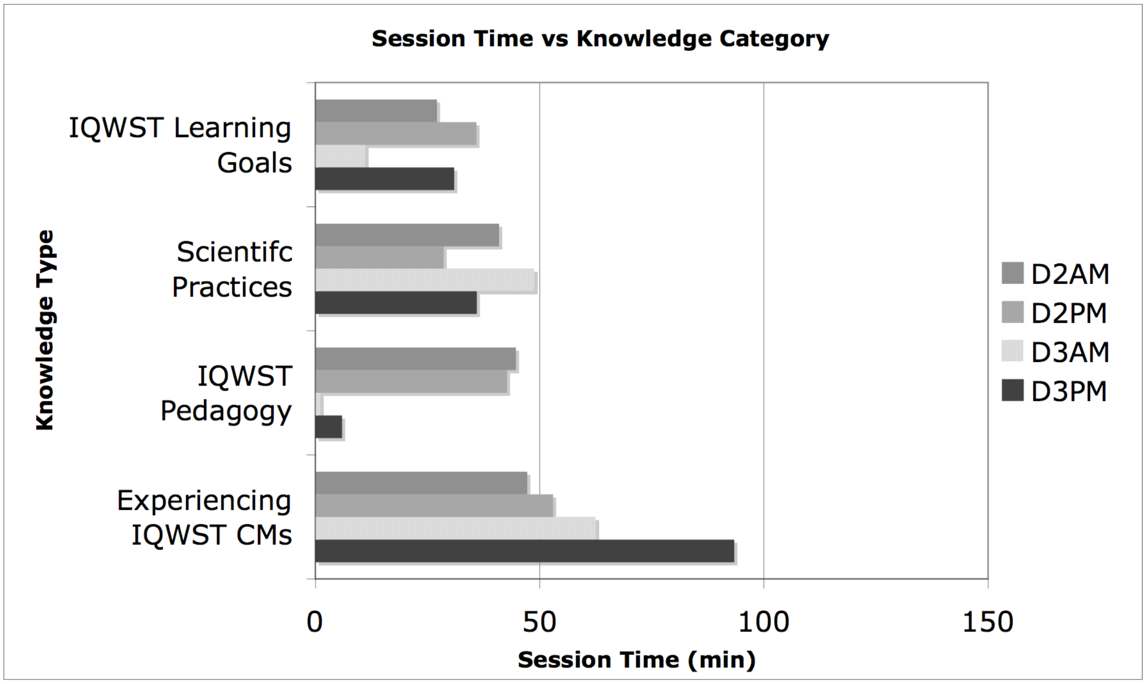


Figure 3.9. Session Time vs. Knowledge Category

When the time spent in the four sessions is aggregated, we can see a representation of what knowledge categories were emphasized across the institute sessions. Figure 3.10 shows the curriculum developers dedicated almost half of the institute's time for teachers to gain experience with using the curriculum materials, and most of the remaining time introducing the IQWST scientific practices with the remaining time split between addressing the IQWST learning goals and pedagogy.

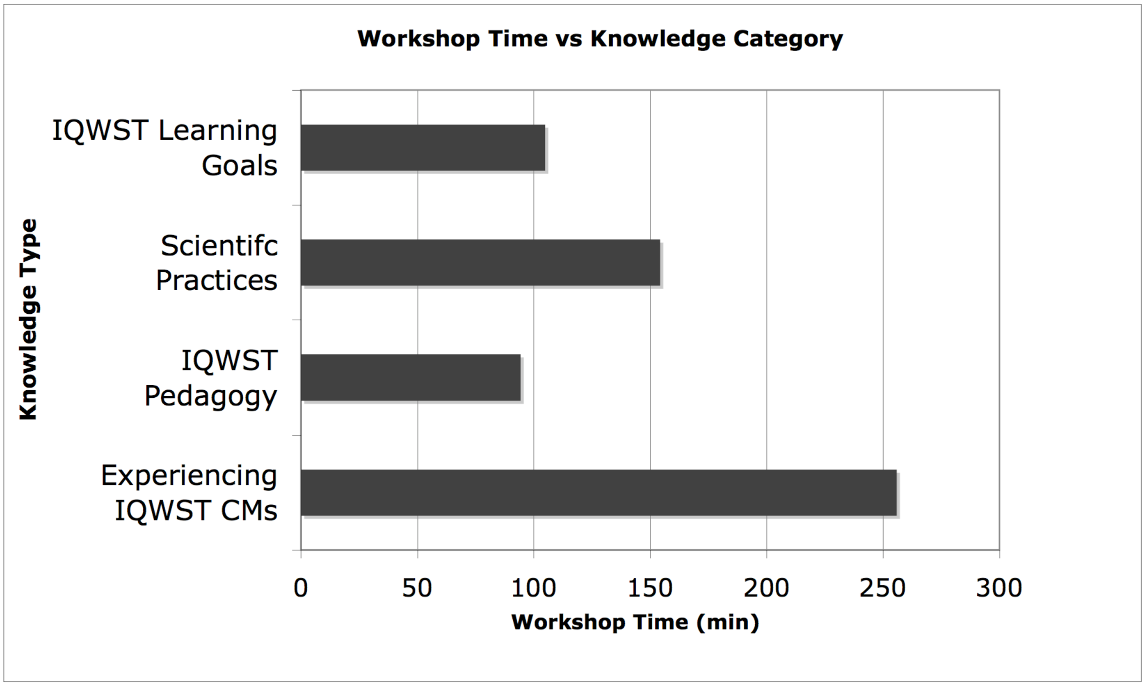


Figure 3.10. Institute Time vs. Knowledge Category

Comparing Knowledge and Strategies for Planned and Enacted Institute Sessions

To compare what the curriculum developers planned for the institute with how they actually enacted their sessions, the time allocated to the same knowledge categories was again plotted. Figure 3.11 shows how institute time was allocated in the developers' session plans and their enactments of each session.

Figure 3.11 suggests that the curriculum developers addressed the topics as they had originally intended with some adjustments to the time allotted to each topic. Though they spent the amount of time planned on learning goals and pedagogy, roughly ninety minutes of the time originally planned for focusing on scientific practices was spent instead providing additional time for teachers to engage with the units' activities.   It is impossible to determine why the curriculum developers re-apportioned their session time, though it is reasonable to conclude that the developers thought it was more important for teachers to complete all of the planned activities from the units than it was to spend the time on the scientific practices originally planned.

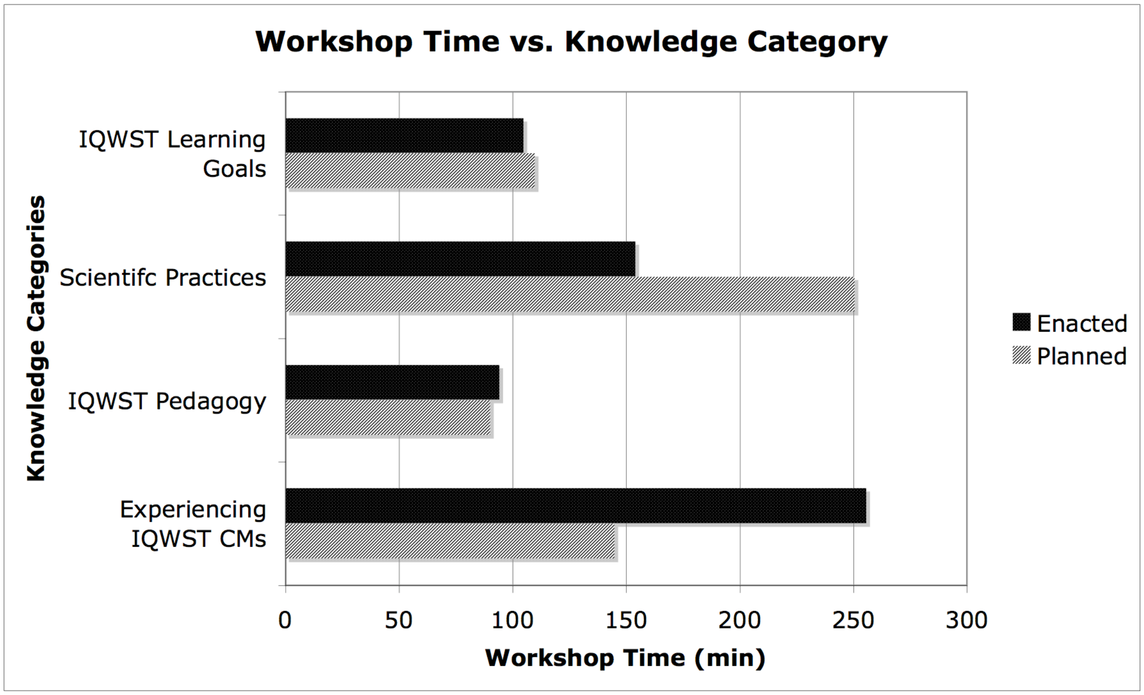


Figure 3.11. Planned and Enacted Institute Time vs. Knowledge Category

In addition to adapting the topics during their sessions, the developers also modified their instructional strategies. Figure 3.12 shows that over the two days of sessions examined, more time than planned was spent by the curriculum developers presenting information, model-teaching, and allowing teachers to exchange information. These changes left less time for facilitator-led discussion, for teachers to use the curriculum materials and examine student work samples. It may seem curious that Figure 11 indicates that teachers spent more time becoming familiar with the curriculum materials while Figure 12 suggests that less time than was planned was spent by teachers using the curriculum materials. This result will be discussed in detail in the next section.

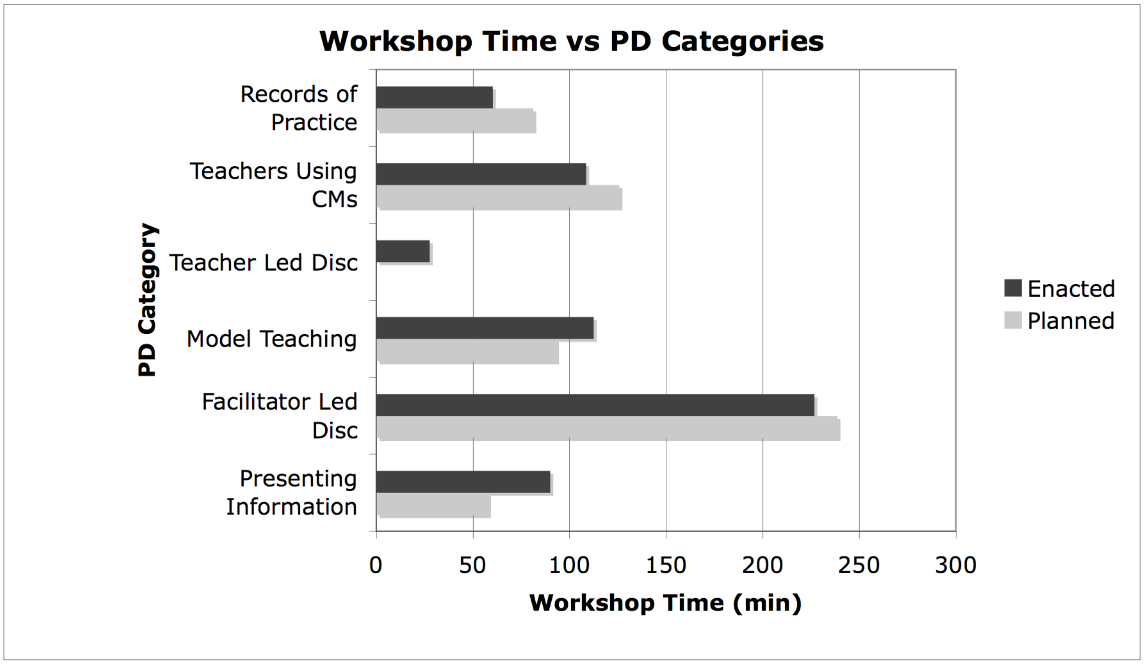


Figure 3.12. Planned and Enacted Institute Time vs PD Category

Discussion

To initiate and sustain the use of reform-rich curriculum materials, teachers need a variety of supports, including opportunities to experience high-quality professional development. This study began by asking what we can learn from planning and facilitating PD experiences that might help us prepare support strategies for local institute leaders trying to sustain their districts' use of the curriculum materials. To inform this question, I focused on three aspects of how curriculum developers planned and enacted an institute introducing the IQWST curriculum. The first aspect was the priorities the curriculum developers set forth for the professional development sessions. The second aspect was how the curriculum developers represented their curriculum materials to teachers in the institute sessions. Finally, assuming the curriculum developers had the expertise necessary to tailor their instruction to meet the teachers' needs, I examined how their enactment of the institute sessions compared with their original session plans. To examine each of these aspects, I looked at how institute time was spent, both in terms of what knowledge was represented and the strategies the curriculum developers used to engage the participating teachers. In this section, I discuss the results for each aspect of this study in light of what we understand about teacher learning and effective professional development, and describe how each might inform our efforts to support locally-led professional development capable of supporting reform-rich curriculum materials.

