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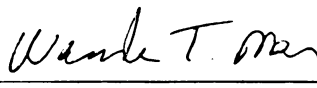
THE ROLE OF A TEACHER STUDY GROUP IN NEGOTIATING
CONSTRUCTIVIST SCIENCE TEACHING IN AN ELEMENTARY
SCHOOL

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Ellen Louise Schiller

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Ph.D. degree in Education


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**THE ROLE OF A TEACHER STUDY GROUP IN
NEGOTIATING CONSTRUCTIVIST SCIENCE TEACHING
IN AN ELEMENTARY SCHOOL**

VOLUME I

By

Ellen Louise Schiller

A DISSERTATION

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

DOCTOR OF PHILOSOPHY

Department of Teacher Education

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ABSTRACT

THE ROLE OF A TEACHER STUDY GROUP IN NEGOTIATING CONSTRUCTIVIST SCIENCE TEACHING IN AN ELEMENTARY SCHOOL

By

Ellen Louise Schiller

This study arose from the frustrations expressed by elementary teachers in a mid-size, urban school district who were involved in implementing a new district-wide science curriculum. The new curriculum was designed to meet the recommendations for constructivist teaching espoused in the current science education reform movement. As a fifth-grade teacher in the district as well, as a member of the science curriculum committee that wrote the new curriculum, I was in the position to hear the frustrations vented by fellow teachers as they struggled to make the shift from a loosely-supervised, textbook-based curriculum to one which emphasized hands-on instruction through four in-depth units at each grade level.

In response to teachers' frustrations, I conducted an action-research study designed to provide a sustained, personalized, professional development opportunity for a group of elementary teachers in the building in which I taught. The study group of five teachers met during the course of the 1996-97 school year to work on familiarizing ourselves with the tenets of constructivist science teaching and learning and incorporating this type of teaching into our own practice. Activities engaged in included: reading relevant literature, viewing

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videotapes of teachers practicing constructivist science teaching, attending physics workshops, working with the intermediate school-district science consultant, and videotaping our own science lessons for the purposes of sharing with the other group members and studying our practice. During the year, I conducted individual interviews with the teacher participants and audiotaped all group meetings in an effort to learn if this experience held value as a means of helping the group members become more constructivist science teachers.

During the year, it became clear that the teachers continued to face many obstacles as they worked to improve their science teaching. While the participants felt they made progress and all agreed that the initiative was of much value, the teachers also felt that they needed to meet more frequently and for a longer period of time. As the study group was a relatively intensive effort compared to one-time workshops, it illustrated the need for ongoing professional development and district support responsive to teachers' needs.

The teachers also valued the study group for the support and collegiality it provided them. It became a means of breaking through the isolation that the teachers felt as they went about their day-to-day business as the only adult within the four walls of their classrooms. The study group created a non-threatening forum for reflection, support, and sharing as each teacher learned she not alone in the struggles and challenges they experienced in negotiating constructivism and the new science curriculum.

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ELLEN LOUISE SCHILLER
2000

To My Parents
who have always believed in me

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ACKNOWLEDGMENTS

I have been fortunate in my life in that I have rarely heard the phrase, “You can’t do that.” spoken in my direction. Unfortunately, this also means that I have a tendency to take on too much. I would not be where I am today without the support and assistance of the many people I have leaned on to help me.

Each of the members of my dissertation committee has served as a role model for learning that is both inspirational and intimidating. My chair, Wanda May, has been my principal advisor since I began my doctoral program eight years ago. Not only has she been instrumental in the preparation and revision of this dissertation, she has also provided both the nurturing and the nudging I’ve needed all through the course of my studies. I have learned so much about teaching and about myself through our conversations.

Andy Anderson has contributed much to my understandings in the field of science education and was especially helpful during the analysis phase of this dissertation. Janet Alleman and Lynn Paine have both been role models for their teaching as well as their learning. In my own graduate-level teaching over the past two summers, I used Jan’s idea for inviting kids to the classroom, and Lynn’s model of equity by placing my name alphabetically within the class address/phone list and sitting in various spots around the circle of students’ seats.

The past eight years have been extremely busy, to say the least. I have continued to teach full-time for most of that period, commuting an hour and a half

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to classes at the end of a busy school day. My husband and I started and completed our family, getting more than we bargained for when both children arrived prematurely and required extended hospital stays and “high maintenance” follow-up care the first couple months. I have sometimes felt that I’m holding down three full-time jobs: teacher, mother, and doctoral student. I know that I haven’t always been as good as I wanted to be in each of these jobs, but I also know that I’d never have been able to try so much were it not for the fact that I have such a supportive, extended family.

Thank goodness my kids are fun to be around! Many relatives have helped with child-care when I had to attend classes, write a paper, attend conferences, or work on my dissertation. My sister and brother-in-law, Laura Swart-Hills and Mark Hills, my in-laws, Jan and Dominic Schiller, and my sister-in-law, Tammi Modderman, have all provided loving, surrogate care when we needed help. My mom has been the most helpful of all. I literally would not have been able to complete this program as a mother of young children, were it not for her. She has been there whenever the kids needed her (in sickness and in health). I owe a huge debt of gratitude to my parents, Jim and Edie Swart, for their incredible support over the years.

Finally, I’d like to thank my husband, Jeff, who has gone along with all of this with barely a whimper. Jeff is a wonderful, loving father to Erica and Ryan and is an equal partner in caring for them. His love, his respect, his sense of humor, (and his computer skills) helped me cope with all the stress.

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CHAPTER ONE

Introduction to the Study

Problem Statement

Historically, science has taken a back seat to other subjects in the elementary curriculum. Not only is it taught less often than reading and math, it is often taught in ways that do not contribute to meaningful learning. The poor achievement of American students on standardized science tests has been unfavorably compared to the higher scores achieved by students from many foreign countries. The 1990 National Assessment of Educational Progress found that 28 percent of the fourth-grade students tested had science less than once a week or were never taught science, while less than half of the students reported having science instruction every day. Less time was spent on science instruction than on other core curriculum subjects (Jones, Mullis, Raizen, Weiss, & Weston, 1992).

Weiss (1987) found that teachers rely heavily on textbooks in grades four through six, with textbooks accounting for 90% of the instructional materials used. Science instruction typically focuses on factual information (Bybee, Buchwald, Crissman, Heil, Kuerbis, Matsumoto, & McInerney, 1989). Little time is spent connecting children's experiences to concept development. Raizen and Michelsohn (1994) state:

Few opportunities exist for exploration and discovery, for developing analytical skills, or for relating science to other disciplines to foster an integrated understanding of the world. As a result, many students

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receive a poor introduction to science in the early grades, a situation compounded in later grades when students elect not to take additional science courses. (p. 2)

Raizen and Michelsohn (1994) go on to discuss several “interrelated” reasons for the predominance of poor, infrequent, elementary science teaching:

- Reading and basic arithmetic skills dominate the curriculum.
- Teachers do not understand the potential for language and mathematics development through science.
- Teachers are poorly prepared in science and do not feel comfortable teaching it.
- Teachers believe that science consists of a body of facts and do not understand the nature of science as a way of knowing.
- Administrative support for science is largely absent at this level. (p. 2)

The aspects of poor science instruction briefly described here may partially explain the poor scores achieved by many American children on standardized science tests. The International Association for the Evaluation of Educational Achievement (Mullis & Jenkins, 1988) reported that American ten-year olds ranked fifth among fifteen nations on science testing conducted in 1986. More recent testing done with thirteen-year olds ranks American students thirteenth out of 15 countries (Lapointe, Askew, & Mead, 1992).

Equally disturbing are the scoring gaps demonstrated between the genders and between various racial groups within the United States. The 1990 NAEP data (Jones, et al., 1992) show that fourth-grade males score slightly higher than girls on earth and space science tests, and this gap increases on up through the grades. There is also an alarming disparity between the scores obtained by Whites and non-Asian minorities: White students score 30-40 points

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higher than non-Asian minorities on a 500-point scale. Large score differentials were also shown to exist between socioeconomically advantaged and disadvantaged students.

The New Science Reform Movement

Given the documented nature and repercussions of elementary science teaching, it is no wonder that efforts have been initiated in the past decade to address the issue of improving science education for students. The 1980s saw the birth of a significant reform movement in science education. Much as Sputnik sparked educational reforms in science during the 1960s, business and industry leaders have voiced concerns about the ill-preparedness of today's employees to handle an increasingly technological and scientifically-advanced workplace. Workers must feel comfortable operating the sophisticated computers, equipment, and machinery that we now rely on, and many must be prepared to troubleshoot and solve problems when these devices fail to work properly. Students who have had little or no opportunity to work with scientific equipment, computer systems, and hands-on activities involving independent thinking and problem solving will be unprepared to enter most professional fields as well as the skilled labor market. Since the workplace is apt to become more complex as time goes on, these concerns have merit.

The difference between the reforms of the 1960s and today's lies in the fact that today's national reformers, such as the American Association for the Advancement of Science (AAAS), the National Research Council, and the National Council of Teachers of Mathematics (NCTM) advocate science literacy

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for *all*, not just an upper echelon of students who may someday become scientists and leaders within the scientific community (Loucks-Horsley, Kapitan, Carlson, Kuerbis, Clark, Nelle, Sachse & Walton, 1990).

Students need opportunities to engage in the same learning processes scientists engage in: reflecting on their prior knowledge, posing questions and hypotheses, working hands-on with peers to investigate these questions and hypotheses, and developing new understandings and conclusions as a result of this work. Most educators now agree that this is the process through which learning occurs. Students do not enter school as empty slates; they bring a myriad of prior experiences and understandings to the classroom, and will mediate what they learn in school through these preexisting conceptions. Engaging science experiences are intrinsically valuable for their potential to teach children *how* to think and learn, not just *what* to think and learn.

Transformation of a Science Curriculum

Proposals for conceptual, constructivist teaching presented by the National Council of Teachers of Mathematics and the American Association for the Advancement of Science have filtered down to state and local school systems, and have been interpreted in as many ways as there are classrooms. The Michigan Essential Goals and Objectives for Science Education (MEGOSE) document (1991) was developed at the state level to guide school districts in updating their science programs to meet the new national reform initiatives. The document conveys the substance of the national-level, science education reform movement and also identifies 216 learning objectives in the categories of Life

Science, Earth and Space Science, Physical Science, Constructing Scientific Knowledge, and Reflecting on Scientific Knowledge.

Ojibway Public Schools, a mid-size urban school district, spent three years developing a new K-12 science curriculum designed to meet the new state standards. The science curriculum committee was the only combined, elementary and secondary curriculum committee within the district, and it strove to coordinate the new curriculum vertically through all the grade levels. The committee worked closely with the MEGOSE document, determining how and when each of the 216 objectives would be taught in the scope and sequence of the curriculum. The new curriculum veered away from the loosely supervised, textbook-based program that was in place, and instead focused on hands-on, in-depth instruction encompassing four units at each elementary grade level. As a fifth-grade teacher in the district and also a member of this science curriculum committee, I was deeply involved in both the development and subsequent teaching of the new curriculum.

Prior to the adoption of the new Ojibway Public Schools' science curriculum in the fall of 1995, the district had not had a written science curriculum for the elementary grades. The Silver-Burdett (1987) science textbook series served as the curriculum. As will be described in more detail in Chapter 4, each grade-level book in the series discussed a wide range of topics, with one or two chapters devoted to each topic. Each year the textbooks "covered" many of the same general topics: plants, animals, weather, etc. The level of detail increased with each grade. Accompanying the text were reproducible worksheets and end-

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of-chapter tests. Each chapter generally contained one or two hands-on activities, but the materials kits had fallen into a state of disrepair after several years, and the commitment to funding consumable materials varied from building to building.

The new curriculum was designed to focus on “depth, not breadth” and thus consisted of four units at each grade level. Limiting the units to four per year allowed greater depth in instruction. Units of study varied in successive grades. For example, the students now studied plants in depth at only two grade levels in the elementary school instead of briefly at each grade level. The intention was to move away from a superficial “coverage” of many topics. By spending approximately nine weeks each on only four units per year, the curriculum committee hoped that students would have the opportunity to delve more deeply into each unit of study, thereby engaging in more thought-provoking experiences and developing deeper understandings of scientific concepts.