Curriculum Developers' Planning Priorities

The curriculum developers were aware of several challenges that arise when trying to introduce teachers to the IQWST curriculum materials. Several of conversations during their planning meetings were required to reach consensus on how institute time would be allocated. In previous curriculum-based reform efforts, curriculum developers focused on providing teachers with opportunities to enhance their understandings of the subject matter knowledge related to the units, knowledge of the unit's activities, and technical knowledge related to using the materials (Fishman, Fogleman, Kubitskey, et al., 2003). In the case of the IQWST materials, there are several pedagogical challenges that teachers must address, including contextualizing each unit's lesson, facilitating classroom discussions, teaching scientific practices, and using the laboratory activities effectively. The developers chose to focus their attention on a subset of these challenges during the institute that stressed helping teachers understand how to use the curriculum materials, supporting students' efforts at scientific modeling and facilitating classroom discussions, an essential element of helping students make sense of classroom experiences that is often omitted by teachers (Wei, Darling-Hammond, Andre, N. Richardson, & Orphanos, 2009).

It is important to note that in addition to the priorities the curriculum developers brought to the task of planning this institute, local PD facilitators will also be concerned with other factors. The priorities of the curriculum developers were focused on representing the IQWST curriculum materials to teachers volunteering to use them in their classrooms. The teachers in this institute had agreed to teach each of the IQWST unit over the course of their school year, and the developers were interested in how the materials contributed to student learning in combination. If these effects were already understood, then the developers might have been more attentive to teachers' adaptation practices for each of the units, as was the case in previous implementation efforts (Fishman, Fogleman, Kubitskey, et al., 2003). To support districts' efforts to take ownership of their teachers' use of the curriculum materials and provide professional development, then the developers will need to help local facilitators address local concerns while maintaining their focus on the principles, strategies, and activities described in the materials. These were not priorities in this institute.

Understanding the Knowledge and Strategies Used in the Institute

Before we develop supports for local facilitators, we as curriculum developers need to examine our own PD practices from several perspectives. This study looked at how time was spent during a series of institute sessions. Professional development opportunities help sustain the use of innovative curriculum materials when they focus on materials that teachers can use in their classrooms, provide teachers with active learning experiences, and foster teacher dialog around their teaching (Penuel et al., 2007; Garet, Porter, Desimone, Birman, & Yoon, 2001). By looking at the strategies used to address each category of knowledge, we can learn more about how each type of knowledge was represented to teachers. The knowledge that developers chose to represent to the teachers and the strategies to represent each knowledge category are shown in Figure 3.13.

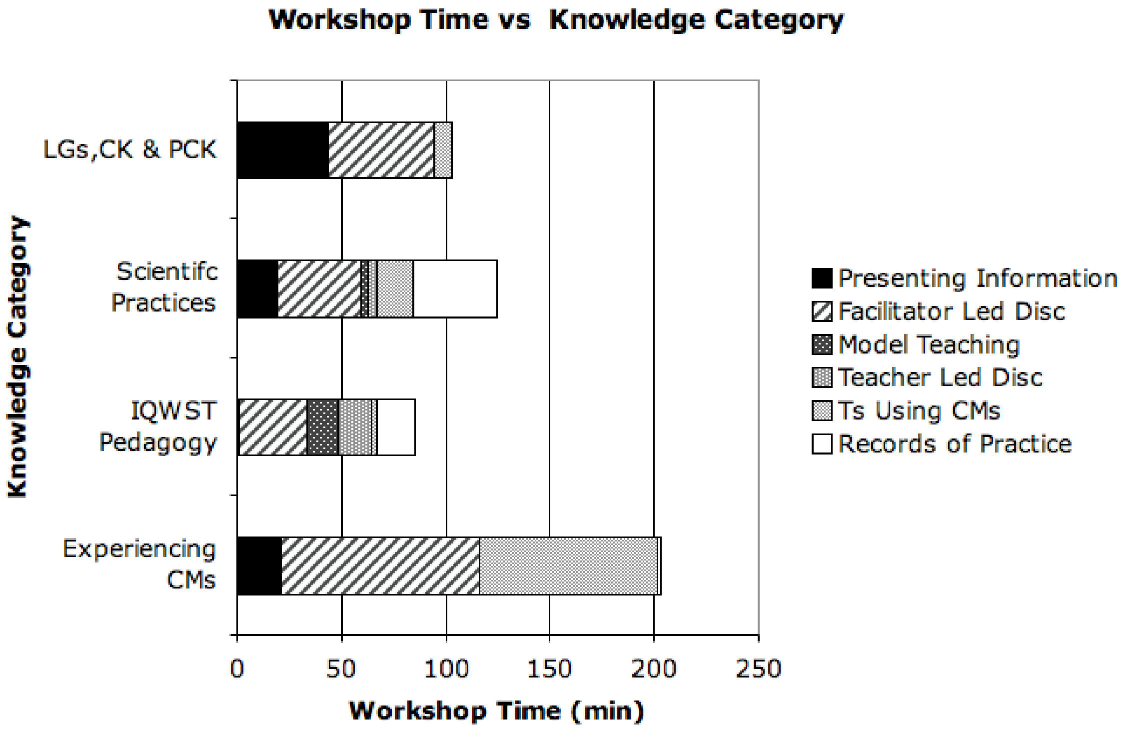


Figure 3.13. Institute Time per PD Category vs. Knowledge Category

In this figure, the PD strategies that were used to address topics in each knowledge category are arranged from least active for teachers (facilitators presenting information) to most active (teachers using materials or discussing records of practice). Though a variety of professional development strategies were used, the facilitators played central roles in most of the institute activities by presenting information, facilitating teacher discussions, or model-teaching portions of their units. Though curriculum developers often consider the foundational elements such the learning goals as essential for teachers to grasp in order to use their materials effectively, Figure 3.13 suggests that teachers were expected to spend most of the time dedicated to these topics either listening or participating in discussions moderated by the session leaders. This figure suggests that before we design PD supports for external facilitators, we need to decide whether our approaches to *each type* of knowledge align with effective PD practices.

Comparing the Planned and Enacted Institute Sessions

As the facilitators enacted their plans, the modifications that they made might provide more guidance for the design of professional development materials. Figure 3.11 compares the enacted knowledge against what was originally planned, and Figure 3.12 makes the same comparison for the PD strategies used across the sessions. The knowledge developers chose to represent tracked closely with what was planned, with the main difference being that more time was spent experiencing the units' activities and less time was spent extending teachers' knowledge of scientific practices such as scientific modeling. It is difficult to determine whether the developers' choice of experience with the materials over more generalizable knowledge about the materials was warranted. The literature on effective PD calls for providing teachers with opportunities to practice using the materials *and* to gain a deep understanding of the materials (Butler, 1992; Garet et al., 2001; Penuel et al., 2007).

Comparing the strategies used by the facilitators with their original plans is useful for identifying design issues that need to be considered before designing professional development materials. Figure 3.12 shows that the facilitators spent more time than was planned presenting information. This is consistent with the curriculum developers' desire for the teachers to understand the curriculum materials at a deeper level than would be possible by having them "walk through" each activity and is consistent with research that indicates that teachers struggle to understand key features of reform-rich lessons (Lin & Fishman, 2006). Unfortunately, there is little evidence that teachers find such presentations salient (Kubitskey, Fishman, & Marx, 2003) or helpful while implementing the curriculum materials (Penuel et al., 2007). Though the institute sessions were active and curriculum-centered, the developers included little time for teachers to talk to each other about how they might use the materials. Such discussions have been identified as critical to developing communities of practitioners capable of sustaining new understandings in the face of the day-to-day pressures of classroom teaching (Putnam & Borko, 1997; Wilson & Berne, 1999).

The working hypothesis in this study was that the way curriculum developers planned and led PD around their own materials would provide insights into the essential features for materials that external facilitators might use to sustain PD at the district level. This approach was based on the assumption that the curriculum developers' knowledge of their materials was sufficient to plan and enact PD successfully *in the first enactment*. Instead, the variations in knowledge addressed and strategies used are consistent with the need to provide teachers with more time to experience the student activities and fact that the facilitator-led presentations and discussions took more time than was planned for, and therefore required adjustments to be made. These patterns suggest that developing the curriculum and planning PD is not sufficient for the facilitators to develop their own capacity to provide PD. This is consistent with previous reviews of curriculum reform efforts that suggest that during the relatively short time periods of most curriculum implementations, it is the curriculum developers who develop their capacity to support and sustain the reforms (Snyder et al., 1992). This suggests curriculum developers and PD facilitators need to find ways to build their own PD capacity more efficiently if they are going to have time to address the problem of supporting external PD providers.

Conclusions

If teachers are to use reform-rich curriculum materials effectively, they must have access to high-quality PD. For this to happen on an ongoing basis, curriculum developers need to eventually provide supports for local PD providers. We are just beginning to address this challenge and one source of understanding at our disposal is to carefully examine how we as curriculum developers have led PD.

There are several strategies for determining the effectiveness of PD opportunities. One strategy is to try to link what teachers learn in curriculum-centered PD to student achievement (Kubitskey et al., 2003; Kubitskey, 2006). Another approach is to compare teachers' perceptions of PD with their enactment of the materials (Penuel et al., 2007). This study uses our understanding of what teachers need to know in order to use curriculum materials effectively and how teachers learn in PD to evaluate how curriculum developers enacted an introductory institute.

This study has several limitations. The first is that it has limited ability to determine the effects of the PD on teachers' use of the curriculum materials. Another limitation is that does not examine the motives of the developers in how they enacted their sessions beyond what was represented in their pre-institute discussions and plans. A third limitation is that the analytical method used, i.e. dividing the plans and enactment into small time intervals and aggregating these intervals by knowledge and strategy types has not been "calibrated" against a accepted PD types to determine whether it is capable of distinguishing PD experiences.

As we begin to design PD supports to allow districts to take ownership and sustain the next generations of reform-rich curriculum materials, it would be beneficial to have some design parameters that would help us use PD time as effectively as possible. By looking carefully at how time is used during developer-led institutes, we can be more cognizant of the need to design PD experiences that align with our understandings of how teachers learn in these settings.

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Chapter 4
Sustaining Innovations Through Lead Teacher Learning: A Learning Sciences Perspective on Supporting Professional Development[4]

Introduction

There is a rich tradition of using curriculum materials to foster reform and innovation in science education (DeBoer, 1991). A key issue in any materials development effort is how to engender high-quality enactments of new materials, and how to sustain and scale-up high quality use so that the materials have a lasting and meaningful impact on the education of students. These issues are far from resolved, but there is a growing focus on scalability and sustainability among researchers in the learning sciences, a field that has developed a broad range of innovative curriculum materials over the past decade (Fishman, Marx, Blumenfeld, Krajcik, & Soloway, 2004; Goldman, 2005). One thing that is clear: this is a challenge with multiple dimensions to be addressed, including educational policy, culture, and the capabilities of teachers and school organizations (Blumenfeld, Fishman, Krajcik, Marx, & Soloway, 2000). In this article, we focus on the dimension of capabilities. Many have argued that professional development is a key to the long-term success of systemic reform initiatives (Committee on Science and Mathematics Teacher Preparation, 2001; Supovitz, Mayher, & Kahle, 2000), and we

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[4] This chapter was originally published as Fogleman, Fishman, & Krajcik (2006).

focus not only on the capabilities of teachers to enact reform-oriented curricula, but also on the capabilities of school organizations to provide leadership in fostering the professional growth and development needed to sustain reform.

Our approach to addressing the district's need to provide its teachers with professional development opportunities is guided by principles from the learning sciences. The learning sciences is an emerging interdisciplinary field that tries to understand learning from the perspectives of a variety of scientific disciplines, including cognitive science, social psychology, anthropology, traditional educational research, as well as artificial intelligence and computational science. At the heart of the learning science's approach is an effort to focus basic science on developing an understanding of how people learn in authentic and instructional contexts and applying that understanding to enhancing the opportunities people have to learn. (National Research Council, 2003).

From the learning sciences, we have used a socio-cognitive (Vygotsky, 1980; Wertsch, 1988) and situated (Brown, Collins, & Duguid, 1989) view of professional learning to guide our efforts. By socio-cognitive, we mean a focus not just on individual cognition, but also on how the interactions of people with each other and with materials of various kinds (Pea, 1993) help to create communities of learning and practice (Lave & Wenger, 1991). By situated, we refer to idea that learning and knowledge is rooted in the contexts of practice and work (Brown et al., 1989). In our work within an established district-university partnership, we apply these perspectives to teacher professional development and the development of teacher leaders to scale and sustain the use of reform-oriented curriculum materials.

LeTUS As a Context for Studying Professional Development Support

The Center for Learning and Technology in Urban Schools (LeTUS) is a four-way district-university partnership involving the University of Michigan's Center for Highly Interactive Computing, Curricula, and Classrooms (hi-ce) and the Detroit Public Schools (DPS), and Northwestern University and the Chicago Public Schools. This paper deals only with the Detroit and University of Michigan part of the collaboration. Begun in 1997 with support from the National Science Foundation, LeTUS produced six inquiry-based middle school science units that have been implemented in a steadily growing number of DPS classrooms over the past eight years. For the past three years, LeTUS has worked to increase the district's capacity to sustain these units by supporting the development of a community of "lead teachers" who are charged with leading professional development workshops pertaining to the LeTUS units.

This article describes how the perspectives of the learning sciences have guided the partnership's efforts to create a learning environment for these district lead teachers where they have deepened their own understandings of the units, planned effective professional development, and increased the district's capacity to sustain the use of the LeTUS units. The first section elaborates on the UM – Detroit partnership and introduces current views of learning and knowing from the learning sciences literature used in our work within the LeTUS partnership. The second section presents two cases that illustrate how these principles guide our collaboration with district lead teachers and a district curriculum supervisor to plan and conduct district professional development supporting teachers' use of specific inquiry practices called for in the LeTUS units. Within these cases, we elaborate on how learning sciences theory motivates and underpins the work of this collaboration.

Background and Theoretical Framework

Over the past eight years, the LeTUS partnership has worked to support systemic reform of middle grade science instruction in the district's schools (Blumenfeld et al., 2000). These reforms included the development and implementation of curricula that foster student inquiry and use of technology as well as professional development that seeks to link professional development activities with student learning (Fishman et al., 2003; Kubitskey, Fishman, & Marx, 2003; Singer, Marx, Krajcik, & Clay Chambers, 2000). A major product of this partnership has been the development of a range of middle school science curriculum units (Singer et al., 2000). Fostering successful teaching using these units forms the core of the partnership's ongoing work.

The LeTUS curriculum consists of a series of six middle school science units. These units are designed according to the following principles (Krajcik, Blumenfeld, Marx, & Soloway, 2000; Singer et al., 2000)

Context that is meaningful to the student and established through the use of driving questions,

- Attention to AAAS and NRC science education standards,
- Activities that engage the student in the processes of scientific inquiry,
- Collaboration and student discourse,
- Learning tools for support of student inquiry,

- Creation of student artifacts,
- Scaffolding of student learning.

In addition to adhering to these design principles, the LeTUS units are designed to provide extensive support for teachers while they are enacting the unit. Each unit is both highly specified, i.e. its purpose and content are explicitly described in the teachers' materials, and highly developed, i.e. including extensive student materials that support each learning activity (Cohen & Ball, 1999). In addition, each unit is designed to be "educative" for teachers (Ball & Cohen, 1996; Davis & Krajcik, 2005), providing opportunities for teachers to learn about new teaching practices, content knowledge, and common student understandings as they enact each unit.

This paper focuses on events related to the seventh grade units "How Can My Friends Make Me Sick?" (Hug & Hi-ce, 2002) on how communicable diseases spread, "What is the Quality of Air in Our Community?" (Wefel & Hi-ce, 2002), on the composition of air and concepts related to chemistry, and "How Do We Get New Stuff From Old Stuff?" (McNeill, Harris, Heitzman, Lizotte, & Sutherland, 2004), on distinguishing substances by their characteristic properties and understanding chemical reactions. The other LeTUS units include another seventh grade unit on water quality, "What is the Water Like In My River?" (Schneider, Krajcik., & Blumenfeld, 2002), an eighth grade unit on force and motion called "Why Do I Have To Wear A Bike Helmet?" (Schneider et al., 2002) , a sixth grade unit on simple machines called "How Can I Build Big Things?" (Rivet, A. & Krajcik, J. S., 2002), and two sixth grade units developed by the BioKIDS group at Michigan, one on biodiversity called "BioKIDS" and another on weather called "Kids As Global Scientists" (Songer, Lee, & McDonald, 2003).

Implementing educational change is an extremely difficult task, especially when the changes cause classrooms to differ from what students, teachers, and other community members think of as traditional schooling (Elmore, 1996; Tyack & Cuban, 1997). As teachers implement innovative curriculum units, they often adapt them so that their enactments are consistent with familiar classroom patterns (Pinto, 2005). Providing professional development opportunities that help teachers understand the original intent of these materials and the effects of their adaptations should increase their efforts to sustain the innovations (Fullan, 1991; Pinto, 2005).

The LeTUS Approach to Teacher Professional Development

Over the course of our partnership, hi-ce has worked closely with DPS personnel to design and provide effective professional development opportunities for LeTUS teachers. At the heart of these experiences are opportunities for discussion between teachers enacting the units and hi-ce researchers. We call the conceptual framework that guides these activities CERA (Krajcik, Blumenfeld, Marx, & Soloway, 1994): Collaborative construction of understanding; Enactment of new practices in classrooms; Reflection on practice; and Adaptation of materials and practices. Professional development activities include a 1-week summer institute and monthly Saturday workshops during the school year. During the first three years of the partnership, hi-ce used a design approach (Simon, 1996) to plan workshop activities based on feedback on teachers' enactments and student assessments (Fishman, Best, Foster, & Marx, 2000). Efforts to document how these professional development strategies influence teachers' enactments of the LeTUS units and subsequent student learning have been described elsewhere (Fishman, Best, Marx, & Tal, 2001; Kubitskey et al., 2003; Kubitskey, 2006; Margerum-Leys, Fishman, & Peek-Brown, 2004). As new teachers decide to enact the LeTUS units each year, the district must have the capacity to sustain the discourse communities around each unit in order to give them access to the expertise that exists across the district.

Three years ago, the district assumed primary responsibility for the LeTUS professional development workshops. An ongoing challenge in any such transition is preserving the essential character of both the curriculum units and the professional development, which is essential in order to maintain the partnership's focus on educational reform. The district chose to meet this challenge by asking teachers who had successfully incorporated the LeTUS units into their classroom practice to plan and conduct the LeTUS workshops. Hi-ce researchers are committed to supporting theses teachers as they assume this new role, and we have adjusted our research on teacher learning in LeTUS (Fishman, Marx, Best, & Tal, 2003) to focus on how to support and help these lead teachers with their own development (Fishman et al., 2003).

This shift in focus to supporting lead teacher learning is consistent with our overall grounding in learning sciences perspectives on knowing, learning, and teaching. Our work is motivated by the situated theories of knowledge (Brown et al., 1989), communities of discourse and practice (Lave & Wenger, 1991), and cognitive apprenticeship and scaffolding (Brown et al., 1989). We will elaborate on what each of these terms means, and what they mean in the context of our work, below through two examples from our work with lead teachers in LeTUS. Before presenting those examples, we describe the methods we use to document and study the work of the lead teachers in LeTUS.

Methods

District Setting

The Detroit Public Schools is a large system serving about 165,000 students from a diverse urban community and employing more than 10,000 teachers and other education professionals. Like most large American cities, students often come from poor families (about half of Detroit's students live at or below the poverty line), are largely minority, and tend to be mobile. Dropout rates are high and students' test scores are low compared with performance of students across the state. The LeTUS schools represent the broad range of schools and neighborhoods in the city, ranging from inner-city schools serving communities with high poverty to schools in middle-class communities on the outskirts of the city, and including several schools in a largely Latino section of the city that has a large population of migrant and recent immigrant families. Across the district, 91% of the students are African American, 4% are Latino, 4% are white, and 1% are Asian.

The approximately 80 teachers participating in the LeTUS community teach sixth, seventh, and eighth grade science at LeTUS schools. These are teachers who teach science as a standalone class for at least one period per school day. University researchers collaborated with senior district administrators in the selection of schools to insure that participating schools were representative of the larger district. The resulting group of teachers is diverse: 70% of the teachers were certified to teach in science, the remainder was not, although several members of this group have had prior professional development experiences in science education.

The Formation of a Workcircle and Identifying Lead Teachers

LeTUS professional development is currently planned and conducted by district lead teachers and the district science instructional specialist, with support from hi-ce researchers. The district instructional specialist responsible for coordinating the LeTUS partnership selects the lead teachers. The initial selection criterion is that the lead teacher candidate be respected by their peers and the hi-ce researchers as "capable enactors." A "capable enactor" has demonstrated, through their students' academic performance, that they have developed sufficient content knowledge, pedagogical knowledge, and pedagogical content knowledge (Shulman, 1986) to help their students succeed. In addition to their proven knowledge of the curriculum, each lead teacher has demonstrated their ability to communicate and collaborate with their peers by their participation in previous LeTUS workshops. There are two lead teachers for each unit, and sometimes lead teachers serve in their leadership role for multiple units within their grade level. Supporting teachers in such leadership roles is broadly recognized as an effective opportunity for their personal and professional development (York-Barr & Duke, 2004).