As the science curriculum committee worked to design the new curriculum, one source the members used to guide their work was the book, *Elementary School Science for the '90s* (Loucks-Horsley, Kapitan, Carlson, Kuerbis, Clark, Nelle, Sachse, & Walton, 1990). This book advocates a constructivist approach to science teaching and learning, as described in the following excerpt:

During constructivist learning, students have the opportunity to verbalize, test, modify, and even abandon their pre-existing ideas and adopt new ones. Through learning tasks keyed to their developmental levels, students have the chance to make sense of the world by actively constructing meaning out of natural phenomena and their everyday experiences. (p. 47)

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The authors proposed a four-step, teaching and learning model based on constructivism. As students passed through these four steps, they would:

- Accept an invitation to learn;
- Explore, discover, and create;
- Propose explanations and solutions, and;
- Take action on what they learned. (p. 59)

While other models also fall into the realm of constructivist science teaching, such as radical constructivism (van Glaserfeld, 1994) and the learning cycle (Jones, 1994; Lawson, Abraham, & Renner, 1989), the four-stage model of constructivism highlighted above was the guiding influence for most of the individual units designed by the curriculum committee. Each of these stages and the ways in which they were interpreted by the science curriculum committee will now be discussed in further detail.

Accept an Invitation to Learn

Each one of the units created by the curriculum committee included an introductory activity designed to engage the learners' interest. These introductory activities varied in nature. Some were based on the conceptual change model (Anderson & E. Smith, 1987; D. Smith & Neale, 1991) and designed to probe the students' current conceptual understandings in preparation for the present unit of study. Students' responses to pre-assessment questions would help the teacher determine an appropriate course of study and the nature of the activities and lessons to be taught from a unit plan that presented many

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options. From a unit binder, the teacher could select the lessons and activities she or he felt would best contribute to the current class's needs.

Other introductions were derived from Madeline Hunter's (1982) Instructional Theory Into Practice (ITIP) model. These "anticipatory sets" were designed to engage the learner through an exciting, interesting presentation that would hopefully reel in the learner and make the student curious to hear and do more.

Falling somewhere in between these two types of invitations to learn were activities which probed the whole class's prior knowledge, but which were not intended to play a large role in determining subsequent instruction. These were activities with which the teachers were already familiar from the district's previous work in improving informational-text reading instruction. The KWL chart and the Anticipation Guide were examples of this type of unit introduction. A KWL chart has three columns, with the headings "What We Know," "What We Want to Know," and "What We Learned." The whole group fills out the first two columns at the beginning of a unit and returns to fill in the third column at the completion of the unit. An Anticipation Guide lists several true or false questions related to the proposed unit of study or individual lesson, which students respond to and discuss. For example, a question related to a unit on photosynthesis might say, "Plants get the energy they need from plant food." The follow-up unit's activities would be designed to help the students develop an understanding of how and why this statement is false.

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The inclusion of an invitation to learn in each unit was based on the constructivist notion that students must be personally engaged in order for learning to occur. The invitations ran the gamut from simply intriguing the learner to garnering specific information regarding students' personal hypotheses and misconceptions, which would play a role in determining the instructional activities the teacher selected for subsequent lessons. In my opinion, the best invitations combined a probe of students' current understandings with an intriguing unit kick-off. These invitations motivated the class and also gave the teacher valuable information for planning purposes.

Explore, Discover, and Create

A major goal of Ojibway's new science curriculum was to give children the opportunity to have a wealth of hands-on science experiences. Students had not had much opportunity to engage in hands-on activities with the Silver-Burdett textbook, and the committee realized that this was something that needed to change. All of the new units heavily relied on experiments and other experiences with manipulatives. The new curriculum was designed so that students would be active participants in learning. Although the textbook and other reading materials were still used, they now constituted only one resource amongst many. Students were expected to construct their own knowledge through the activities, discussions, and readings they experienced.

Students also were involved collaboratively with their peers as they learned. The Silver-Burdett textbook instruction centered on individual learning tasks such as reading, completing worksheets, and taking tests. Teachers also

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led whole-class discussions, lectures, and few hands-on activities. While teachers and students still engaged in some of these activities, the new curriculum stressed cooperative group investigations. Most of the investigations involved students working in small groups of about four students, making observations, recording data, discussing their work, manipulating materials, etc. The teachers' role was to guide students through these learning activities by posing questions and alternative ideas, helping with materials and methodology, and facilitating positive group dynamics.

Propose Explanations and Solutions

The Silver-Burdett textbook series presented facts. It did little to promote student thinking. In contrast, the new curriculum asked students and teachers to propose explanations for what they observed during experiments, and to suggest solutions for problems and challenges they encountered. These tasks were demanding and placed new requirements on students and teachers.

Students had to feel comfortable taking risks. Learning was no longer passive; the new curriculum required that students be active risk-takers as they openly discussed their observations, data, and conjectures. They had to feel comfortable speaking out in both small and large groups as they expressed and sometimes defended their explanations and solutions. This was a new experience for many students, one that demanded active engagement and deep thinking, and the willingness to share ideas with others.

Actively involving students in proposing explanations and solutions required different abilities from teachers as well. They could no longer rely on

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the textbook or themselves as the sole authorities. Students' ideas were important, but the teachers had to have an understanding of the scientific concepts themselves that would allow them to skillfully guide students toward meaningful understandings as they worked through each lesson and unit.

Taking Action on What They Learned

Most of the units, especially at the upper elementary grades, required students to do something with what they had learned or to make further connections to their own world. For example, in a fifth-grade unit on ecosystems, students spent several weeks building aquariums and terrariums, and studying the plant and animal life within them. They read about the various life forms living in the ecosystems and made observations of their growth (and often death) and activities. They learned how the living members of an ecosystem rely on non-living objects as well as each other. At the end of the unit, the students added fertilizer, road salt, and chemicals simulating acid rain to some of their ecosystems and compared their observations with what they saw happening in their control habitats. In applying what they observed to their real world, the students discussed what they could do to minimize the environmental damage these chemicals cause. For example, they could encourage adults to stop using chemical fertilizers on their own lawns and using road salt on their driveways and walks. The students themselves could write letters to governmental agencies advocating for environmental responsibility.

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A Vision of Constructivist Science Teaching

The *National Science Education Standards* (1996) states that scientific inquiry “refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work.” (p.23):

Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world.

Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. (p. 23)

This vision of scientific inquiry was a far cry from the Silver-Burdett textbook series, which was written before the MEGOSE objectives or the national standards were published.

In painting a portrait of what constructivist science teaching looks like, Anderson (1991) describes how two experienced teachers differed in their instructional methodologies as they each taught a unit about plants. “Mrs. Copeland” engaged her seventh graders in an opening discussion of photosynthesis. Rather than lecture, Mrs. Copeland planned for her students to dominate the discussion with their conjectures, theories, and questions. He contrasts this with the teaching of “Mr. Barnes,” who conducted the same lesson by passing along accurate information to his students through the lecture method. Mrs. Copeland’s students were more engaged and achieved higher scores than Mr. Barnes’ class on a unit post-test.

Anderson (1991) states that there is a growing body of empirical evidence showing that students exposed to constructivist teaching do not just learn *differently*, they learn *more*. In discussing how most teachers are not prepared at the preservice level to teach this way, he states, "Mrs. Copeland was able to overcome these difficulties and construct in her classroom a rich and meaningful representation of the scientific enterprise. Most teachers, unfortunately, are not" (p. 20).

It appears that many elementary teachers are unprepared to teach science in conceptual, constructivist ways. Nonetheless, Mrs. Copeland and others like her somehow find a way to develop this type of teaching within their own classrooms. Anderson states that "successful teaching requires a lot of knowledge about social arrangements in classrooms, about pedagogy, about science and about students" (p. 24). Interviews with Mrs. Copeland revealed that she had developed these characteristics based upon her own classroom teaching experience, apart from formal teacher's guides and training programs.

What Constructivist Science Teachers Need to Be Able to Do

Constructivist science teaching is hard to do. It demands a paradigm shift away from the "delivery" model of instruction, which dominated most of my own schooling, to a model in which learners construct their own meaning as a mediation of their prior conceptions and new understandings. Most teachers have spent years upon years in schools as learners and instructors in traditional settings. Traditional teaching is comfortable and relatively easy for most of the teachers I know. Textbook usage allows teachers to follow prescribed steps with

little thought, input, or reflection. The materials, such as books and reproducible worksheets, are accessible and easy to use. Assessments are “objective” and easy to grade.

Constructivist teaching is hard work. It requires the mind to be constantly engaged. It taxes our intellectual resources as well as our ration of time. Planning, teaching, assessment, and reflection are all more demanding. Materials often have to be gathered or ordered and require set-up and clean-up time. Students are noisier and more active. The teachers must share “control” with the students. This type of teaching is not easy, and neither is this type of learning.

When one of the Ojibway teachers set out to plan a science lesson using the Silver-Burdett textbook, she or he merely had to open the teacher’s manual, jot down the week’s successive pages in neat little boxes in the plan book, note any accompanying dittos and experiments or test days, and be done with it. Constructivist teaching requires much more. A teacher needs to determine what the students already know, or think they know, and plan pursuant instruction accordingly. If students are bringing a variety of previous experiences or misconceptions with them, the teacher must plan how he or she will build upon these or seek to change their thoughts. Pre-assessment and planning become much more cumbersome and time-consuming.

The teacher must also have the scientific background knowledge to identify any misconceptions students have that may undermine their understanding of the important concepts they need to learn and be able to

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design, rework, or select lessons accordingly. This background knowledge also will be vital to the teacher as he or she teaches. The ability to engage and guide students' thinking through the use of thought-provoking questions and inquiry rests on a teacher's thorough familiarity with the concepts being taught and what makes them particularly difficult for children to understand.

The constructivist teacher must be able to provide appropriate hands-on experiences for students that will give them the opportunity to explore and form questions. As students work with materials in small groups, the teacher must also know how to group students for effective collaboration, how to manage and coordinate active behavior in the classroom, and how to create a non-threatening atmosphere where students feel free to take risks, question, and share their ideas.

The constructivist teacher must be able to assess students' ongoing learning using a variety of authentic assessment strategies, such as group presentations, informal questioning, individual pre-assessments, portfolios, etc. This is much more difficult than simply running off 25 copies of the "Chapter 5 Test" at the end of a unit.

A teacher using the Silver-Burdett textbook wouldn't need to spend much time reflecting on his or her teaching. It's too hard to get through the entire book in one year as it is without making provisions for re-teaching based on a teacher's ideas for improving instruction. The materials remain the same for the next year; reflecting doesn't serve much purpose when a teacher is destined to use the same textbook the next year anyway.

Constructivist teaching demands constant reflection: before the lesson when choosing materials and questions to ask, during instruction as a teacher is required to think on her feet in conversation with students, after instruction when reflecting on the progress or difficulties students are experiencing, and when planning for teaching the unit again.

Given the demands that constructivist science teaching places on teachers, it is vital to ask how teachers will be able to learn how to practice the visions of the national reform movement. Tyack and Cuban (1995), writing about school reform over the past century and the ways in which various reform efforts have been adapted, rejected, or embraced by practitioners, note that practitioners have the ultimate control over how reforms are enacted in the classroom and school. Reformers have often neglected to include teachers as they devise their recommendations for improving education and should not be surprised by the fact that their suggestions are often adapted and rejected by teachers as they negotiate the curriculum. Just as many other reform movements over the past century have been initiated by “policy elites” outside of the K-12 classroom, the current science reform movement arose from documents such as *Science for all Americans* (1990), Project 2061’s *Benchmarks for Science Literacy* (1993), and the National Research Council’s *National Science Education Standards* (1996). Although a select number of teachers were involved in developing both the Benchmarks and the Standards documents, thousands of teachers who have been influenced by these documents were not. It is clear that many of these teachers are struggling with bringing the reformers’

vision into practice (Tobin, Briscoe, & Holman, 1990; D. Smith & Neale, 1991; Anderson, 1997), and are negotiating paths that serve their own needs and interests as well as their students'. As they struggle, we can learn from the stories of individual teachers.

The national reformers have set an ambitious agenda for improving science teaching. In order for teachers to work toward the goals of the reform agenda, teachers need opportunities to engage in the same learning processes that they are expected to guide students through. These opportunities need to be substantial enough that constructivist teaching practices become as second nature to teachers as traditional teaching methodologies have become. Elementary teachers are accustomed to working in isolation. Constructivism requires engaging in dialogue with peers, engaging in substantive, reflective, conversation about science teaching practice. Elementary teachers are accustomed to "delivery model," professional development inservices. Learning to *be* constructivist requires a contextualized, professional development experience that focuses on process, not product. This is truly an ambitious undertaking.