A major tool in the partnership's efforts aimed at increasing the district's ability to sustain the LeTUS units is a professional development "workcircle" (Reiser et al., 2000). For our purposes, a workcircle consist of people from different areas of expertise who come together to address a common problem or task. Participants in the workcircle include the district science instructional specialist, lead teachers from each of the grade levels, and members of the hi-ce research group from the university. The workcircle meets for two hours after school one or two weeks before each Saturday workshop, and also plans for the more extensive summer LeTUS workshops.

Data Collection and Analysis

As participants in the workcircle, we recorded fieldnotes for fourteen monthly planning meetings that took place during the 2003-2004 school year and the first half of the 2004-2005 school year. Each five-hour monthly workshop was videotaped. After the workshop, the videotape was used to complete detailed workshop notes. Conversations during the workshops between the lead teachers and participating teachers that were relevant to topics of workcircle discussions were transcribed and included in the workshop fieldnotes. When additional planning meetings between lead teachers and university researchers were held, attendees were interviewed to determine topics discussed in the meeting.

As we read through each of the field note entries and planning documents, we listed issues and problems that workcircle participants brought up for discussion while planning the upcoming workshop. These ranged from district-level issues such as how changes in testing schedules might affect teachers’ progress through the units, to strategies to improve student learning across the units. Issues lead teachers felt were relevant for all of the LeTUS units, e.g. strategies for improving students’ literacy skills, were revisited repeatedly over the course of several meetings. To develop our examples, discussion records around two issues considered in planning meetings were compiled, along with the related professional development activities the lead teachers conducted. Each of these issues was related to strategies called for in the units the lead teachers found challenging to enact. For each example, a narrative describing the contributions of each workcircle participant to the topic and the subsequent activities used by the lead teachers in the workshops was developed. These narratives were then used to assemble evidence supporting each idea about teacher learning from the learning sciences. Our assertions and the corresponding evidence were reviewed with DPS and hi-ce personnel involved in the workcircle to strengthen their validity.

Findings and Discussion: Two Cases of the Work of Work Circles

In the remainder of this paper, we present two examples from the workcircle that illustrate how it functions to increase lead teacher (and therefore district) capabilities. In the first example, we describe how the workcircle provided support for teachers' efforts to improve their students' scientific explanations. Our second example involves assistance to lead teachers learning how to support teachers' use of concept mapping for both learning and assessment. In each of these examples, we describe how a learning sciences framework shapes our approach to fostering increased capacity through professional development. Learning sciences theory that is highlighted in this work includes: the situated nature of teachers' knowledge, communities of practice/discourse, cognitive apprenticeship, and scaffolding. We explain each of these theories in the context of our LeTUS collaboration.

Case 1: Learning How to Support Students in Making Scientific Explanations

The ability to create a scientific explanation is an essential element of students' scientific inquiry as well as an opportunity for students to clarify their understandings (McNeill & Krajcik, 2007; National Research Council (NRC), 1996). District teachers and hi-ce researchers developed strategies that use scientific explanations to link students' observations with scientific concepts by having them support a claim with evidence and reasoning(Sutherland et al., 2006). The district instructional specialist recognized writing scientific explanations as a task that district students struggle with on the statewide high-stakes science examination, and some of the lead teachers had already developed strategies for scaffolding their students' efforts. In addition hi-ce had provided example rubrics and strategies as part of the educative curriculum materials. Though having students construct scientific explanations is a feature of several LeTUS units, the importance of improving student literacy made it clear that teachers needed additional support as part of the professional development to learn how to use the models and strategies that were presented in the curriculum materials.

A Situated View of Knowledge

The workcircle takes advantage of the learning sciences' view of knowledge as highly situated both physically and culturally (Brown et al., 1989) to help lead teachers address students' scientific explanation difficulties through professional development. The recognition of the benefits of supporting students' explanations was put forward by the lead teachers themselves, and the workcircle started to address the problem by discussing scaffolding and assessment strategies created by two of the lead teachers to support their students' scientific explanation writing. One lead teacher presented a graphical organizer that represented the scientific explanation's reasoning as a bridge between a claim and several statements of evidence. Though this graphical organizer had been developed by the lead teacher in the context of another project, she observed that her students were able to use the organizer to construct better sentences for each component of their scientific explanations, but she was having difficulty fading the scaffold and transitioning her students to writing their explanations in paragraphs. Another lead teacher shared an activity that helped her students identify the claim, evidence, and reasoning statements in example paragraphs before constructing their own explanations. Each of these strategies were meant to augment existing activities within the LeTUS units to address difficulties the lead teachers found in their classrooms. Working toward solutions to these problems required hi-ce researchers to present research-informed ideas about what constitutes effective scaffolds and teachers' to share ideas about how to support students' construction of scientific explanations. How these workcircle discussions enhanced the lead teachers' understandings of challenges they initially addressed in their own classrooms is described later is this section.

Community of Discourse/Practice

By meeting on a regular basis around a common set of curriculum units, the workcircle became a discourse community and eventually a community of practice. Theory suggests that teachers need discourse communities in which to discuss and refine their understandings of reforms (Putnam & Borko, 1997). Though the lead teachers used the curriculum materials effectively, the workcircle provided a forum for them to align their goals and establish a shared language around issues they see as important. As the discussions about scientific explanations progressed, the lead teachers from different grade levels looked for ways to align strategies that supported students' explanations across grades. Lead teachers felt that sixth grade materials should focus students on making scientific claims and citing evidence from their investigations. Lead teachers for the eighth grade units saw that they could build on the seventh grade units' use of claim, evidence, and reasoning, by having their student consider alternate explanations for the same phenomena. Eventually, this led to revisions in the LeTUS units so that explanations students were asked to construct increased in complexity from grades six to eight. In addition to developing a shared way of understanding, the workcircle became a community of practice (Lave & Wenger, 1991) whose main activity was leading the Saturday workshops. In the case of teaching about scientific explanations, the workcircle discussions resulted in professional development activities that addressed student difficulties shared by the hi-ce researchers and the lead teachers.

Cognitive Apprenticeship and Scaffolding

As the workcircle considers issues that need to be addressed in upcoming workshops, knowledge is introduced within the workcircle using a cognitive apprenticeship approach. If knowledge is viewed as situated, then it must be presented to novices in a meaningful context. The cognitive apprenticeship model suggests that experts introduce new knowledge by modeling how the knowledge might be used (Brown et al., 1989). During the workcircle discussions pertaining to students' scientific explanations, both the lead teachers and the hi-ce researchers moved in and out of the center of the community (Barab & Duffy, 2000), providing research-based knowledge, concrete examples of student work and classroom assessments so that the other lead teachers could try them on their own. In the case of the “bridge” graphic organizer described earlier, hi-ce researchers presented posttest results that confirmed the lead teacher’s observation that her students had difficulty making the transition to writing their scientific explanations in paragraph form. In addition to some students’ over-reliance on the graphic organizer, they also struggled with translating information presented in a data table into evidence statements, and identifying evidence to support their claims. The lead teachers noted the importance of teachers providing opportunities for students to practice writing explanations and providing formative feedback, and discussed strategies for modeling this process in the LeTUS workshops. Because each of the participants possesses expertise that is essential to planning and conducting the monthly workshops, the workcircle provides a opportunity to align theory, research, and classroom realities so that relevant and effective opportunities for teacher learning are planned.

Scaffolding is a key component of cognitive apprenticeship theory (Brown et al., 1989) in which support is provided as needed, especially early in a learning task, and then faded as the learner becomes more skilled. Scaffolding provides the bridge that enables learners to cross the zone of proximal development (Vygotsky, 1980) towards greater knowledge and skills. In the case of our collaboration in the workcircle, university personnel provided knowledge and support where needed for teachers in terms of: scientific knowledge, glosses of the literature on professional development, and information about the uses of technology in their classrooms (Fishman, Fogleman et al., 2003). In early workcircle meetings, hi-ce researchers presented research-based information about the characteristics of effective professional development so that lead teachers could understand the pedagogical features of previous workshops conducted by university personnel. As time went on, and lead teachers' expertise increased, the need for this kind of support decreased and thus the focus of the workcircle, and the support provided by university partners could shift to new topics.

Case 2: Learning to Support Student Creation of Concept Maps

While documenting the effects of the Saturday workshops on participating teachers' classroom practice, a hi-ce graduate student met with the two lead teachers preparing the workshops for the Communicable Disease unit. One feature of the unit that had challenged teachers in the past was a series of activities that called for students to construct and refine concept maps that represented their understandings of the relationships among the unit's main ideas. Concept mapping provides an opportunity for students to represent their understanding of the relationships between concepts and teachers an opportunity to provide formative feedback (Novak, 1984). Based on observations of past enactments across the district, hi-ce researchers were concerned that the concept mapping activities were not being used as opportunities for teachers to provide feedback on students' understandings, as they were originally intended. The lead teachers had reservations about the concept mapping assignments as well, noting that teachers found them difficult to assess and that students often did not see the point in revisiting the maps repeatedly as called for in the unit.

A Situated View of Knowledge

The lead teachers' experience enacting the unit allowed them to recognize some of the difficulties teachers participating in the workshops might have using concepts maps as intended in the curriculum materials. In order to use concept mapping successfully, teachers needed support in translating the theoretical elements of effective concept maps into three necessary changes in their classroom routines. The first change was to introduce students to concept mapping procedures, i.e. constructing a list of concepts and linking words, organizing the terms hierarchically, and looking for cross-links across the map. The second change was to assess students' work as they completed their maps and provide formative feedback throughout the activity. The last change was to establish an activity structure or classroom routine that made students' revisiting their concept maps through the course of the unit seem meaningful. These underlying pedagogical challenges exemplify the situated nature of teachers' expertise (Borko & Putnam, 2000). The lead teachers' previous experiences with concepts maps led them to problematize teachers’ uses of concept mapping and to plan workshop activities that addressed each of the difficulties they anticipated. Though university personnel who had led the workshops in the past had presented effective concept mapping strategies, the lead teachers were now able to understand the rationale behind strategies such as having students sort their concepts from general to specific in light of their own students’ work. Being able to situate concept map theory in this was key in developing strategies for other teachers to use, which became the core of the professional development.

Community of Discourse/Practice

During one of the planning discussion, the hi-ce graduate student reviewed the essential characteristics of effective concept maps and the lead teachers came to realize that they were not adequately addressing one concept map feature with their students, hierarchy. These discussions illustrate the importance of the lead teachers participating in a discourse community not situated exclusively in the classroom. According the Putnam & Borko (1997), such discourse communities provide a setting to align one's understandings of reforms with the understandings held by others. Though the lead teachers' previous concept mapping experiences initially made them wary, they were willing to consider new information from these discussions and reflect on how the requirement that student concept maps be hierarchical might change how they "worked" with their students. Moving beyond discussion to action provided a need to solidify these shared understandings. The fruits of this process were evident in the workshop when one of the lead teachers started the discussion of concept maps by showing, as an example, one of her students' maps from a previous year that resembled a "web diagram" without linking words. After asking for a show of hands from teachers whose students produced similar concept maps, she described how revisiting the essential elements of concept maps was going to improve their students' work in the upcoming unit.

Cognitive Apprenticeship and Scaffolding

As in the above example about scientific explanations, the work between the graduate student and the lead teachers around concept mapping is an instance of cognitive apprenticeship and scaffolding theory in action. In the previous year's enactment of the unit, the hi-ce graduate student had shared with the lead teacher results from her study of what professional development strategies teachers found most useful (Kubitskey et al., 2003). In response to concerns for this enactment, she reviewed the theoretical principles of concept mapping from the research literature and the curriculum materials. These were combined with the lead teachers' own knowledge about concept maps in order to help them learn to think about supporting concept mapping in new ways. In the first workshop for the unit, the lead teachers used concept mapping as unifying theme through many of the workshop’s activities. To explore the unit's first learning set, teachers worked in small groups to identify the central concepts. After reviewing the theory and mechanics of concept mapping, the lead teachers asked participants to work in their groups to construct concept maps. As each group presented their map, the lead teachers then modeled the process of assessing the maps and providing formative feedback. Throughout that workshop, the lead teachers repeatedly and enthusiastically endorsed the value of the hierarchically arranged concept maps, and made it clear that they believed these strategies would make concept mapping more meaningful to both students and teachers during the upcoming enactment.

Conclusion

Experience suggests that bringing about educational change in school organizations is a long and challenging process. The simultaneous goals of sustaining reforms through a long enough period so that teachers learn to use them effectively and scaling up innovations so that more teachers begin to use them each year requires the district to develop the capacity to provide teachers with access to ongoing professional development opportunities (Fishman et al., 2004). In the LeTUS partnership, hi-ce has worked with DPS curriculum specialists and lead teachers in a professional development workcircle to build this capacity.

Our approach has been based on socio-cognitive views of learning consistent with a learning sciences view of knowledge and learning as complex and situated in particular contexts (Kolodner, 2002). The work we report on is both grounded in and supports the idea that knowledge is situated culturally and physically within communities of practitioners (Brown et al., 1989). Our work emphasizes the viewpoint that accomplished teachers develop knowledge that is situated in their classrooms and schools (Putman & Borko, 2000), and extends that viewpoint by introducing the importance of expanding the circle of influence to include a broad range of knowledgeable others. The cases presented illustrate how the work circle provided opportunities for lead teachers to share their expertise around the LeTUS units and to bring their classroom experiences into contact with research-based knowledge and the units' theoretical foundations, forming a more robust basis for professional development.

Providing district teachers with access to a supportive professional community as they are trying to implement innovations is one way to support their learning (Putnam & Borko, 1997). Though lead teachers provide a natural center for such communities, there is a possibility that less experienced teachers will rely too heavily on the lead teachers’ own classroom activities (Silva, Gimbert, & Nolan, 2000). Workcircle discussions allow lead teachers to hear a variety of teachers’ concerns and to pool their classroom strategies along with knowledge from the university researchers as resources that they can draw upon to plan workshop activities. By aligning these activities with the goals and strategies called for by the LeTUS units, the lead teachers plan professional development that maintains the LeTUS materials as the foci of their respective grade-level teacher communities.

Our work within the LeTUS partnership illustrates the importance of innovators exploring strategies for supporting the use of their materials in classrooms beyond the time necessary for the first wave of teachers to learn to use them effectively (Fishman et al., 2004; Fullan, 1991; Penuel, Fishman, Yamaguchi, & Gallagher, 2007). District-university partnerships provide an excellent test bed for developing strategies and resources for sustaining and scaling reforms so that they are more likely to become part of the district's persistent institutional fabric.

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Chapter 5
Conclusion

Given the longstanding consensus on the need to improve science instruction, one has to ask why it is so difficult to incorporate and sustain innovative approaches to teaching science in our classrooms. The three studies that comprise this dissertation aim to understand more about how teachers enact innovative curriculum materials and how curriculum developers and district personnel can provide supports teachers need to continue using them. Historically, science curriculum implementation efforts have been criticized for their relatively weak influence on classroom instruction (Fullan, 1991; Welch, 1979). The track record for innovations that has fueled these criticisms has led researchers to recognize the need to design innovations and supports in ways that increase their chances of being widely adopted and long-lasting (Coburn, 2003; Fishman & Krajcik, 2003). The problem of how to support and sustain innovations at the district level is multifaceted and complex (Blumenfeld, Fishman, Krajcik, Marx, & Soloway, 2000; Coburn, 2003). This dissertation has focused on one of these facets: the challenge of providing PD that supports teachers' understanding and use of reform-centered curriculum materials.

In this concluding chapter, I relate my findings to current understandings of teacher knowledge and learning to suggest steps that curriculum developers can take to increase their materials' chances of success in schools. I begin by describing Kubitskey's (2006) model for a sustained program of PD workshops designed to support reform-centered curriculum materials. I use the results of each study of this dissertation to suggest three ways to refine this model in light of our current understandings of teacher learning and PD. These refinements include leveraging the situated nature of teachers' knowledge and practice, refining the high-level consensus of what constitutes effective PD into usable design principles for curriculum-centered PD programs, and taking seriously the need to shift ownership of our innovations to the districts that decide to adopt them.

A working model for sustaining workshop-based PD at the district level

Based on her studies of middle-level teachers within an urban district participating in curriculum-centered PD, Kubitskey (2006) developed a model for sustained, workshop-based PD that is designed to sustain curriculum based reform within a district. Kubitskey found that though teachers adapted the lessons described in innovative curriculum materials as they were teaching, a sequence of PD workshops that included all the district teachers who were simultaneously using the new curriculum materials helped teachers understand the materials in ways that enhanced student learning. Her model calls for PD workshops for teachers using the same curriculum materials that provide "just in time" learning about the curriculum, opportunities for personal reflection, and peer exchange (Kubitskey, 2006). The content of these workshops is influenced by both the rationale behind the curriculum materials as well as feedback from teachers about what was going on in their classrooms. These monthly PD workshops are run initially by curriculum developers and eventually by district teachers with extensive experience with the materials. The model is shown in Figure 5.1.

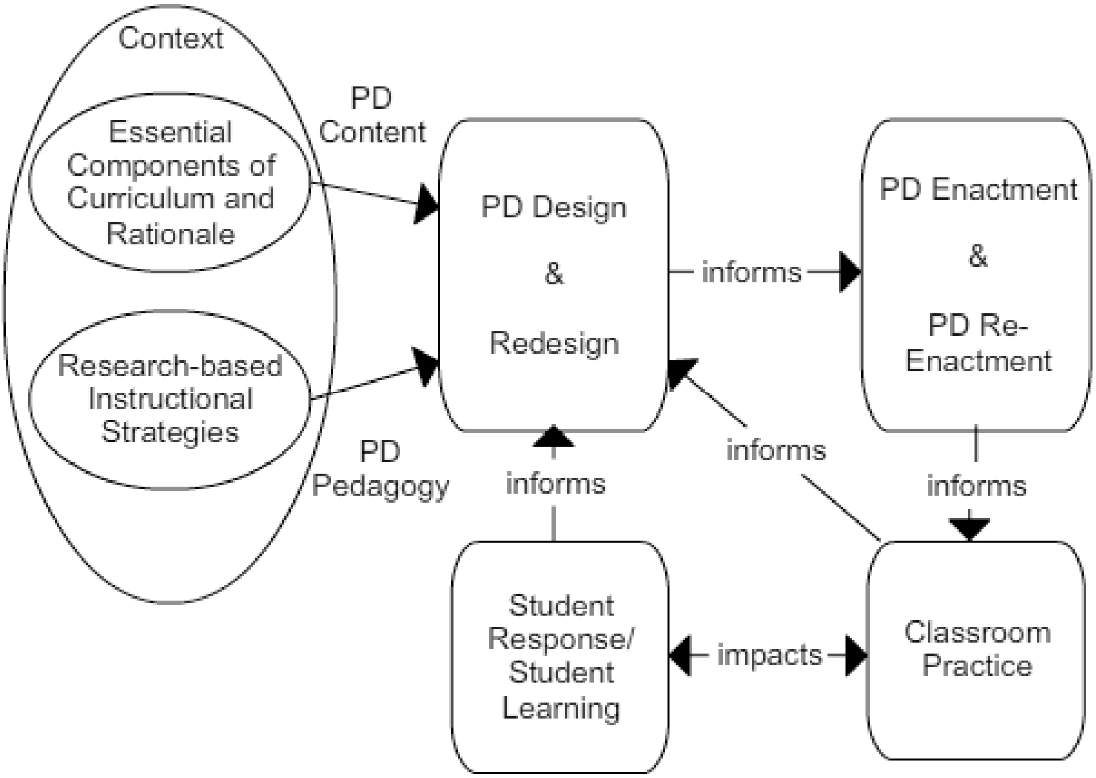

Figure 5.1. Kubitskey's (2006) design model for sustained workshops.

Kubitskey's model provides a research-based approach to the problem of providing ongoing support to teachers as they refine their understanding of challenging curriculum materials over several enactments. What is not clear, however, is what capacities are needed to put such a model in place. In the remaining sections of this chapter, I will summarize the findings from my three studies, relate them to current views on effective PD and what is needed to sustain reforms, and suggest the implications of this research for helping districts sustain their support of innovative materials.

Leveraging the situated nature of teachers' work

Though widely accepted as a way of describing teacher knowledge, there is still room to leverage the situated nature of how teachers understand and utilize curriculum materials to design strategies for supporting and sustaining curricular reforms. When we say that teachers' knowledge is situated, we mean that teachers' knowledge, attitudes, and beliefs about their teaching are often shaped and warranted by their educational and professional contexts (Putnam & Borko, 1997). Teachers are strongly influenced about what constitutes acceptable practice through formal and informal contacts with their professional colleagues (McLaughlin & Talbert, 2001). Though these de facto communities of practice (Lave & Wenger, 1991) are effective for reinforcing accepted behaviors among established members and newcomers, the adoption of new curriculum materials calling for different instructional strategies requires teachers to have access to new or evolving communities to provide a venue for making sense of new practices (Putnam & Borko, 1997).

The challenge of changing established classroom practices was seen in the first study of how teachers used the IQWST curriculum materials described in Chapter 2. The *Stuff* unit called for students to investigate carefully selected phenomena and engage in teacher-led discussions where they could explain how their observations served as evidence for theoretical concepts such as particle nature of matter. Though several teachers did report enacting the materials as intended by the designers, others chose the more traditional approach of having students experience phenomena through whole-class demonstrations. Videotaped lessons revealed that in some classrooms when students completed the investigations on their own, there was often little time to discuss their results in light of the main scientific concepts. These discussions are an essential aspect of reform but are often omitted in traditional instruction (Weiss, Pasley, Smith, Banilower, & Heck, 2003).

To strengthen our support of reform-based curriculum materials the situated and social nature of teachers' practice should be incorporated into teachers' PD experiences. To change classroom practices, PD should be organized around the development and support of a community of teachers trying out new practices at both the school and district levels. Kubitskey (2006) showed that teachers' practice and subsequent discussion and reflection are critical learning experiences when learning to use new curriculum materials. The PD enacted by curriculum developers analyzed in Chapter 3 focused more strongly on functional elements of the curriculum such as its learning goals and activities than on nurturing the formation of a community of practitioners around the materials. The PD workcircle described in Chapter 4 included researchers and district personnel helping lead teachers plan PD for district teachers. The case study's two examples showed that district lead teachers with significant experience using the new curriculum materials used the workcircle's discussions to refine their understanding of critical elements of the curriculum materials such as concept mapping in the course of planning ongoing PD workshops for their peers.