My experience as both a teacher within the district and member of the Science Curriculum Committee led me to believe that teachers were having difficulty interpreting the new curriculum as it was intended. While the developers of the curriculum (the teachers who were part of the Science Curriculum Committee) had spent several years acquainting themselves with the intentions of the national science reform initiatives and the state standards, the

rest of the district's elementary teachers were not provided a similar opportunity. Therefore, they could not be expected to be familiar with constructivist science teaching as it was to be practiced in the new curriculum. A pilot interview study conducted for my doctoral research practicum confirmed this belief. In general, teachers felt overwhelmed and underprepared. They communicated a desire for more support as they explored constructivist science teaching.

While the teachers interviewed were able to express general, though somewhat varied, definitions and understandings of the theory behind constructivist *learning*, they were less clear about how they might do this kind of *teaching*, as well as what it looked like in practice. Most of the district's elementary teachers were not science majors or minors in college and consequently had weak backgrounds in the disciplinary subject matter of the natural sciences and in the processes that the scientific community engages in.

The *National Science Education Standards* (1996) states that while it is realistic and appropriate for elementary teachers to be generalists, all teachers of science must be able to:

- Understand the nature of scientific inquiry, its central role in science, and how to use the skills and processes of scientific inquiry.
- Understand the fundamental facts and concepts in major science disciplines.
- Be able to make conceptual connections within and across science disciplines, as well as to mathematics, technology, and other school subjects.
- Use scientific understanding and ability when dealing with personal and societal issues. (p. 59)

The teachers I spoke with expressed feelings of inadequacy regarding the proclivities and abilities listed above. Among other needs, the interviewees all felt that some type of role modeling was necessary for them as they sought to better understand constructivist teaching and incorporate it into their practice. The idea that simply seeing a proper role model would provide great assistance in their struggle was an ironic indication of how far so many of us were from even recognizing how difficult this type of teaching was going to be. We expected the students to construct their own meaning through powerful learning experiences with their peers and a guiding teacher, but we felt that our own learning needs could be met through a delivery system of simply observing a role model and adapting what we saw.

Those responsible for directing the implementation of the new science curriculum did not seem to make accommodations for the learning needs of teachers. As will be illustrated in Chapter Four, a large discrepancy existed between the efforts spent in curriculum development and those spent on helping teachers mediate this curriculum. The administration acted as though creating a written curriculum was enough. There was very little attention given to supporting teachers as they began to interpret and negotiate the new curriculum and weave it into their classroom practice. Given the demands associated with the teaching practices advocated by national reformers, it was obvious that more needed to be done to help teachers explore and develop constructivist ways of teaching science.

Understanding the process that a small group of elementary teachers went through in negotiating the new science curriculum became the focus and conceptual framework of this study. As the teachers in our study group struggled with refining our emerging practice of constructivist science teaching, we made choices regarding our professional development needs. We negotiated the curriculum by deciding which lessons to teach, and we adapted these lessons to contexts mediated by our own teaching methodologies, time constraints, background knowledge, and instructional priorities. Each of us made decisions about which aspects of our teaching we shared with the rest of the participants. We negotiated personal interpretations of the national science reform agenda, and we struggled with what we wanted to do and what was possible to do, given the personal and organizational contexts we were working with. Along the way, we often felt overwhelmed and frustrated, but we also experienced many moments of collegiality and “success.”

Fullan (1993), speaking of what he envisions the “new work” of teachers entailing, summarizes the importance of this type of effort:

Teachers must develop the habits and skills of continuous inquiry and learning, always seeking new ideas inside and outside their own settings....Teachers must immerse themselves in the mysteries, and highs and lows of the dynamic complexity in the change process – how conflict is inevitable, how vision comes later, how individualism and collectivism co-exist in dynamic tension, how arbitrary disturbances in the environment are par for the course, how you never arrive, and how sometimes things get worse despite your best efforts. (p.81)

The negotiation process the teachers in this study went through was akin to Fullan’s description of the “new work” of teachers described above. Negotiation will be a term frequently used throughout this study to describe the process the

study group members engaged in as they investigated the tenets of constructivism and its influences on their science teaching, worked through their relationships with various science support people and other group members, interpreted the new curriculum, and struggled with the constraints and obstacles they faced in their efforts to change their practice.

Origin of the Study

As a member of the district science committee, I had a vested interest in ensuring that the spirit of the new curriculum would come into fruition in the elementary classrooms of our system. I pondered what could be done to help teachers in the Ojibway School District become more comfortable with the tenets of constructivist teaching and with the new science curriculum. Peer group support is mentioned as a possible strategy for increasing the practice of constructivist teaching in several major books, including *Developing and Supporting Teachers for Elementary School Science Education* (Loucks-Horsley, Carlson, Brink, Horwitz, Marsh, Pratt, & Worth, 1989), *Elementary School Science for the '90's* (Loucks-Horsley, et. al., 1990), and *The Practice of Constructivism in Science Education* (Tobin, 1993). Peer group support has become a popular form of professional development outside the science education arena as well, exemplified in the work of such educators as DiShino (1987), Miller (1990), and Lieberman (1988).

Designing a research project that focused on a teacher study group as a viable form of professional development was appealing to me for several reasons. As an elementary teacher, I often felt isolated in my own classroom.

As a doctoral student, I longed to be able to converse with my fellow teachers about important educational ideas, much as I did in class during the few hours a week I was on campus. I wanted to initiate a form of constructivist professional development that would give teachers the opportunity to dialogue, support each other, educate themselves, and develop new understandings and abilities.

I proposed to form a small study group of four to six teachers at the elementary school where I taught. As members of this group, we would take the time to familiarize ourselves with the literature on constructivist science teaching and experiment with this type of teaching in our own classrooms. We would meet throughout the 1996-97 school year to discuss our successes and failures, thoughts, concerns, and questions. I would provide the initial bridge between research and practice, but I wanted to encourage other group members to empower themselves to lead our questions and interests in the direction that concerned them. Our goal was to redefine our science teaching and learning so that it became more constructivist and conceptual as we tried to implement the new curriculum.

Originating in the theoretical framework of interpretivism, this was a collaborative, action research-based study seeking to elucidate the role that a study group of colleagues plays in teachers' own efforts to negotiate the practice of constructivist science teaching.

The Research Questions

The guiding research question framing this study was:

What role can a teacher study group play in helping elementary teachers understand and mediate constructivist science teaching?

Subsidiary questions branching from this guiding question were:

- What previous experiences, knowledge, opinions, and misconceptions regarding science and science teaching do teachers bring to the discussion of constructivist science teaching?**
- Within a peer study group, what types of activities can help teachers bridge the gap between constructivist theory and practice, resulting in a feeling of preparedness and comfort in teaching science?**
- How can the support and constructive criticism of a peer study group help elementary teachers refine their practice of constructivist science teaching?**
- What tensions and struggles do teachers experience as they work together to mediate constructivist science teaching?**
- What tensions and struggles do teachers experience as they seek to become constructivist learners themselves?**

It was my hope that this study group would learn to engage in the same process we hoped to be able to do with our students: a constructivist process.

Along the way, we learned that it was not an easy process. It required unanticipated demands on us as teachers and as learners. At times, we found it difficult to push ourselves to do the “hard” work and thinking we wanted our students to be able to do. This dissertation focuses on the experiences of this group of teachers and the struggles and successes it experienced as its members faced the paradoxes inherent in our difficulty doing the same kind of hard work and learning we expected of students.

The Setting

Westdale Elementary School was located within a middle-size midwestern city. The school served a working class/lower-middle class neighborhood within the Ojibway Public School District. There was a great deal of racial and socioeconomic disparity within the district coupled with *de facto* segregation. The inner-city schools served predominantly poor, Black children living in neighborhoods filled with dilapidated rental housing, while schools in newer neighborhoods located on the city outskirts served more White children and those from higher-income households. Achievement scores, as defined by the Michigan Educational Assessment Program, were consistently higher at the “fringe” schools, while the inner-city schools struggled.

Westdale School's student composition was approximately 75% White and 25% African-American. Historically, the school has enjoyed an active PTA, an effective and popular principal, and moderately-high test scores. It has held “high status” within the district as a place to teach. In a district where teachers are allowed to choose among open positions on the sole basis of their seniority, Westdale had become a bastion of veterans with very low staff turnover. The entire teaching staff was female. There were two African-American teachers on the staff, and the remainder were White. Not surprisingly, the teaching was predominantly traditional and didactic in nature, with the majority of student desks arranged in rows and very little cooperative learning taking place in classrooms. This was an assessment with which the principal, who had been in the position almost 20 years, agreed.

However, a retirement incentive at the end of the 1994-95 school year led to the turnover of seven teachers. The “new” teachers (including myself) who transferred in from other buildings brought a mix of teaching styles and progressive methodology with them, and this led to a revitalization within the building. The principal and district consultants took advantage of this change, and several inservices on “multiple intelligences” and cooperative learning were held during the next school year. In addition, a bond issue passed, providing for the construction of a new, upper-elementary wing, media center, arts center, office space, and a “Discovery” science room completed in September of 1997. The new building was wired for fiberoptic technology, with each room containing several computers, internet access, phone lines, and a TV/VCR. Westdale Elementary School was poised for change and appeared to be an ideal setting for a study designed to guide the development and implementation of progressive pedagogy.

While all of the elementary schools within the Ojibway Public Schools were experiencing the same challenges in implementing the new science curriculum, Westdale Elementary School had one advantage, which I believed would make it easier to conduct this study. One major obstacle in implementing constructivist science teaching is the procurement and set-up of materials for hands-on experiments. Westdale was fortunate to have a science paraprofessional who purchased and set up all experiment materials for teachers in the science lab. This eliminated one frequently-mentioned difficulty that teachers have in implementing nontextbook-based science programs and would

make it easier to focus on the role of the study group as a means of professional development.

Audience

The results of this study should be of interest to policymakers, curriculum developers, administrators, science educators, and professional development coordinators: those who are interested in the challenges teachers face as they struggle to develop the dispositions and abilities they need to practice constructivist teaching. Reformers have set an ambitious agenda. This study sheds light on how individual teachers working as a group in one building make sense of that struggle. As leaders seek to promote the effective implementation of constructivist science teaching, it will be necessary to incorporate activities that help bridge the gap between vision and practice. In addition, I believe that this study will be of interest to teachers, serving as an example of teachers empowering themselves to be learners and inquirers in their own right.

Organization of the Text

This dissertation tells a story. It is the story of one small group of teachers and its efforts to bring the vision of science education reform into the classroom over the course of one school year. It tells the story of how one group of teachers came to recognize the difficulties and challenges inherent in constructivist science teaching, and how they prioritized and reconciled these struggles in their teaching. This group of teachers, who were engaged in a constructivist learning experience themselves, often found it a difficult process. It

was hard work for the kids, and it was hard work for us. We did learn -- not always what we thought we'd learn or how, but we did learn.

Chapter Two presents a brief review of the literature relevant to this study. Chapter Three specifically addresses the research methodology used in this study, along with a brief overview of the history and tenets of action research. The fourth chapter paints a more detailed picture of the “old” and the “new” Ojibway district science curricula, and explains the process of curriculum development the committee went through. The study-group's teacher participants are introduced in the fifth chapter.

Chapters Six and Seven take the reader through the activities of the study group. A detailed description and analysis are presented in these chapters. The final chapter concludes the analysis and highlights the implications and recommendations that arose from this research.

CHAPTER TWO

Literature Review

A Gap Between Vision and Practice

Research indicates that the experiences of the Ojibway teachers seem to be typical of what is happening throughout Michigan, as well as in other states. Districts are revising their science curricula in an effort to meet the agenda of the reform movement and are facing many obstacles that hamper the progress teachers are able to make. Studies have been conducted to explore the progress districts and teachers have made, and analyze possible obstacles and aids to success. Research studies also have examined the potential of various professional development efforts designed to assist teachers as they struggle to adapt their science teaching practices. Several common themes run through this research. These themes, which will be presented at the end of this chapter, help define a need for further research and form a basis for this study.