A situated view of teachers' understanding and use of curriculum materials suggests some ways to extend Kubitskey's (2006) model of workshop-based PD in ways that would help sustain the use of new curriculum materials. Kubitskey (2006) recognized that the teachers attending a sustained PD sequence as they enacted innovative curriculum material constituted a community of practitioners around those materials. The challenges teachers experienced while using these materials suggests that they might benefit from such contact at the school level, not just at district-level workshops. These school-based community cells should be interlinked at the district-level workshops to build capacity at each level of the district organization. Instead of being seen as a secondary effect, there is ample evidence that the presence of a supportive professional communities both at the school and district levels are essential if teachers are going to use new materials well (Penuel, Fishman, Yamaguchi, & Gallagher, 2007). As more school-based supports are provided, curricular reform efforts will need to be aligned and integrated with other school improvement efforts, including the school's efforts to align their teaching with local standards and prepare their students for high-stakes testing.

Refining our understanding of effective curriculum-centered PD programs

In addition to recognizing the situated nature of teaching, we can increase the sustainability of curricular innovations by refining what we know about effective curriculum-centered PD. Effective PD provides learning experiences that help teachers acquire knowledge or transform their practice (Wei, Darling-Hammond, Andre, Richardson, & Orphanos, 2009). Teachers learn from experiences that support their efforts to examine, reflect upon, and refine their teaching. These experiences should be collaborative, active, and closely tied to their own needs (Desimone, Porter, Garet, Yoon, & Birman, 2002; Guskey, 2003; Penuel et al., 2007; Wei et al., 2009). Formal workshops and school-based follow-up experiences such as participation in a professional learning community play important roles in sustaining the use of innovative materials (Penuel et al., 2007; Wei et al., 2009).

Our current knowledge of what constitutes effective PD provides only partial guidance for designing PD that is intended to support teachers who are learning to use innovative curriculum materials (Borko, 2004). One difficulty that remains is a lack of knowledge about how to plan PD experiences and sequences of experiences that are effective and efficient. Though we have agreed on the *ingredients* of effective PD, we do not yet have PD *recipes* that are coherent or reliable. The study of the design and enactment of the introductory PD workshop described in Chapter 3 showed curriculum developers having to choose from among goals and strategies that they knew were important, resulting in strong experiences for teachers to develop their understanding of the curriculum materials, but little opportunity for teachers to collaborate, share their concerns, or engage in authentic work such as assessment or planning. In the case of PD planning described in Chapter 4, the researchers influenced the PD planning process by bringing their knowledge of effective PD into the workcircle they shared with a district curriculum specialist and lead teachers. The workcircle activities constituted "joint work" (Little, 1990) and, along with the enactment of the workshops themselves, provided a source of PD for the lead teachers.

Kubitskey's (2006) design model for sustained PD answers some of these questions by virtue of its proximity to teachers' practice. In this model, district lead teachers rely in part on their own experiences with the curriculum as a basis for providing workshops for co-enacting teachers. Though collaborations between curriculum developers and district personnel such as the PD workcircle expand the lead teachers' repertoire of effective PD strategies, developers could increase the capacity of districts to provide PD by developing coherent PD sequences that deepen teachers' understandings of the essential character of their materials over time. Currently, districts have little guidance for fashioning learning sequences that address the most challenging topics such as facilitating classroom discourse, and there has been little research on districts using existing PD materials sustain curriculum they decide to implement (Borko, 2004).

Shifting ownership of PD

In addition to leveraging our current understandings of teacher knowledge and learning, new views on what is necessary to increase "scale-up" an innovation should inform the design of curriculum-centered PD. Coburn (2003) argues that, in addition to increasing the number of teachers using it, bringing an innovation to scale requires attention to other factors such as increasing the depth that it is being used, supporting its continued use over time, and helping increase the ownership local stakeholders assume over the innovation. Because reform-based curriculum materials often seek to change teachers' practices, the supports in place for teacher learning play an important role in the scaling process.

Kubitskey's (2006) model of district-led PD workshops addresses several of these concerns. PD workshops that take place throughout the year provide participating teachers with a setting to share and refine their understandings of the materials and use the materials more effectively. Having district lead teachers facilitate these workshops grounds them in local practice and increases the capacity of the district to assume ownership of the innovation.

The studies in this dissertation shed additional light on the problem of how curriculum developers and districts can collaborate to build local capacity to support the use of new material and eventually shift ownership of the reforms to the district. For a district to provide ongoing workshops capable of sustaining new curriculum materials as described in the Kubitskey model, it must develop a capability to accurately represent the intent and strategies called for by the materials. Figure 5.2 provides a model of how a district's capacity to sustain PD can be developed.

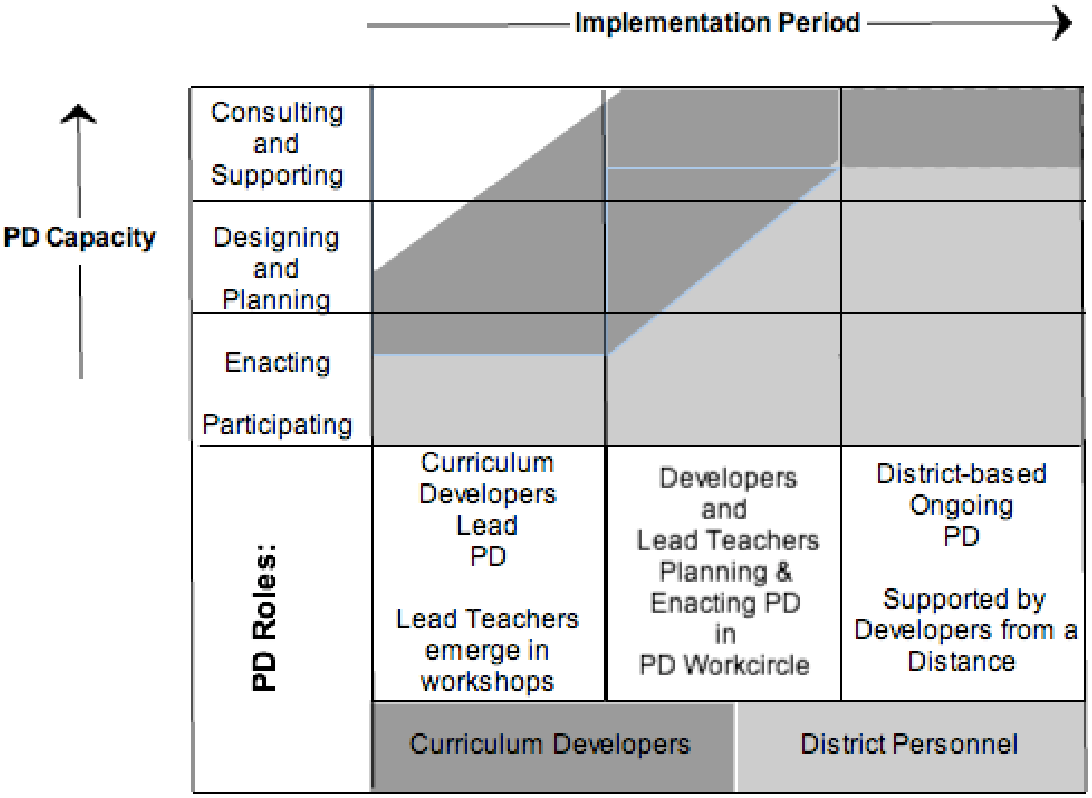

Figure 5.2. A model for building a district's PD capacity.

A district's capacity to provide reform-sustaining PD includes the ability to plan PD experiences and design resources that help teachers incorporate new materials in their teaching. In this model, the time that the district has committed to introducing reforms is represented along the horizontal, while the capabilities needed by district increase vertically. The study of the first introductory workshop offered by curriculum developers indicated that early in implementation period, the PD capacity of both the district and the curriculum developers is relatively low. As curriculum developers work with teachers early in the implementation process, they develop their own understanding of how teachers understand and adapt the new materials, and the effect of these adaptations on student learning (Kubitskey, Fishman, & Marx, 2003; Pinto, 2005).

As teachers continue to participate in PD led by the curriculum developers, experienced teachers take on a more active role in the workshops. Chapter 4 describes how teachers who have used the materials extensively can emerge as lead teachers for the district and take over planning and conducting the workshops needed to sustain the material's use. In this middle implementation stage, curriculum developers and researchers provide "just in time" support to these lead teachers within a PD workcircle that deepens their understandings of both PD and the curriculum materials.

The right-most column of the model represents the time when the district's lead teachers take over the PD entirely, with the curriculum developers maintaining contact for consultations as needed. There is little research on this stage of implementation, which Fullan (1991) calls institutionalization. He points out that a common drawback of efforts to implement classroom innovations is the inability of the innovators and districts to introducing the now-established materials to new teachers entering their system each year. In this model, new teachers have access to an ongoing community of practitioners who possess extensive experience using the materials. Eventually, as new lead teachers emerge the initial lead teachers can "rotate off" the responsibility of providing ongoing PD, hopefully remaining available as consultants to those who take up these roles.

The significance of this research

The studies that comprise this dissertation seek to clarify and extend our understanding of designing PD experiences and supports that can contribute to the sustained used of curriculum materials within a district. In the first study, teachers' adaptations of reform-based curriculum materials were assessed in light of their students' understandings. The results of this study provide evidence for the importance of having students investigate phenomena themselves instead of experiencing phenomena second-hand in the form of teacher demonstrations.

The second and third studies contribute to our understanding of the challenge of designing professional development that supports the use of new curriculum materials. The second study illustrates that challenges and subsequent design decisions made by curriculum developers in their early attempts and designing PD around their curriculum materials. This descriptive study documents the complexity choosing topics and strategies for introducing such materials to teachers. The third study examines one strategy, a PD workcircle, that curriculum developers used to support district lead teachers as they assumed responsibility for providing PD focused on reform-centered curriculum materials for the district's teachers. Both of these studies suggested ways to extend our current models for designing sustained PD programs at the district level.

Summary

For curricular reform efforts to improve science instruction, we need to design the materials and support programs to sustain the use of the innovations beyond the period when curriculum developers and researchers are working closely with district personnel and the teachers who are early adopters. This dissertation is comprised of three studies examining how teachers use new curriculum materials and how they are supported through PD led by developers and district personnel. In this chapter, I suggested refinements to Kubitskey's (2006) model for sustained PD. To design more sustainable materials and PD, we need to refine our understanding of teacher learning, PD design, and strategies for transferring ownership of innovations to schools and districts.

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Appendix 1.1: Sample Test Items

Sample Multiple-Choice Items:

1. To determine if a chemical reaction occurred, you should measure and compare which of the following?
   - A. volume of the materials
   - B. shape of the products
   - C. properties of the substances
   - D. mass of the reactants

2. A chemical reaction occurs when a student mixes carbon dioxide (CO_2) and water (H_2O).

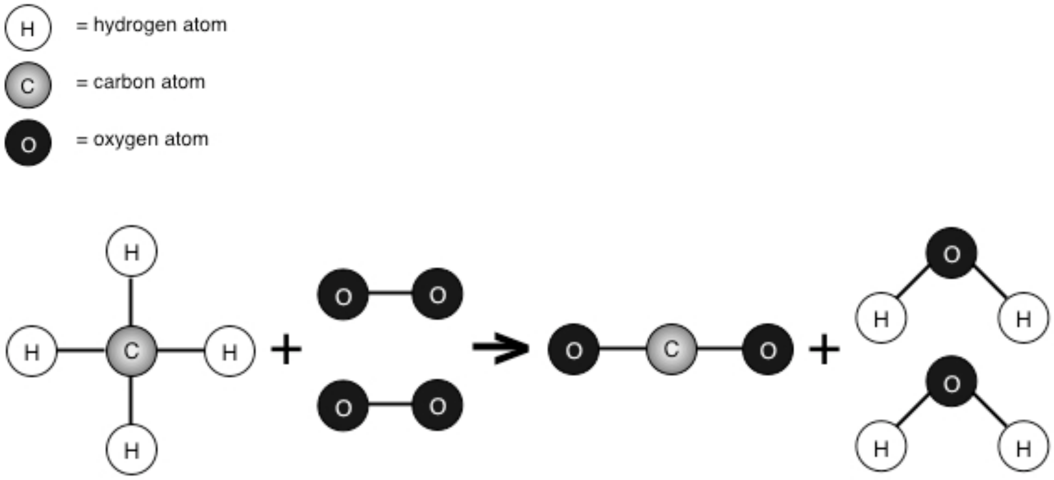
$$CO_2 + H_2O \lozenge \quad ?$$

A. Using the principle of conservation of mass, which of the following could be the product of the reaction?

1. $H_2O_2 + CO_2$
2. H_2CO_3
3. $H_2O + CO_2$
4. H_3CO_2

Sample Open-Ended Item:

3. A student creates a model to show what happens before and after a process.



A. Does the model represent a chemical reaction? Why?

B. According to the model, do you think that the total mass before is equal to the total mass after? Why?

Appendix 1.2: Sample Survey Page
How Can I Make New Stuff From Old Stuff?

Curriculum Questionnaire

Name:_______________ School:_______________ State:_____ Unit Start Date?______ Unit End Date?_______

Learning Set I
Properties and Substances: How is this stuff the same and different?

Lesson 1: How is this stuff the same or different? [Properties]

	Activities were done by		Level of completion was			Your comfort level was			Students' understanding was			Reader was used		
Lesson	teacher (demo)	students	com-pleted	partially completed	not used	low	med	high	low	med	high	at home	in class	not used
1.1 Describing fat and soap														
1.2 Box of “Stuff”														

1.3 Initial concept map														

Approximate number of days spent on this lesson:_____ ***In which of your classes did you use this activity?***

Comments about lesson:

Describe any modifications to the lesson:

Appendix 3.1: Knowledge Types and Professional Development Strategies

Knowledge Type/Topics		Operational Definition	Enactment Example
Subject Matter Knowledge		The concepts, facts, and disciplinary practices (CFPs) which are either prerequisite or background knowledge related to a curriculum topic.	
	Chemistry - Matter	CFPs related to each particular topic.	Background knowledge about the different regions of shadows.
	Inquiry - Scientific Models		
	Physics - Light Behavior		
	Physics - Shadows		
Pedagogical Content Knowledge		"Information that helps teachers anticipate and interpret what learners may think about or do in response to the activities in the unit, what understandings they may hold on to, and how to respond to those ideas during instruction." (Davis & Krajcik, 2005)	
	Chemistry - Matter	CFPs related to determining and responding to students' understandings of specific unit topics.	A description of the terms used to delineate different regions of shadows from non point-sources of light.
	Physics - Light Behavior		
	Inquiry - DGOA		
	Inquiry – Scientific Models		
Curricular Knowledge		"Knowledge of the curriculum materials, including their learning goals, the instructional strategies the materials are designed to support, the learning principles that underlie these strategies, as well as the conceptual and procedural connections within and across different instructional units." (Davis & Krajcik, 2005)	
	Unit Learning Goals	Information about what students should learn during the unit.	A discussion of the main ideas about light addressed in the physics unit.
	Context and Sequencing	Information related to the Driving Questions, Driving Question Board, or other strategies for providing a meaningful context for learning; information about how lessons are sequenced and connected.	An explanation of how the shadow investigation is supposed to be an opportunity for students to apply their scientific model of how we see.
	Supporting Inquiry	Information about unit activities focused on scientific practices, including designing investigations, DGOA, scientific modeling, and constructing scientific explanations.	A discussion of how students are supposed to arrive at a consensus model of light by first developing their own model and then comparing their model with others.
	Using Teaching Materials	Information about using CM resources, including the teacher's guide and student activity sheets.	Pointing out why activity sheets used late in the unit are designed to have students draw their own data tables.
Practitioner Knowledge		Information shared by participating teachers on topics related to using the CMs.	Descriptions of how to facilitate consensus-building discussions.

Appendix 3.2: Professional Development Strategies

Strategy	Operational Definition	Enactment Example
Sharing Workshop Plans	Facilitators (Fs) describe and explain workshop plans.	F explains changes to session's agenda due to time constraints.
Facilitator-Led Discussion	Verbal exchanges that are mostly characterized by Fs asking questions for Ts to answer.	F asking Ts questions to activate their prior knowledge of the particle model of matter.
Teacher-Led Discussion	Verbal exchanges that are mostly characterized by Ts asking each other questions.	T sharing video of discussion occurring in her classroom.
Examining Student Work	Ts examine and discuss student work samples from unit activities.	F presents a series of slides showing students' models of how odors travel across a room.
Assessing Student Work	Ts examine and assess student work samples from unit activities.	Ts assess student models of how we see.
Presenting Information	Fs presenting information directly to teachers.	Fs summarizing the misconceptions about light typically held by students.
Teachers Using Curriculum Materials	Ts using materials as teachers.	Ts use CMs to plan and investigation activity.
Reflecting on Peer Enactment	Ts examine and discuss peer enactment	Ts watch and discuss video recordings of a classroom discussion.
Teachers Acting as Students	Ts completing activities as Ss.	Ts collecting data on how light reflects off a mirror.
Model Teaching	Fs enacting unit activities in a manner that represents how Ts might use the CMs.	Fs facilitating a discussion with the Ts as called for in the unit's Teacher's Guide.

Appendix 3.3: IQWST PD Summer Institute 2006

	Monday	Tuesday	Wednesday	Thursday	Friday
9:00 – 9:30	Welcome Introductions	Welcome Announcements	Welcome Announcements	Welcome Announcements	Welcome Announcements
9:30 – 10:00	Anchoring Activity	Physics Learning Set 1 Building Scientific Models and Applying Them Facilitating Consensus-Building Discussions	Physics Learning Set 2 Using Data Facilitating Synthesizing Discussions	Physics Learning Set 3 Assessment in the Physics Unit	IQWST Logistics Overview
10:00 – 10:30	Creating Driving Question Board				Discussion: What do you need going forward?
10:30 – 11:00	IQWST Curriculum Overview				How do the IQWST units fit together?
11:00 – 11:30					
11:30 – 12:00					Feedback / Evaluation
12:00 – 12:30	Lunch	Lunch	Lunch	Lunch	Lunch
12:30 – 1:00					
1:00 – 1:30	IQWST Learning Goals	Introduction to the Chemistry Unit Using Scientific Models in Chemistry	Introduction to the Earth Science Unit Designing Investigations in Earth Science	Introduction to the Biology Unit Constructing Scientific Explanations in Biology	
1:30 – 2:00					
2:00 – 2:30	Using IQWST Materials: Reader Educative Features				
2:30 – 3:00					
3:00 – 3:30					
3:30 – 4:00					
4:00 – 4:30	Feedback / Evaluation	Feedback / Evaluation	Feedback / Evaluation	Feedback / Evaluation	

Appendix 3.4: Transcript of Day 2 AM: Physics

Clip: LS 1 Overview

Collection: Day 2 AM > 01 Sess Ovrw
Time: 0:00:59.9 - 0:03:11.2 (**Length:** 0:02:11.3)
Episode Transcript: Day 2 AM T1 E1
Clip Transcript:

TITLE OF SLIDE: Learning Set 1

F1: Provides an overview of learning set 1. Kids use light boxes to determine 4 characteristics that allow us to see.

Lesson 3, 4, 5.
Shows Ts the light sensor. Eyes are similar to
Reads Learning goals, and science practice.
Previews debriefing.
Clip Keywords:
Curricular Knowledge : CurrK.Teaching.Lesson Sequencing
PD Strategies : PDStrategy.Presenting Information

Clip: What lessons skipped

Collection: Day 2 AM > 01 Sess Ovrw
Time: 0:03:11.2 - 0:04:16.1 (**Length:** 0:01:04.8)
Episode Transcript: Day 2 AM T1 E1
Clip Transcript:
F2 takes over session.

Explains that we can't do every activity.
Our guide for what to include: What are core activities that Ts need to see?

We're skipping lesson 2.

Now let's move into Lesson 3...

Where we're creating models, a unique feature of IQWST Units.
Clip Keywords:
Curricular Knowledge : CurrK.Teaching.Lesson Sequencing
PD Strategies : PDStrategy.Presenting Information

Clip: Lesson 2 SMK Recap

Collection: Day 2 AM > 02 Lesson 3
Time: 0:04:16.1 - 0:06:07.3 (**Length:** 0:01:51.2)
Episode Transcript: Day 2 AM T1 E1
Clip Transcript:
What are the things we need in order for to see an object? (Uses overhead summary and light box.)

Need:
1. Light
2. An Object
3. An Eye
4. An unblocked path. (evidence: effect of dividers)

(Reviews evidence for each element.)

Summarizes lesson 2

Clip Keywords:
PD Strategies : PDStrategy.ModelTchg.Facilitating Discussions
SMK : SMK.Physics.Light Behavior

Clip: Connecting to DQB

Collection: Day 2 AM > 02 Lesson 3
Time: 0:06:07.3 - 0:06:17.6 (**Length:** 0:00:10.3)
Episode Transcript: Day 2 AM T1 E1
Clip Transcript:
Points to overhead containing driving question and sub-questions for unit.

We're in first quadrant: How does light help us see? That's what we're working on today.

Clip Keywords:
Curricular Knowledge : CurrK.Unit Context or DQ
PD Strategies : PDStrategy.ModelTchg.Facilitating Discussions

Clip: What is a Model?

Collection: Day 2 AM > 02 Lesson 3
Time: 0:06:17.6 - 0:08:11.7 (**Length:** 0:01:54.0)
Episode Transcript: Day 2 AM T1 E1
Clip Transcript:

Today, we're going to be building a model.
What is a model?
We're going to create some different models.

T: Physical representation
T: Pictures
T: Globe

There can be different models of the same thing.
Clip Keywords:
Curricular Knowledge : CurrK.Inquiry.Scientific Modeling
PD Strategies : PDStrategy.ModelTchg.Facilitating Discussions

Clip: Circle - Rays Model of Sun

Collection: Day 2 AM > 02 Lesson 3
Time: 0:08:11.7 - 0:11:38.9 (**Length:** 0:03:27.2)
Episode Transcript: Day 2 AM T1 E1
Clip Transcript:

(Starts discussion with blank transparency)

F2: What is the one of the most basic or common ways that you see light represented, you probably seen this (assuming you're sixth graders again) in elementary school, what are some ways that you might have seen the sun represented?

What are some ways that we've seen the sun represented?