The Michigan Statewide Systemic Initiative (MSSI) is a large-scale, three-phase National Science Foundation-funded study of science reform efforts in Michigan. The MSSI reported in its document The Local Government Policy System Affecting Mathematics and Science Education in Michigan: Lessons From Nine School Districts (1995) the many difficulties faced by local schools in implementing the AAAS' agenda. In the areas of Vision and Pedagogy, the MSSI's four major findings from the first phase of research were:

- Lesson 1 – Although local educational agencies [school districts/school boards] were pressing reforms that were in the

direction of state and national visions, in most districts these efforts focused on content coverage at the expense of encouraging fundamental changes in teacher's ideas about teaching, learning, and subject matter.

- Lesson 2 -- The understanding that local educators had of key ideas about reforming mathematics and science education frequently differed from the recommendations of national reformers.
- Lesson 3 -- Most local education agencies were working to align their instructional policies to create more coherent guidance for teachers about mathematics and science education.
- Lesson 4 -- In most districts, the pedagogy of the policies developed by the local education agency were traditional. (Spillane, Thompson, Lubienski, Jita, & Reimann, 1995)

The researchers found that the majority of those in charge of curriculum development at the local level really didn't share an accurate understanding of the national reformers' vision of meaningful science teaching. Their renewal efforts still centered on the *topics* to be taught instead of on the *pedagogy* that should be used in order to teach these topics to students in a more constructivist, conceptual way. In fact, most districts seemed unable to move away from traditional didactic pedagogy to a new kind of science teaching focused on students' meaning-making through intellectual engagement with important scientific ideas.

All nine districts studied by the research team were making what seemed to be sincere efforts to reform their science curriculum, but they were still experiencing varying degrees of difficulty, sometimes unwittingly, in translating national recommendations into action in the classroom. This research exposes the gap that exists between vision and practice in the implementation of science reforms in Michigan classrooms. It is disturbing to note that many of the districts

studied seemed to be “missing the point” and had no realization that they were doing so. In the midst of their sincere reform efforts, these districts lacked a clear understanding of the intent of the science/mathematics reform vision and were unwittingly perpetuating traditional pedagogy. The specific reasons for this paradox could be expected to vary somewhat with each individual district, school, and teacher. Bryan and Abell (1999), in their longitudinal study of a preservice teacher, expose some of the potential reasons on a more microscopic level.

Bryan and Abell (1999) explored the gap between vision and practice through their case study of “Barbara,” a preservice elementary teacher. The researchers studied Barbara’s experiences, thoughts, and actions in a semester-long, science-teaching, methods class and in her subsequent student teaching assignment. Although Barbara enthusiastically espoused a constructivist teaching paradigm, she had a great deal of difficulty putting her espoused philosophy into practice. Like many teachers, Barbara reflected back on her own science learning experiences and felt that the most positive experiences had been those which involved hands-on activities and other forms of active participation. She wanted to model her own teaching on those positive learning experiences, as opposed to the lecture-and-textbook methods of which she had negative memories. As Barbara prepared to begin her student teaching, she was committed to using the conceptual change model she had been introduced to in her science methods class.

As Barbara observed teachers and taught science herself throughout her student teaching experience, her espoused philosophy of constructivist science

teaching was dealt a blow when she realized that not all of the children were "getting" the concepts through hands-on activities. Barbara was frustrated that the children were not understanding certain concepts and firmly believed that teachers should not go on to anything new until the children had "mastered" the current concept being studied. Bryan and Abell (1999) elaborate:

When Barbara extrapolated her experiences to actual teaching practice, she believed that it was the responsibility of the teacher to bring every student to the right answer by spending more time with the class or individual students. When Barbara saw in actual classroom practice that a teacher moved on without all students understanding, the resulting tensions between her vision and the observed practice began to perturb her thinking about science teaching and learning. (p. 129)

Although Barbara espoused a "learning process" philosophy in theory, in practice she was struggling with the impact made by her years of experiencing a "learning outcomes" philosophy. Her need to have students "get it" led her to intervene in group work and manipulate the materials herself so the experiments would work "right." Through reflection, discussion, and watching herself on videotape, she was able to recognize the inconsistencies and tensions these two paradigms produced:

In analyzing her practice Barbara recognized that she was contradicting her vision of students as active science learners. Barbara saw that she did not simply guide or facilitate student learning – she directed and controlled it. (p. 134)

Realizing the incompatibility between her beliefs and her practice, Barbara began to change her teaching practice. She asked open-ended questions instead of those aimed at producing divergent, factual answers. She guided students rather than taking over the equipment herself. She encouraged the students to do more predicting, explaining, and discussing as she circulated around the classroom.

By the end of her student teaching, Barbara was beginning to be able to practice a form of science teaching that more closely mirrored the constructivist philosophy she espoused.

Bryan and Abell (1999) stress the difficulty Barbara faced in bringing her vision into reality and the challenges she will continue to face after she graduates and begins her career. Her years of experience as a science learner caused her to fall back on ways of teaching that did not mesh with the constructivist methodology she wanted to practice. This “apprenticeship of observation” (Lortie, 1975) conducted during her own schooling was difficult to overcome. Her limited knowledge of and experience with alternative teaching strategies had initially led her to blame the students for their lack of understanding. Through reflection, she learned to shift the focus to modifying her own teaching. As Bryan and Abell elaborate, this was challenging work:

Barbara also learned that modifying her practice to reflect her beliefs was a difficult, thought-intensive task. It was not easy for Barbara to confront and critique her own teaching, especially during student teaching, when certainty, self-confidence, and time to reflect thoughtfully are rare commodities. (p. 135)

Barbara experienced personal and contextual obstacles and resources in her efforts. Her own experiences, knowledge base, and beliefs served to both hinder and aid her efforts to become a constructivist science teacher. She was assisted in her efforts by her participation in the study, which afforded her the opportunity to reflect on her practice with focused, personalized, expert assistance. However, this was a rare opportunity for individualized, guided reflection. Most practicing teachers do not have an opportunity to experience the

type of expertly-guided reflection that Barbara did. The presence or lack of personal and contextual resources such as these can serve to facilitate or impede changes in practice (Fullan, 1997).

Obstacles and Aids to Progress

As a result of the second phase of the Michigan Statewide Systemic Initiative's (1996) research, in which 133 stakeholders (including school administrators, teachers, parents, school board, and community members) representing nine districts were interviewed, the researchers identified three resource categories that made an impact on local education agencies' capacity to support ambitious instructional reform in the areas of math and science. These three areas were human capital, social capital, and financial resources.

Human capital consists of the knowledge, skills, and dispositions of people within the district. Districts in which leaders had a strong disposition to acquaint themselves with the "meat" of the reform efforts, as well as a sincere desire to provide teachers with opportunities to do the same, were making more meaningful progress.

Social capital is identified as social links within and outside the district, together with the norms and trust to support open communication via these links. Successful districts sought help from outside sources, such as university faculty, consultants, and boards for professional standards, as they revised their math and science curricula. There also tended to be open communication and trust between these resource people and district personnel, as well as between administrators, consultants, and teachers within the district.

The final factor, financial resources, is defined as money allocated to staffing, time, and materials. Although more prosperous districts had more fiscal resources, this did not ensure that money was spent wisely. Researchers found that both rich and poor districts were able to allocate their financial resources in efforts that truly helped and were just as able to waste available dollars. Some of the poorer districts had used creative means of managing financial shortages and had made more progress in promoting ambitious reform than their more affluent neighbors (Spillane & Thompson, 1996).

Just as the presence of support in these three resource areas can facilitate positive change, lack of these resources can create obstacles to progress. Cannon and Crowther (1997) investigated the opinions of elementary classroom teachers regarding the recent implementation of a standards-based science program in a large, county-wide, public school district in Northern Nevada. The researchers hypothesized that the school district was not meeting the needs of the teachers due to the numerous negative anecdotes offered to the researchers. The district's previous science curriculum was based on the Holt textbook series, which did not include a hands-on component. The new program, Scholastic's Science Place (1995), consisted of four unit kits per grade level. Each kit included a wealth of hands-on materials for activities, accompanying student booklets that guided students through the investigations and provided related reading material, and teacher support materials. While the researchers determined that there was broad support for the pedagogy and

content of the new program, several obstacles that slowed the momentum of science education reform were identified.

First, inservice support during the first year of the program was minimal. Scholastic provided training for a cadre of ten local “teacher-trainers,” who then led after-school inservices at the district’s 56 elementary schools. The first inservices were held three months after school began. There had been no initial introduction at the beginning of the year. No money was available for additional professional development, as school-district adoption funds could only be used for the purchase of educational materials.

Funding was also the source of the second impediment to progress: teachers were required to share materials because the budget was not large enough to provide everyone with individual kits. Teachers reported that arranging for the sharing of materials was burdensome. The third problem was that attendance at the optional, after-school workshops was poor. The researchers felt that the inservices needed to be mandatory, with teachers offered either monetary compensation or credit toward recertification. Cannon and Crowther (1997) state:

While the school district came very close to implementing real change, only time will tell in the near future, if the innovations will remain in place or be replaced with a less ambitious elementary science program. (p. 9)

It is interesting to note that while the teachers complained about the lack of initial and long-term inservice opportunities, they also turned out in low numbers for the inservices that were held. While Cannon and Crowther (1997) do not give details about the nature of the inservices, which might explain why

teachers avoided them, it is natural to wonder about the level of commitment the teachers had to the new program. Given the dramatic change from a textbook series with no hands-on component to a program which included investigations in almost every lesson, one can assume that most teachers would be upset that the district provided no professional development until school had been in session for three months. Added to this was the fact that the teachers were forced to share an inadequate amount of materials. Instead of facilitating a difficult enough transition to inquiry-based science teaching, it appears the district created a discouraging and burdensome situation for teachers.

Shymansky (1996) provides insight into the special challenges elementary schools present to the science reform movement:

Imagine a teaching assignment of ten or more preparations. Imagine a class rich in diversity – children varying in backgrounds, interests, and abilities. Imagine a classroom with limited materials beyond printed texts and paper and pencils. Then imagine having major responsibility for the emotional, social, intellectual, conceptual, and motor skill development of these children. Add to these responsibilities playground, lavatory, and lunchroom duty, and a picture of what it's like to be an elementary school teacher begins to take form. In addition to teaching all the curricular areas, an elementary school teacher has to know about child development, nutrition, behavior disorders, and family counseling and know how to fix broken zippers, untie knots, play kickball, and eat lunch in ten minutes. (p. 186)

Shymansky's description of the life of an elementary school teacher may be humorous and somewhat exaggerated, but there is no doubt that the typical teaching day leaves little time for reflection and experimentation with new pedagogies.

Shymansky (1996) worried that teachers who are already integrating subjects as much as possible so as to fit in all the components of an ever-

expanding curriculum will have the time to do justice to the *Benchmarks for Science Literacy* (1993). How will elementary teachers, who already are handicapped by weak science backgrounds and anxiety regarding science teaching (Cox & Carpenter, 1989), be able to determine the “big ideas” in science and lead learning accordingly? Will elementary teachers interpret the “Less is More” tenet as permission to deprioritize even further the core subject which has traditionally received the least attention? Or will they unintentionally eliminate important concepts from the curriculum as they pick and choose which scientific topics stay and go in the movement from “breadth to depth.” Shymansky raises important concerns to be considered in the rush toward science education reform. How can we facilitate constructivist science teaching given the difficult contexts facing many elementary teachers?

There is evidence that elementary teachers are inclined to favor the inquiry-based pedagogy of the science reform movement, even if they are largely unprepared and inadequately supported in practicing this pedagogy. Despite Czerniak (1989) finding that female, primary teachers have less content knowledge and lower teacher efficacy than other groups of teachers, Haney, Czerniak, and Lumpe (1996) found that members of this same population often had the most positive attitude toward Ohio's new reform-based science model and also the highest intentions of practicing the tenets of the model. They hypothesized that this may be due to the active learning advocated by the reform movement that is in keeping with the child-centered learning approach favored by many elementary teachers. This hypothesis suggests that elementary teachers,

whatever other handicaps might stand in their way, may at least be expected to appreciate the goal of creating classrooms where science teaching engages students in active thinking, participation, and knowledge construction. In fact, as will be seen, the teachers in the Westdale Elementary study group all embraced the general notion of constructivist science teaching from the time the study began. There was no question in their minds that the science reform recommendations posed greater potential for student learning than the textbook-based instruction previously in place. They were less certain of how they might actually engage in the practice of this type of teaching, however, no matter how wholeheartedly they supported its merits.

In summarizing their finding that teachers' attitudes toward implementing the strands of the Ohio model appear to be critical components to the educational change process, Haney, Czerniak, and Lumpe (1996) stress that professional development must foster positive attitudes toward the science reform initiative. They state:

Conceptual change models of staff development may help teachers accommodate these attitudes. The data suggest that teachers lack support structures needed to bring about changes in professional behavior. Specifically, administrative and community support and involvement in the science reform process seem to be lacking, yet nevertheless needed. Finally, teachers perceive that they do not possess the ability to bring about educational change. They believe that barriers (lack of effective staff development opportunities, available resources, administrative organization support, etc.) impede their ability to implement educational reform. Therefore, empowering teachers by providing them with both decision-making opportunities and needed resources appears to be central to educational reform. (p. 991)

These findings echo those shared by the Michigan Statewide Systemic Initiative (1996) and Cannon and Crowther (1997). Lack of resources, whether in the form

of professional development and support, personal scientific background knowledge, facilities and science equipment, or a thorough understanding on the part of administrators regarding the tenets of the science reform movement, can create severe impediments to a teacher's ability to practice constructivist science teaching.

As Cannon and Crowther (1997) found, teachers were able to elicit the factors that created a shaky introduction to the northern Nevada district's adoption of an inquiry-based science program. All too often, however, teachers do not have a strong voice in determining how new programs will be introduced or in allocating financial resources toward the purchase of materials. Unfortunately, poor decisions by the personnel who do make these determinations all too often negatively affect how well teachers are able to enact change. Empowering teachers to take a more participatory role in district decision-making has the potential for eliminating some of the frustrating problems they face.

The ways in which curriculum implementation is approached and studied closely follow the theoretical paradigms that guide research (which will be discussed in the next chapter). Snyder, Bolin, and Zumwalt's (1992) review of the literature on curriculum implementation distinguished three approaches: the fidelity perspective, the mutual adaptation perspective, and the enactment perspective. Most research has focused on the fidelity perspective of curriculum implementation. Researchers in this area are interested in determining the degree of implementation of an innovation as it was originally planned and the

factors that facilitated and impeded the implementation. It is assumed that the desired outcome is fidelity to the original plan.

Mutual adaptation researchers study how an innovation is adapted during the implementation process, rather than measuring the degree to which the innovation is implemented as planned. Mutual adaptation evolved from fidelity research as people came to realize that reforms and innovations are adapted by teachers in specific contexts:

Mutual adaptation is seen as that process whereby adjustments in a curriculum are made by curriculum developers and those who actually use it in the school or classroom context. This implies a certain amount of negotiation and flexibility on the part of both designers and practitioners. (p. 410)

Curriculum enactment researchers assume that curriculum will be shaped through the “evolving constructs” of teachers and students, and are interested in exploring this process (p. 404). Less research has focused on curriculum enactment, a recently evolved perspective, than on fidelity or mutual adaptation. Research into curriculum enactment focuses on how teachers and students grow through the process of negotiating educational experiences. Snyder, Bolin, and Zumwalt (1992) elaborate:

The externally created curricular materials and programmed instructional strategies at the heart of the fidelity and mutual adaptation perspectives are seen as tools for students and teacher to use as they construct the enacted experience of the classroom. (p. 418)

The above authors point out that the use of the term “implementation” is troublesome in the study of curriculum implementation; this term has connotations which make it suitable for discussing the fidelity perspective, but problematic for discussing mutual adaptation and enactment. They also contend

that while it might at first appear that the three perspectives operate along a continuum, the three perspectives are often difficult to separate, and the lines between them blur when examining innovations. Many researchers have come to believe that innovations are never implemented exactly as intended, and that practitioners always play some role, small or large, in adapting innovations to particular contexts. And those who are interested in curriculum enactment reject the notion that innovation could or should ever be implemented as “ordained”; curriculum is meant to be mediated through the teachers and students involved in the process of teaching and learning.

As will be discussed in later chapters of this dissertation, the blurred lines between fidelity, mutual adaptation, and curriculum enactment impacted the Ojibway science curriculum program renewal in all phases from planning to refined “implementation.” Different stakeholders in the district held philosophies that aligned more clearly with one perspective than another, and at times we viewed our negotiation of the new science program from more than one perspective simultaneously.

Professional Development

The professional development activities engaged in by the study group in this research project incorporated many of the suggestions currently advocated in the literature on professional development in science teaching. Several authors have called for professional development which mirrors the very same constructivist methods the reforms are advocating for children’s science learning experiences (Keys & Golley, 1996; Loucks-Horsely, Brooks, Carlson, Kuerbis,

Marsh, Padilla, Pratt, & Smith, 1990; Tippins, Nichols, & Tobin, 1993). Teachers must have opportunities to contribute to the creation of the curriculum they will teach, to pose questions, to reveal their prior knowledge and misconceptions, and to reflect on their experiences. Just as students are being encouraged to examine their own conceptions and ideas, work through new ideas and experiences, and rethink their understandings, teachers must engage in similar processes as they work to understand and practice constructivist pedagogy. As Loucks-Horsely, et al. (1990) state:

Staff development must encourage teachers to make sense of their experiences, to construct their own meanings from new information, and to form theories that help explain the world. When the process is done well, these theories lead to curriculum and instructional strategies appropriate for students. (p.19)

Traditional professional development inservices often function as one-shot, “detached from context” workshops that offer teacher attendees generic, prescriptive advice for improving their instruction. There is rarely any follow-up support for teachers once they have returned to their classrooms, who either struggle with or reject what was presented. If teachers are to understand and internalize constructivist pedagogy, they must participate in the process as learners as well as teachers. If we truly feel that students are thoughtful individuals with their own ideas and experiences, not “empty vessels,” then we must view teachers this way as well.

Unfortunately, Judith Warren Little’s (1992) research in a staff development policy study shows that most local professional development opportunities are based on a service-delivery model that promotes the “empty

vessel" paradigm. Little discusses the preponderance of "service delivery" inservice opportunities, as evidenced by a "nearly inexhaustible market-place of packaged programmes and sophisticated presenters" (p. 175). Administrators tend to favor these generic workshops when they have responsibility for approving staff development expenditures, and the appealing materials and fast-paced exercises secure favorable ratings from participants. However, these programs rarely offer any follow-up services or coaching to teachers when they return to the classroom, which relegates participants in such programs to the role of passive audience for the presenter's performance. Little elaborates:

Present service-delivery strategies reinforce the idiosyncratic, individualistic character of teachers' work.... To participate in activities and exercises designed by someone else is a different matter altogether from assuming intellectual command of the entire enterprise. Few were the instances in which teachers emerged as true students of teaching, and learning, engaged in inquiry of their own making. (p. 177)

Little found instances of teachers engaged in intellectually rich, substantive, professional development projects that were highly regarded by local educators. However, these were greatly outnumbered by the service-delivery, off-site type of workshops. She hypothesizes that, ironically, participant-led, collaborative, long-term, professional development projects may outwardly seem slow in their ability to effect change, as compared to polished workshops and training programs. And teacher participants, experimenting with collegial change efforts, may not appear as outwardly impressive as experienced presenters.

In summarizing the findings of the Rand "Change Agent" study, McLaughlin and Marsh (1979) found that effective staff development activities should incorporate five general assumptions about professional learning:

- Teachers possess important clinical expertise.
- Professional learning is an adaptive and heuristic process.
- Professional learning is a long-term, nonlinear process.
- Professional learning must be tied to school-site program-building efforts.
- Professional learning is critically influenced by organizational factors in the school site and in the district. (pp. 90-91)

McLaughlin and Marsh go on to state, “For teachers, this approach to staff development implies long-term teacher responsibilities, collaborative planning, and implementation of significant change in schools” (p. 91).

This is a view of teacher professional development which seems to make obvious sense, but which has been slow in coming to fruition. However logical it appears to actively engage teachers (the primary agents of instruction) in reflective, long-term, contextualized professional development, many teachers still find their days too consumed with the responsibilities of minute-to-minute instruction to have much time or energy for reflection and collaborative work. Someone has to “mind the kids” every minute, substitutes are expensive and increasingly difficult to find during the current teacher shortage, and teachers are often too tired at the end of the day to engage in meaningful dialogue and collaboration. Although some teachers manage to do it, and some schools have created innovative solutions (such as late starts once a week, which gives teachers an opportunity for professional development during the time when students normally would be in class), professional development opportunities are still largely relegated to off-site workshops. Rarely is time scheduled after a

workshop for teachers to dialogue and reflect back in their schools on how new learning might influence their practice. This raises the question of how much instructional change these workshops actually promote.

“Canned” professional development packages which provide a generic, prescriptive presentation or workshop have been shown to be largely ineffective in sustaining long-lasting, significant school reform (Lieberman & Miller, 1979; McLaughlin & Marsh, 1979). Instead, there appears to be hope in on-site, long-term efforts that involve teachers in collaborative reflection and self-directed learning. Since this process is by nature individualized to meet the myriad of concerns each participant brings to the table, professional development activities of this type engage teachers in a constructivist experience as they learn. Through this process, teachers have the time and opportunity to look at their own attitudes, abilities, and experiences in contextualized professional development opportunities, mediating new teaching methodologies through their own experiences over time. This creates an opportunity for teachers to experience constructivist learning as they work to become constructivist teachers. This was this type of professional development I wanted to facilitate for the members of the Westdale study group.

Tippins, Nichols, and Tobin (1993) describe the Professional Practice Community Project, designed to promote science education reform through “long-term school-university partnerships in which participants are empowered to construct themselves as learners” (p. 67). The project began in the summer of 1990 when a group of teachers at an elementary school near Florida State

University approached the college for assistance in changing some of their practices, particularly in regard to science and mathematics teaching. A collaborative project was formed between the teachers at Sabal Palms Elementary School and education faculty members from Florida State. The elementary teachers expressed a desire to change the school's current culture of isolation to a culture that stressed collegiality and caring. Professors introduced action research as a method for helping teachers identify and implement changes they wished to make. The structure of faculty meetings was reconceptualized to allow a forum that encouraged all teachers to have a voice. The authors explain:

Teachers organized heterogeneous grade-level groups of four faculty members each that met during a portion of faculty meetings to share ideas and discuss professional issues. The first year of collaboration resulted in the establishment of a culture conducive to encouraging collegial conversations about science teaching and learning among university and school faculties.... We began to envision Sabal Palm as an ideal site to bring together the mutual interests of school and university by establishing a Professional Practice Community grounded in the ideas of teacher learning, equality, and emancipatory interests. (pp. 67-68)

The participants in the Professional Practice Community (PPC) worked together to establish a community of learners in which everyone, whether elementary teacher or university professor, had an equal voice.

The aspect of this project that I found most appealing is that the impetus came from a group of elementary teachers approaching the university, as opposed to the other way around. The Professional Practice Community Project arose from the elementary teachers' active request for assistance and guidance related to the improvement agenda the teachers had set for themselves and their

school. The professional development paradigm held by the university faculty members was conducive to the self-directed interests held by the Sabal Palm teachers. Thus, university faculty were able to work collaboratively with the teachers in an atmosphere of mutual respect and learning which acknowledged diverse opinions and needs. Tippins, Nichols, and Tobin (1993) explain:

Learning in the context of the PPC should provide all participating groups with opportunities to reflect on beliefs about teaching and learning in relation to their prior learning experiences.... Though the learning needs and goals of PPC learners will differ, they are brought together in a democratic partnership, united by the desire to improve science teaching and learning in the classroom. We encourage all participants to view one another as co-learners in order to promote mutual trust, risk-taking, equity, and support for learning. (p. 69)

In the PPC project, elementary and university faculty were able to work collaboratively, with a common aim of improved science teaching and learning. Each group was able to accommodate their own learning and research interests through the community of learners established by the project. With the members of each group respected for the unique knowledge and experiences they brought to the forum, each group was able to make progress toward reaching a common goal.