Teachers: A circle with lines or rays coming from the circle.

Facilitator draws circle on transparency.

F2: Okay, we have our sun. And you say we need what coming out of it?

Ts: Rays.

Facilitator also draws a house and a tree...

F2: Okay, here is a very simple drawing. Are there ways you can think of this drawing as a model? What could this drawing help us do or understand?

T: How the sun shines on the trees.

F2: Now how does that help you? How does this model tell you that the sun is shining on the trees?

T: Because the lines that you have there tell me that the sun is shining near the trees.

F2: Are there other things that this model tells you about how the sun is shining?

T: It says that the sun is above the trees.

F2: So it says something about the sun's location.

How can this model understand how the sun is shining?

Draws sun as a ball with rays emanating out from ball.

How does this model of the sun help us understand how the sun shines?
T: Rays

Ts: The sun is shining,

Are there limitations of this model?

Ts: Earth sun distance,
T: Relative motion between earth and sun.

Which way is light traveling in this model?

Are there ways to improve the model to show motion?

T: Add arrows...
Clip Keywords:
Curricular Knowledge : CurrK.Inquiry.Scientific Modeling
PD Strategies : PDStrategy.ModelTchg.Facilitating Discussions

Clip: Est Limitations of 2D Light Model

Collection: Day 2 AM > 02 Lesson 3
Time: 0:11:38.9 - 0:14:36.4 (**Length:** 0:02:57.6)
Episode Transcript: Day 2 AM T1 E1
Clip Transcript:
F2 represents sunlight on transparency as a circle with toy cars facing out in all directions from it center.

What do the cars allow us to do? What do cars do?

Ts: Allows us to represent that light is moving.

How do we do this?

Ts: We can update the representation to show motion.

T: Are we supposed to be looking this model in two or three dimensions?

F2 asks why that matters, and prompts for changes in the model if we were to consider it in 3D. Based on prompts, he shows the need for a car that would travel vertically from the transparency.

F2: A limitation of this model is that it is a 2D picture. Are there other limitations?

T: Right now, it seems that light comes in little chunks.

So we have different representations of light that include both rays and chunks. As sixth graders at this point, do we know which one light is?

This might be an area that our model can improve upon later.

As physics teachers, do we really understand this?

So our model at this point has some limitations. '

Clip Keywords:

Curricular Knowledge : CurrK.Inquiry.Scientific Modeling

PD Strategies : PDStrategy.ModelTchg.Facilitating Discussions

---

Clip: More limitations of naive mdl

Collection: Day 2 AM > 02 Lesson 3

Time: 0:14:36.4 - 0:15:40.0 (**Length:** 0:01:03.6)

Episode Transcript: Day 2 AM T1 E1

Clip Transcript:

F2: In this lesson, you're going to get a chance to build your own three-dimensional model of how we see.

What limitations does this model have for explaining how we see objects?

F2 returns to poster showing the essential elements of a model of how we see and points out that our model of the sun does not have three of the four necessary elements, but instead only has one: light.

So we're missing some things in the model, so as you're building your model, you should be asking whether it represents all four things that are required.

Clip Keywords:

Curricular Knowledge : CurrK.Inquiry.Scientific Modeling

PD Strategies : PDStrategy.ModelTchg.Facilitating Discussions

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Clip: F2 explains model building act

Collection: Day 2 AM > 02 Lesson 3

Time: 0:15:40.0 - 0:17:29.1 (**Length:** 0:01:49.1)

Episode Transcript: Day 2 AM T1 E1

Clip Transcript:

Moving into teacher mode: In reality, Ss work over 3 days in groups of 4 to construct their models.

You will only have 15 minutes to build your models. I bought building materials at the dollar store.

Describes materials that can be used.

Clip Keywords:

Curricular Knowledge : CurrK.Teaching.Use of Resources

PD Strategies : PDStrategy.ModelTchg.Facilitating Investigations

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Clip: Ts develop 3D Light Models

Collection: Day 2 AM > 02 Lesson 3
Time: 0:17:29.1 - 0:25:19.9 (**Length:** 0:07:50.7)
Episode Transcript: Day 2 AM T1 E1
Clip Transcript:
Ts begin working on 3 D Models

F2 moves between groups, asks T about elements of his model: So this is the object?...

F2, F1, etc walk between the groups and ask clarifying questions: Do you have an object? ....

Asks how we see the bear... In order for us to the see the bear, ...
Clip Keywords:
Curricular Knowledge : CurrK.Inquiry.Scientific Modeling
PD Strategies : PDStrategy.Teachers as students

Clip: Ts constr 3D Mdls

Collection: Day 2 AM > 02 Lesson 3
Time: 0:00:00.0 - 0:04:11.8 (**Length:** 0:04:11.8)
Episode Transcript: DY2T1E2
Clip Transcript:

F2: Trace the path of light from here to here that allows this person to see the bear. Finish up in about two minutes...
Clip Keywords:
Curricular Knowledge : CurrK.Teaching.Use of Resources
PD Strategies : PDStrategy.Tchrs Using CMs

Clip: F2 Expl 3D --> 2D Transition

Collection: Day 2 AM > 02 Lesson 3
Time: 0:04:11.8 - 0:07:29.6 (**Length:** 0:03:17.8)
Episode Transcript: DY2T1E2
Clip Transcript:
F2: At this point, it would be really good if the different student groups had a chance to explain to each other what they did.

Students would share how their model explains the different aspects of how we see.

We're skipping this.

To examine modeling, we need common language.

Problems with models include that they contain different things, and its 3d nature is inconvenient.

We will now move back to a 2d model.

Introduce icons: eye, chicken, light source,

F2: Take a look at your 3d model that you built and represent it with the provided icons.

Take 3 minutes to translate your 3d model into a 2d model using the icons. Ts should use glue sticks to fix icons to large piece of paper.

F2 circulates between groups. He asks one group about meaning of arrows that they have drawn. What does direction of arrow tell us?

F2: Each group should post their 2d model on the front board.
Clip Keywords:
Curricular Knowledge : CurrK.Teaching.Use of Resources
PD Strategies : PDStrategy.Presenting Information

Clip: Ts create 2D Models

Collection: Day 2 AM > 02 Lesson 3
Time: 0:07:29.6 - 0:11:19.1 (**Length:** 0:03:49.5)
Episode Transcript: DY2T1E2
Clip Transcript:
Teachers work on 2D Models in Groups

F2 moves around between groups to ask how Ts are translating between models.
Clip Keywords:
Curricular Knowledge : CurrK.Teaching.Use of Resources
PD Strategies : PDStrategy.Tchrs Using CMs

Clip: F2 leads 2D Model Comparison

Collection: Day 2 AM > 02 Lesson 3
Time: 0:11:19.1 - 0:17:13.1 (**Length:** 0:05:54.0)
Episode Transcript: DY2T1E2
Clip Transcript:
Though we have converted our 3d models in to 2d models, we still have four models that all have different ideas.

Can we briefly share our models with each other?

Now lets go to the next model. Is this yours?

Are there differences between these two models? Are there things in each model that help us understand some aspect of how we see?

T from Group 1: We have the sun as our light source two objects, and two eyes at the bottom.

The eye on the left can see both objects clearly. The eye on the right can only see the chicken on the left because the chicken that is right in front of him is blocked by a tree.

T2: The teacher did not ask for all that now... (laughter).

T fr Group 2: Our chicken is DEAD. (represented on poster as an upside-down chicken) That's the sun, coming to sun, and then coming to an eye.

So you're saying that distance could be a factor...

T: One line is solid and the other is dotted.

T: The first model has the tree and two men.

T: According to this model, the path of the light will be different depending on the locations of the object, etc.

The second model has light coming from sun and hitting the object, and then going to the eye, while in the first model, the light goes from the sun directly into both eyes.

Is there anything that the first model helps us see that the second model does not have?

So the first model has the advantage of allowing us to see not only why we might see an object but also why we might not see an object.

Clip Keywords:
Curricular Knowledge : CurrK.Teaching.Disc.Consensus
PD Strategies : PDStrategy.ModelTchg.Facilitating Discussions

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Clip: F2 models consensus discussion

Collection: Day 2 AM > 02 Lesson 3
Time: 0:17:13.1 - 0:24:32.9 (**Length:** 0:07:19.8)
Episode Transcript: DY2T1E2
Clip Transcript:

What we are going to try to see now is what we call a "consensus" model.

Can anyone tell us what the word "consensus" might mean?

T: Everybody has to agree on it.

Good. And where will we get what goes on our consensus model?

Does anyone have any suggestions?

T: Light source is most important.
T: Yes
T: An eye

Rays are leaving light source. We represented this differently in our models.

Is showing that rays are leaving the source in all directions important to include?

What else do we need?

Reviews location of eye in all models and asks where we should put it.

It is not as important where the eye is placed as it is that there is an unobstructed path between the eye and the chicken (object). So we can really put it anywhere.

T: So if you put the eye between the sun and the chicken, it seems like the light would be blocked by my head and I would not be able to see the chicken. Since I can see the chicken, there must be light coming from somewhere else and hitting the chicken.

T: I don't agree with the idea that that a consensus model can only contain what was in our previous models because part of development a consensus is building a better understanding...

It sounds like we are now getting in to areas of transparent and opaque objects, which is later in unit.

If our consensus model is to only contain things that were in our original model, can we agree about what is in the model at this point?

T: So I can live with it where it is... but if I'm a kid whose attached to my idea strongly then I would insist that the consensus model has to allow for my idea to be true.

T2: So what would you include?

T: I would have more rays of light hitting the chicken so that if some of the rays are blocked, I can still see the chicken.

Whoa whoa... right.

T: Right now, instead of showing many light rays coming from the sun or many light rays coming from the chicken, our model has one line to the chicken and one line to the eye. The eye can go almost anywhere based on what we see there (in the consensus model poster)...

T2: So you would expect a model to look like the sun more...

Thanks good. So one of the issues that (F1) is supposed to discuss in the debrief is that there are many issues that arise from this distinction between 2 and 3 D models.

T: Can I just say one thing... You have to be determined to stay in line with what we're trying to do... the steps we have there (consensus model). Our 1, 2, 3, and 4.

At this point, just because I have committed to (F1) to be done by 9:50, we're going to wrap that up. (Points to consensus model poster) In terms of this, what I'm hearing is this (draws line from chicken to eye). That there may be some additional ideas that we need to discuss in terms of our consensus model.

This is not a fifteen minute discussion you can have with students, it is much longer. But it's all we had time for.

All Ts: Yes

T(c): An you can always tell them: This is our consensus model in the beginning, but we can always change it. So are we comfortable with just the basic part of what we know now but later we might know more and we can add in Gretchen's idea and maybe this idea... but right now we need a basic understanding. And that satisfies them.

And does our consensus model contain these four things?

T(g): I just want to be clear that number 4 ("An unblocked path") is an unblocked path between the object and the eye, not between the light source and the eye.

T: But it is an unblocked path (on the model) between the ....

T(c) But we'll get to that... just like you know what's ahead in the chemistry unit, I know what is coming up in this unit. We get to that. When you know what's coming, you'll be able to deflect that question... we just need the basic model at first.

T(g): I would do it differently. Instead of saying "wait for another two days or whatever"... I would ...

Other Ts say no... we need to stick with what we have up there.
Clip Keywords:
Curricular Knowledge : CurrK.Teaching.Disc.Consensus
PD Strategies : PDStrategy.ModelTchg.Facilitating Discussions