In another qualitative study that examined elementary teacher/university faculty collaboration, Keys and Golley (1996) probed participants' experiences in a reflective teaching model component of the Georgia Initiative in Mathematics and Science. In the study, both classroom teachers and university faculty assumed the roles of mentors and mentees, and engaged in collaborative lesson planning, mentee teaching and mentor observation, and post-lesson debriefing and feedback sessions. From this study, the authors drew several implications

for science teachers' professional development. They recommended that professional development programs which include reflective mentoring emphasize the following strategies:

- Discussion surrounding the issue of teacher as learner
- Practice with nonjudgmental listening and asking probing questions
- Practice interpreting teaching situations
- Engagement in collaborative planning
- Reflection on the processes of planning, teaching, and debriefing (p. 243)

The Westdale teacher study group adapted these strategies into our work. The videotaping portion of the study group's activities allowed the teachers to begin to reflect on their own teaching and enabled them to get feedback from their peers, something that the isolation of classroom teachers makes difficult in ordinary situations. The viewing members gained practice in interpreting teaching situations, both through critiquing each other's tapes and through viewing professionally-produced examples of exemplary science teaching. Teachers tried to offer constructive, non-threatening criticism to other members and practiced asking probing questions. During group meetings and interview sessions, and when sharing their own videotape, teachers reflected on the processes of planning and teaching.

In this regard, the above study was similar to a group of eight elementary teachers studied by Smith and Neale (1991) who participated in a four-week summer program on teaching primary science. The program combined content instruction with teachers, team-teaching science in pairs to small groups of

students, videotaping lessons and discussing these lessons the same day with the team-teaching partner (partners alternated between teaching and coaching duties during the second and third weeks of the study), interviewing children during the last week of the program, and planning for the following year. These teachers were observed teaching and also were interviewed before the summer program began, during the program as they taught science to small groups of children, and the following school year. In the spring prior to the summer program, the vast majority of the teachers discussed their lack of science knowledge. They were observed telling the children incorrect information during observations and admitted that they avoided teaching science, especially physics.

During the initial interviews and teaching observations, it became apparent that what most of the teachers espoused and said they were doing didn't match what was actually seen during classroom observations. One teacher who was strongly committed to "hands-on" discovery science actually taught science lessons which were the "epitome of straight didactic lessons: short answer, factual, with reading of text and brief explanations by the teacher" (p. 210). The researchers were struck by the teachers' lack of attention to children's ideas, predictions, or explanations.

As a result of participation in the program, the participants did greatly increase their personal understanding of light and shadows, which was the instructional content focus of the summer program and the unit taught to the children. They also became more adept with science teaching based on the

conceptual-change model. In the final interviews, all eight teachers said that the biggest changes occurred in the new attention that they gave to students' thinking (1991, p. 222).

Strong lines of communication between all parties involved will be necessary for teachers to find the support they need to practice constructivist science teaching. Loucks-Horsely, et al. (1990) stress the importance of mutual collaboration and support in their recommendations for staff development for middle-grade science teachers. They recommend that staff development:

- be continuous and ongoing;
- provide opportunities for teachers to choose among staff development opportunities that match their interests, stage of development, and competence;
- provide opportunities for teachers to examine and reflect on their practice and their schools, and work together to formulate new and better learning opportunities for their students;
- model the constructivist perspective on learning;
- include support and facilitation by knowledgeable, capable people whose role is focused primarily on teacher growth;
- attend to the goals of the school and district as well as the needs and interests of teachers;
- involve administrators in key roles of advocate, supporter, and facilitator of change in classrooms;
- take full advantage of local and regional resources to expand teachers' opportunities to explore, create, and grow;
- integrate different kinds of opportunities to enlarge teachers' repertoires of effective approaches and strategies; and
- provide teachers with opportunities to assume leadership and support roles with others. (p. 33)

Conventional wisdom says that teachers have a long history of bemoaning reform movements and resisting change. They do not have a history of being active directors and vocal participants in change efforts. The structure of the school day does not allow teachers much opportunity for positive, collaborative professional development. Ineffective practices are perpetuated year after year, and reform efforts die because we have not created a widespread culture for incorporating professional development into teachers' everyday work. Nor have the opinions and expertise of elementary teachers, derived from the experience of their own practice, enjoyed a large-scale, respectful audience. Few teachers have the time or opportunity to stay abreast of current research in education and reflect on how this research could influence their teaching. If teachers and researchers enjoyed a culture of closer collaboration, one could speculate that support for reform efforts would be more widespread. Teachers would have a better understanding of the positive benefits of recommended pedagogical change and would hopefully be more inclined to work toward making these changes a reality.

In summarizing the potential of the school as a setting for on-the-job learning, Feiman-Nemser (1983) states that there is growing evidence that a professional development approach which views teachers as professionals and visibly supports their efforts to learn has the potential to be effective and enduring. She states that the capacities that enable teachers to find success are not unique to particular innovations or programs:

They are the same capacities that teachers use when they develop and evaluate materials, adapt their instruction to fit the needs of individual

students, monitor their teaching and make necessary changes. If schools were organized so that teachers engaged in these activities as part of their work, we would not have to mount special training efforts in response to every new social mandate. The structures to deal with social change would already be in place. (p.166)

Many potentially positive, educational reform efforts have failed to take hold in schools, often not because the reform lacked merit, but because there was an inadequate support structure in place for bridging the gap between theory, policy or reform, and practice.

Themes From the Literature

Several themes that run through the cited literature impacted my thinking as I designed, conducted, and analyzed this study. These themes influenced my decision to organize the teacher study group as a method of professional development and pointed to some of the benefits, obstacles, and struggles the group might experience as they negotiated the new curriculum.

The recommendations of the national science reformers have not made an easy transition into practice. The road to realizing the vision of constructivist, inquiry-based science education in American schools has been rocky. The recommendations often have been misunderstood by local school-district personnel, which has resulted in traditional pedagogy being perpetuated. There has been little understanding on the part of local administrators of the complexities inherent in constructivist learning and teaching, resulting in inadequate and inappropriate professional development efforts accompanying local science-education reform efforts. Financial resources often have not been adequately allocated to accommodate the materials required for inquiry-based

instruction. Teachers frequently lack the scientific background knowledge, pedagogical expertise, and comfort level necessary to practice constructivist science teaching. Most schools do not have a support structure in place that can accommodate the time and opportunities necessary to address teachers' professional-development requirements. For these and other reasons, a gap exists between the vision of the national, state, and local reformers and the actual progress made in bringing inquiry-based science teaching into widespread, classroom practice.

Contextualized, long-term professional development efforts that engage teachers in constructivist learning offer hope for creating and sustaining teacher growth and expertise. Off-site, generic inservice programs that utilize the "delivery-model" approach have not been effective in addressing individual teacher needs or promoting long-term educational change. Instead, professional development efforts that engage teachers in constructivist learning processes are more apt to help them learn and internalize the tenets of the reform movement. Only through engaging in constructivist learning processes themselves can teachers hope to understand and appreciate the potential of this reform paradigm and weave it into their own instruction. Teachers must go through the process of examining their own practice, chewing on new ideas gleaned through dialogue with "experts" and mediating what they learn through experimentation and reflection in/on their own practice.

Professional development efforts that acknowledge the plethora of reasons for the difficult transition to constructivist science teaching must be

developed. Teachers and schools are confronted with a variety of challenges, such as lack of funding for teacher planning and reflection time, which are best addressed through local interventions in the classroom and building context. Interventions that actively involve teachers in planning, experimenting, reflecting, and debriefing will create an atmosphere for sustained, supportive growth.

Teachers must become active leaders and participants in science education reform. All too often, teachers have been the unprepared victims and scapegoats of well-intentioned reform efforts that failed to live up to expectations. Teachers must strive to create an environment where their voices are heard and respected. Their professional judgment and clinical expertise must be respected to the point where insufficient materials, insufficient and inappropriate professional development, and top-down mandates that fail to acknowledge and address the realities of teaching (and teachers) are a thing of the past. If constructivist science teaching is to take hold, then teachers must take a leadership role in ensuring that the supports necessary to bring the reforms to fruition in the classroom are provided.

Whining in teachers' lounges out of earshot of district powerbrokers and reform leaders does not promote positive change. Schools are full of good teachers who want to do the best job they can but whose good intentions are hampered by factors that are often beyond their immediate control.

Summary

I am interested in exploring ways in which teachers can create opportunities for themselves to take an active leadership role in determining their

own professional development activities, activities which will enable them to become classroom facilitators of constructivist science learning. The research has identified a gap between vision and practice in the arena of science education reform, often related to teachers' and other local school personnel's current capability of understanding, supporting, and enacting the tenets of constructivist science teaching.

Recent studies also have shown initial promise in efforts that actively engage teachers in collaborative, collegial, professional development activities. This study examined one such effort, an effort that arose from a group of well-intentioned teachers' negotiation of one district's attempt to revise its science curriculum to meet the recommendations of the national science reform initiative.

CHAPTER THREE

Methodology

The Birth of This Study

In January of 1996, I came back to a new semester of teaching as well as my last semester of doctoral coursework. As I pondered ideas for my dissertation, it dawned on me that I could kill two birds with one stone. I could develop a project that would not only fulfill the dissertation requirement but also had the potential to benefit the teachers who were struggling to implement the curriculum I had worked so hard to develop. The frustration my colleagues and I were feeling at seeing the district drop the ball during the initial implementation of the new science curriculum could be channeled into this project in a positive way.

As a teacher in the district and a member of the science curriculum committee, I had a vested interest in helping my fellow teachers (and myself) change our practice. I had been influenced by Giroux's (1986) writings about teacher empowerment and teachers as "transformative intellectuals." If the district was not going to provide us with the staff development that we needed to successfully engage in constructivist science teaching, then we could take the initiative to teach ourselves. The idea for this project was born, and I spent the spring semester of 1996 crafting my proposal.

Many of my fellow teachers voiced frustrations in regard to the new science curriculum that went beyond mere complaining. Most of the comments I heard expressed genuine professional concern over a personal inability to meet

the instructional expectations of the new program. As I listened to teachers share their perceptions of their inadequacy in constructivist pedagogy and their lack of science content knowledge, I thought that this informal sharing could be channeled into a more structured forum designed to help teachers address and overcome their concerns in a collegial partnership. Thus I created a study group as a form of teacher-led, professional development and collaboration.

As mentioned earlier, it was my hope that the teachers would engage in a constructivist learning setting through their participation in the study group. We struggled to become constructivist learners as well as teachers. A common complaint that had been voiced about the half-day workshops on constructivist science teaching was that the science consultant lectured instead of “modeling” constructivist pedagogy. Teachers seemed to feel that if she had *shown* them what to do, they would know what constructivism looks like and would be able copy this instructional style. This was a naïve assumption that the study group found difficult to reject. Constructivist pedagogy is very complex and requires a great many skills and resources. In order to understand constructivist principles and pedagogy, the teachers in the study group needed to experience this method of learning as both teachers and learners.

Research Questions

My proposed dissertation was based on the following research question:

What role can a teacher study group play in helping elementary teachers understand and mediate constructivist science teaching?

Subsidiary questions branching from this guiding question were:

- What previous experiences, knowledge, opinions, and misconceptions regarding science and science teaching do teachers bring to the discussion of constructivist science teaching?
- Within a peer study group, what types of activities can help teachers bridge the gap between constructivist theory and practice, resulting in a feeling of preparedness and comfort in teaching science?
- How can the support and constructive criticism of a peer study group help elementary teachers refine their practice of constructivist science teaching?
- What tensions and struggles do teachers experience as they work together to mediate constructivist science teaching?
- What tensions and struggles do teachers experience as they seek to become constructivist learners themselves?

Investigating these questions necessitated the development of a research design based on a qualitative paradigm. I was interested in investigating the struggles that the teachers in our study group faced as they mediated the new science curriculum, the processes they employed as they sought to become more constructivist teachers and learners, and the actions and thinking of the teachers as they participated in the study group throughout the school year. I was not interested in quantitatively “measuring” teacher growth or change over the course of the year, nor was I interested in measuring changes in student achievement that may have resulted from the teachers’ pedagogical shift toward constructivist teaching. Rather, I was intrigued by the meanings and experiences of these teachers, and the nuances of their struggles as they coped with a science education reform agenda for which they were largely unprepared.

Theoretical Framework and Design

The design of this study was based on the principles of qualitative, collaborative action research, and arose from interpretivism as a guiding theoretical framework. The interpretive paradigm holds that quantitative investigations are an insufficient means of discovering and explaining all natural and social phenomena. Instead, many different truths may coexist as a result of diverse human thoughts and experiences. In interpretive social-science research, the researcher serves as a subjective filter who explores the nuances inherent in the social reality of a specific context and the data collected. Bogdan and Biklin (1982) elaborate on the interpretivist assumption that human experience is mediated by interpretation:

The meaning people give to their experience and their process of interpretation is essential and constitutive.... To understand behavior, we must understand definitions and the process by which they are manufactured. People act...as interpreting, defining, symbolic animals whose behavior can only be understood by having the researcher enter into the defining process through methods such as participant observation. (p. 33)

The research methods I used, which stem from an interpretive theoretical framework, aligned with my interest in creating a structure that enabled teachers to engage in critical reflection on their own teaching, individual negotiation of the science curriculum, and determination of their own professional development needs. Throughout this study the personal negotiations, definitions of constructivism, and goals of the members of the study group were explored and analyzed in a search for understanding each member's experience as she worked to improve her science teaching.

Our study group arose out of the frustrations expressed by teachers as they were introduced to teaching the new science curriculum. The study group created a means for addressing these frustrations. We met together as peers, colleagues, and active practitioners, discussing and reflecting on our current science-teaching practice. We sought to learn more about constructivism and science, and to address our feelings of dissatisfaction and inadequacy. I was interested in exploring the process the study group engaged in and in the thoughts and feelings of the teachers involved as they negotiated the new science curriculum.

These interests also aligned with a qualitative approach to inquiry that focuses on subjective human experiences and the meanings they make of their experience. This study fit the assumptions proposed by Merriem (1988) in describing qualitative research:

- Qualitative researchers are concerned primarily with *process*, rather than outcomes or products.
- Qualitative researchers are interested in *meaning* - how people make sense of their lives, experiences, and their structures of the world.
- The qualitative researcher is the *primary instrument* for data collection and analysis. Data are mediated primarily through this human instrument, who is a participant-observer.
- Qualitative research involves *fieldwork*. The researcher physically goes to the people, the setting, site, or institution to observe or record behavior in its natural setting.
- Qualitative research is *descriptive* in that the researcher is interested in process, meaning, and understanding gained through the words, actions, and interactions of participants.

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- The process of qualitative research is *inductive* in that the researcher builds abstractions, concepts, hypotheses, and theories from details. (pp.19-20)

This study rested on all of the above assumptions. Therefore, I chose to employ data-collection methods such as interviews, journal keeping, artifact analysis, and audiorecordings of study-group meetings that fit a qualitative research paradigm (Creswell, 1994) and my theoretical framework. A variety of data-collection methods was used in an attempt to triangulate the data by looking for common themes and patterns that arose from different sources, such as similar comments made by a participant in both an interview as well as a group meeting.

Within the larger context of qualitative research, I chose to employ action research methodology. Action research is a form of qualitative research that involves the systematic study of ones' own practice, with the goal of improving one's understanding and practice. Action research involves an agenda that goes beyond gaining new insights; changes and improvements in practice are sought as a result of these new insights. Action research was a natural extension of my interpretive interests.

The term "action research" dates back almost 50 years to Kurt Lewin (1952) who first coined the phrase. He envisioned this type of research as a spiraling continuum of analysis, planning, fact-finding, and execution, which would involve the participants themselves in recognizing and addressing undemocratic practices. Although the concept of action research has evolved over time, three of Lewin's original tenets remain: action research is *participatory*,

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it stems from a *democratic* impulse, and it makes a *simultaneous contribution to social science and social change* (Grundy, 1987). Relating this to education, teachers are active participants in the inquiry process, they direct their own learning and actions, and there is a goal of making positive changes as a result of participation in the inquiry process. A more recent definition of action research emerged from participants in a National Invitational Seminar on Action Research held at Deakin University, Geelong, Victoria, Australia in May, 1981. Grundy (1987) presented this definition:

Educational action research is a term used to describe a family of activities in curriculum development, professional development, school improvement programs, and systems planning and policy development. These activities have in common the identification of strategies of planned action which are *implemented*, and then systemically submitted to *observation, reflection, and change*. Participants in the action being considered are integrally involved in all of these activities. (pp. 164-165)

One example of action research is a dissertation conducted by John Henry (1985) to improve science teachers' questioning skills. In a collaborative study, teachers studied transcripts of their own teaching to analyze how their classroom practices and inquiry styles hampered students' opportunities to think critically and divergently. This group of teachers then worked to promote more critical thinking and student independence by changing their questioning practices.

Henry's (1985) study, as well as my own, are examples of research as *praxis* (practical action). In defining *praxis*, Grundy (1987) summarized:

The essence of the Greek notion of *praxis* (practical action) was that action should be taken on the basis of a thorough understanding of the situation. Furthermore, it was considered that understanding was achieved only by deliberation and debate through which the meaning of

a situation or event became clear. The outcome or consequences of action can never be completely known beforehand. (p. 65)

As a teacher in the Ojibway district and a member of the science curriculum committee, I felt I had an intimate understanding of the difficult situation teachers were in, and I knew that something had to be done to help teachers feel more comfortable and prepared as they tried to teach the new science curriculum. As will become clearer in the next chapter, when I discuss the development and initial introduction of the new curriculum, other teachers expressed their frustrations as well.

By forming a study group in which all the teacher participants would have a voice in determining our goals and activities, I knew that the exact course of this study would not be totally within my control of our project. This was the intriguing aspect of *praxis*. I wanted and intended for the other teachers to share control. Although I provided the initial agenda (partially based on the other participants' expressed needs in the first interview), I did not want to assume total responsibility for planning all of our ensuing activities. Instead, I wanted to be as equal a participant as possible and act as a "resource coordinator" as we worked toward our common goals.

I had hopes that this study would influence positive change in our school and in our individual practices teaching science. The teachers felt that the Ojibway school district had let them down. Those of us on the Science Curriculum Committee who had worked so hard over the course of several years to develop the new program were disheartened by the administration's failure to educate and support teachers during the implementation phase. By listening to

my colleagues, I learned that other teachers had similar feelings. By helping ourselves, we could become “transformative intellectuals” (Giroux, 1986) who would be able to effect change as a result of educating ourselves and using this knowledge as a source of empowerment and positive influence. As a participant, I was empowering myself as well. Even the simple action of seeking access to the district and approval for conducting this study alerted my principal and the curriculum director to the fact that the professional development support provided thus far was viewed as inadequate by teachers.

In describing action research, Grundy and Kemmis (1982) state that the process of action research is grounded in two essential principles: improvement and involvement. This study incorporated both of these principles. The new science curriculum was an effort to improve students’ educational opportunities in science. Unfortunately, the professional development provided for teachers during the implementation phase was insufficient and largely inappropriate. This study was an attempt to help a group of teachers reach our goal of improving our own science teaching by working together to familiarize ourselves with the new science reformers’ vision and trying to incorporate this vision into our practice. I was equally involved in this process, as I also sought to become more adept at constructivist science teaching myself.

Grundy (1987) expanded on this description of action research as being internally-directed by the participants:

Since [action research] is a form of social research rather than, for instance, physical or historical research, it is arenas of human interaction and practice which form the sites for investigation and improvement. This means that action research is concerned with the improvement of

social conditions of existence. Within this process, however, improvement is not to be imposed upon the participants in any situation from “elsewhere,” but it is the participants themselves who are to be the controllers of the improvement process. (p. 142)

The study group had sole control of our goals and actions. We were not beholden to administrators, consultants, or anyone else outside our group as we determined our own agenda of activities. We had a product (the new science curriculum) we were responsible for implementing, and we looked to outside sources for a vision of exemplary science teaching, but we met privately with no one looking over our shoulder, guiding or judging either our actions or the outcome of our work. The goals we set, we set for ourselves. I prepared the research questions myself, but the group determined the course of action we would take as we began meeting.

This reveals a paradox inherent in action research (Habermas, 1974). When a researcher from outside the school intervenes to organize an action research study, the autonomy of the teacher participants is influenced to varying degrees by the presence and actions of the researcher. Grundy (1987) expanded on this problem:

One of the problems in educational action research is that people involved in education do not “naturally” form action research groups for the organization of their own enlightenment.... Some intervention is necessary. But this places the person who intervenes in a special category, which is paradoxical, given the commitment of critical educational science and educational action research to participatory, collaborative forms of critical self-reflection. It appears to elevate the person intervening to the status of someone with superior knowledge to impart to potential participants in the action research process. (pp. 200-201)

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While I served the dual role of teacher and researcher, I do not believe my role as researcher unduly intimidated or influenced the other participants. They were accustomed to associating with me as a teaching colleague on a daily basis. They had never seen me on campus “behaving” as a doctoral student. For them, it was more natural to view me as a peer, which I was, and the challenging discussions we had during our meetings confirmed that. While they respected my contributions, they did not seem to view me as an unquestionable authority. I believe that my position as a researcher in the same school in which I also taught gave me a unique opportunity to explore the development of an action research project sparked by an “insider,” in an appropriate, defensible way

Primary Data Collection Methods and Sources

Figure 1 on the following two pages shows the primary data sources and methods of data collection used to explore my main research questions. The principle data-collection methods used were: participant-observation in eleven study group meetings, four semi-structured interviews with each teacher, videotaping and group sharing of teacher-participant science lessons, and artifact analysis. As discussed earlier, these sources and methods are consistent with a qualitative study. Following the chart, I describe the methods of this study, beginning with entry to the site and recruitment of teacher participants, and proceeding to an outline of the study group’s activities over the course of the 1996-1997 school year. The data-collection methods and sources are described in further detail in the outline of the study group’s activities beginning on page 73.

Research Questions	Data Sources	Data Collection Methods
1. What previous experiences, knowledge, opinions, and misconceptions regarding science and science teaching do teachers bring to the discussion of constructivist science teaching?	Transcriptions of first audio-taped interviews with teacher participants	Individual “baseline” interviews conducted prior to the study group’s first formal meeting designed to paint a bibliographic picture of each teacher and their science learning and teaching background/experiences, as well as probe their current science teaching professional development needs and goals
2. Within a peer study group, what types of activities can help teachers bridge the gap between constructivist theory and practice, resulting in a feeling of preparedness and comfort in teaching science?	Transcriptions of audio-taped study group meetings and individual interviews, researcher’s journal, artifact analysis of videotapes, literature, curriculum materials, etc.	Participant observation, artifact analysis, semi-structured interviews. Within study group meetings, held 11 times during the project: activities such as the discussion of relevant literature and inservice experiences; viewing, discussing, and critiquing videotapes of participants’ own science teaching as well as videotapes from academic and professional sources, including local ISD science consultant at two meetings as a guest “expert,” discussion of frustrations and successes in practice; collaborative refinement of the science curriculum. Conduct follow-up interviews with participants three times during the study to query their perceptions of the study group process and helpfulness.
3. How can the support and constructive criticism of a peer study group help elementary teachers refine their practice of constructivist science teaching?	Transcriptions of audiotaped study group meetings and individual interviews, artifact analysis of videotapes and feedback forms.	Participant observation, interviews, artifact analysis. Focus on videotape sharing at five of the group meetings – each participant shares a videotape of herself teaching a science lesson. Study group discusses and critiques video, and each teacher completes a feedback form for the sharing teacher. Follow-up interview with each sharing teacher conducted within one week of her meeting.

Figure 1 Primary Data Collection Sources and Methods

Figure 1 (cont'd).

Research Questions	Data Sources	Data Collection Methods
4. What tensions and struggles do teachers experience as they work together to mediate constructivist science teaching?	Transcriptions of audio-taped study group meetings and individual interviews, researcher's journal	Participant observation, interviews. Eleven study group meetings held during the school year, two semi-structured interviews conducted during the study, along with a final interview at the end, reflective notes taken in researcher's journal throughout the study
5. What tensions and struggles do teachers experience as they seek to become constructivist learners themselves?	Transcriptions of audio-taped study group meetings and individual interviews, researcher's journal	Participant observation, interviews. Eleven study group meetings held during the school year, two semi-structured interviews conducted during the study, along with a final interview at the end, reflective notes taken in researcher's journal throughout the study

Entry to the Site

My dissertation proposal was approved by the University Committee on Research Involving Human Subjects in May of 1996. While I had already achieved tentative entry to the site from both the principal of Westdale school and the district's Assistant Superintendent/Curriculum Director at the earliest stages of developing my proposal, in May I gave each one a copy of the dissertation proposal to read. After reading the document, they gave me their official permission to conduct the proposed study. Both parties were made aware of the necessity of confidentiality, and that any debriefing at the end of the study would be limited to information that could be shared without endangering the confidentiality of the participants. In addition, the principal asked to be allowed to attend the brief orientation/scheduling meeting planned for late May, simply to participate in our planning of the group's future meeting dates. He wanted to avoid creating any conflicts with special activities or building meetings, and planned to bar the scheduling of any school events on our scheduled meeting dates.

Recruitment of Teacher Participants

I verbally approached teachers who I thought would be willing and able to commit to a year-long project, and who appeared to me to demonstrate an eagerness to change and improve their practice: those who seemed to have an ongoing commitment to personal learning and professional growth. I was interested in a perceived desire to become more proficient. My perceptions were

based on working closely with these teachers over a two-year period and also on the comments they made in lounge discussions.

I knew of several teachers who were concerned about their weak scientific backgrounds and the impact this was having on their teaching. Some of these teachers were quite vocal about their desire to do better, but they seemed at a loss as to how to accomplish this. I also knew two other teachers who felt very confident teaching science. I decided that a mix of teachers, some who felt more proficient and some who felt more like novices in their science instruction, would be best for the study group. First, the “novice” teachers would benefit from hearing the input of those who felt more comfortable and competent. Secondly, the questions that the less confident teachers asked might provoke the more comfortable teachers to examine their own practice more closely and possibly see areas for their own improvement. I also felt that having a mix of teachers operating at different comfort levels would not only be realistic in terms of what one might see in any given school; it would bring up a broader range of issues and give a richer picture of the concerns diverse teachers deal have when they engage in their own self-reflective, professional development.

I initially approached six teachers at Westdale. Five of the six chose to read the research design portion of the proposal as well as the Expectations and Consent Form for Teacher Participants (see Appendix). Four of those teachers agreed to participate and signed the consent form. Although I had attempted to recruit a range of grade levels as well, because I was interested in understanding the experiences of teachers at different levels, we ended up with a group that

consisted predominantly of middle and upper-elementary teachers. The group included one second-grade teacher, one teacher assigned a 3-4 “split” classroom for the following year, one fourth-grade teacher, and two fifth-grade teachers (including myself). As the staff of Westdale Elementary consisted entirely of women, the study group members were all women as well. The members brought to the group a range of comfort levels in science teaching.

Outline of Study Group Meetings and Activities

The study group held a brief initial meeting in May of 1996 with the principal in attendance. At this meeting, we reviewed the research design and consent form, as well as the Parent Consent/Student Assent form (see Appendix). It was decided that the principal would make copies of this form for each teacher to distribute on the first day of school with the rest of the year’s “kick-off” notes. Teachers would be responsible for collecting permission forms from all of their students and returning them to me for safe keeping, as well as informing me of any students whose parents refused consent. Each teacher also was asked to get signed consent forms from any new students who moved in during the school year. We selected a date and place for our first meeting: August 22, 1996 in the school library. I also individually contacted each participant to select a date, time, and place for the first individual interview.

In June of 1996, I conducted an hour-long, semi-structured, interview with each teacher participant. This interview provided “baseline” information such as each teacher’s educational background, her perceived current science knowledge and teaching practices, perceptions of constructivist science teaching,

opinions of and experiences with the new science curriculum, and suggestions for making the study group beneficial (see Appendix C). These interviews were audiotaped and transcribed for purposes of planning activities that would most benefit the members of the study group as they pursued improving their science teaching. I identified common themes that emerged from the interview responses and shared these with the other study group members at our initial meeting of the 1996-97 school year.

In August of 1996, the study group met for an initial exploration of the concepts of constructivist science teaching. I planned to serve as the leader of our study group for this initial session and the first few meetings that followed. The first meeting was an all-day event preceding the beginning of the school year. The remaining meetings were held after school at mutually agreed-upon dates and times, and generally lasted an hour and a half. All meetings were audiotaped, and the tapes were transcribed. The purpose of these initial meetings was to model, elucidate, and discuss the practice of constructivist science teaching as well as to build a cohesive community of teacher-learners. Activities engaged in during the first four meetings included:

- Viewing and discussing the *Frameworks* videotape featuring the teaching of Dr. Kathy Roth at Michigan State University as she leads a group of elementary students through a unit on photosynthesis and then conducts follow-up interviews with four of the students
- Viewing and discussing selected videotapes from the *Mr. Wizard Teacher to Teacher* series, which each feature a master teacher leading his or her class of elementary students through a science unit and discussing the experience in an hour-long segment
- Reading relevant literature and case studies regarding the nature and implementation of constructivist science teaching

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- **Hosting the science consultant from the local intermediate school district as a guest presenter/participant**
- **Completing a “definitions” paper asking participants to list their personal definitions of key terms involved in constructivist science teaching**
- **Discussing the “big ideas” that guided each member’s first unit of science study for the academic year**
- **Discussing each member’s personal goals and setting an agenda for the year**

After the first four meetings had been held, I conducted follow-up interviews (see Appendix D) in November, 1996 with each teacher to determine any changes in teacher attitudes and knowledge about constructivist science teaching. As I listened to and transcribed these interviews, I analyzed them for emerging themes and patterns that the participants had in common, as well as for individual characteristics. For example, it became apparent during the second round of interviews that all of the teachers were having difficulty finding enough time in an already busy schedule to reflect on and work to improve their science teaching. The findings from this set of interviews influenced the activities we engaged in at our next two meetings, which were held in December of 1996. We discussed ways of managing our time that might help to alleviate this problem and also addressed other common concerns that had arisen.

Each participant was asked to videotape herself teaching self-selected science lessons (the number of which varied according to each participant’s personal preference and choice) during each unit and to share a lesson with the study group. Consent and assent forms for student videotaping were signed by

parents and students at the beginning of the school year (see Appendix E). All parents and students involved did sign the forms, which made it possible for all students to be shown on film.

Once videotaping had commenced in December, 1996, the group observed and discussed one member's videotape during each successive after-school meeting, along with any lesson plans, student artifacts, reflections, etc. that the member wished to share. As per the consent form, the teacher had the right to refrain from sharing any of her videos with the rest of the group, as well as the right to refuse or stop videotaping. All of the participants took sole control for arranging their own videotaping (using the school's camcorder and videotapes I provided them) and selected which lesson they wished to share with the group. Some of the group members taped several lessons and chose one to share, while others taped only one or two lessons.

During the five group meetings held between January, 1997 and April, 1997, each member took a turn leading the group and sharing her own videotape. Most of the members introduced their tape by highlighting the lesson's content and objective(s), and by pointing out aspects of their teaching about which they were specifically anxious for feedback. At one of our December meetings, I introduced to the group a simple "videotape sharing," feedback form I had designed (see Appendix F). My intention was to provide a means of communicating written feedback to each participant as she shared and to help the rest of us record our thoughts as we viewed each member's tape. I asked the group to use the form as I shared my lesson in January. The group

members agreed. All of the teachers liked this idea, and we ended up using the form for each member when her turn came to share. Each teacher was given a copy of the rest of the group's feedback forms after her sharing session. I kept the originals to use for my data analysis.

Within a week after each member had shared her videotape with the other members of the study group, I conducted an individual interview with each of the participants. These interviews were done after school in each teacher's classroom and were approximately a half-hour long. The purpose of this post-video interview was to probe for teachers' emerging understandings of the practice of constructivist science teaching, the merging of this type of teaching into their own practice, their questions, feelings of frustration, success, etc. I was also curious about the helpfulness of the video sharing. Was this a beneficial experience for the participants?

Over the course of the year, I made myself available to individual teachers or grade-level teams as a resource in the interpretation of the curriculum and in planning appropriate lessons and activities. These interactions were informal and neither audiotaped nor videotaped.

As part of our goal to strengthen our background knowledge in science, the group also decided to enroll in a series of workshops held at the local intermediate school district. Entitled "Michigan Operation Physics: The Wonders of Physical Science," the classes were held monthly after school throughout the school year. Each session focused on one topic, such as electricity, astronomy, or forces. We all attended the second workshop together (the first conflicted

with our parent-teacher conference schedule). Thereafter, the members attended individual sessions based on the topic's relevance to our own curricular responsibilities. We frequently discussed highlights of the sessions at our regular study group meetings and how what we learned had impacted our teaching. However, as this was a separately sponsored event and not regularly attended by every group member, I did not officially document what transpired at these workshops.

During the course of the study, I kept a personal journal documenting all of my interactions with group members as well as my reflections on our progress. I asked, but did not require, teachers to do the same. They could choose to share their journals with other members of the group or keep any or all portions confidential. In the end, no one chose to share her journal because no one had written anything. Although they had enthusiastically taken the spiral-bound notebooks I disbursed, time constraints and the demands of teaching prevented any of the participants from making the journals a priority. Extreme care was taken to adhere to the time parameters of this study. Time is a premium for elementary teachers who must plan and prepare for several different subjects each day. This study was intended to benefit teachers, not burden them further.

Artifact analysis was also used as a method of data collection during the study, both by the study group as a whole and myself in the course of designing, conducting, and analyzing the study. I examined curriculum documents and science teaching materials (from the old science curriculum as well as the new) as a means of characterizing the nature of both programs, and the instructional

differences presented by both. I previewed professional literature and videotapes, selecting those to share with the study group. The study group as a whole viewed these videotapes, read pieces of literature, viewed each other's videotaped lessons, and engaged in discussions surrounding these artifacts.

In May of 1997, I conducted a final interview (see Appendix G) with each teacher participant. These interviews lasted approximately 45 minutes and took place after school in each teacher's classroom. This interview gave each teacher an opportunity to reflect on the past year's experience teaching science and meeting with the study group. Conducting the interviews also allowed me to probe each teacher's thinking regarding the project's emergent themes and patterns I had begun to identify.

Data Analysis

As befits a qualitative research study, data analysis was ongoing throughout the data collection phase and continued after the formal study group activities ended in May, 1997. During the course of the data collection phase from June, 1996 to May, 1997, I examined the data in an attempt to uncover emerging themes and patterns. These themes and patterns influenced the specific goals and activities that the study group's members felt were personally beneficial in mediating constructivist science teaching within their classrooms. The emerging patterns also directed the content of subsequent interview protocol questions. As the participants began to identify personal obstacles, frustrations, and goals for improving their own teaching, I was able to gear follow-up questions toward each teacher's own experience. Following the data-collection

portion of the study, I looked back at the year with the help of my journal, videotapes, audiotapes, and accompanying transcriptions to reexamine the nuances and possibilities inherent in using teacher study groups as a means of meeting the professional development needs that constructivist science teaching requires.

To assist in organizing the data analysis process, I created several data-analysis matrices. These matrices helped to clarify themes and patterns that emerged during the study, as well as to organize the interview responses expressed by the participants. Several of these matrices appear in later chapters of this dissertation.

Anonymity and Confidentiality Issues

Before beginning any data collection for this research, I sought and obtained consent from the Michigan State University Committee on Research Involving Human Subjects (UCRIHS). Consent forms were signed by all teacher participants, as well as all parents of students being videotaped or contributing work samples for teacher sharing and discussion (see Appendices A, B, & C). Assent was sought and obtained from all students, also. While it would be impossible to ensure anonymity and confidentiality within the study group itself, I took careful measures to assure confidentiality outside our group. I kept all interviews confidential, restricting access to tapes and transcriptions only to myself (individual participants were free to look at their own transcripts). All materials were permanently stored within my home office. While any materials were at school (such as interview and meeting audiotapes that had just been

recorded), they were kept locked in one of my classroom desk drawers. I realized that the possibility existed that a teacher would choose to bring up her own interview responses during a group meeting. However, all participants were apprised of the need for confidentiality and that all discussions within the group must be restricted to group members only.

During the writing phase of this dissertation, pseudonyms were used to disguise the names of all persons, schools, districts, cities, etc. in order to prevent their identification. In addition, due to the small participant sample, some identifying characteristics not relevant to the study were changed for some of the participants to further ensure that readers familiar with the district and the study would not be able to distinguish individual participants.

Limitations of the Study

This study focused on teacher learning, not student learning. Therefore, I did not attempt to ascertain or analyze student achievement in science as a means of judging the effectiveness of this project. I sought to explore the possibilities inherent in a study group's efforts to explore and mediate constructivist science teaching. I wanted to describe this process and the participants' experiences in doing this, not "measure" growth by quantitative means. That would not be appropriate for this study and my theoretical framework. Finally, while this study may be of interest to educators at many levels, the results cannot be generalized to all other elementary schools. Qualitative studies seek to elucidate, in as much descriptive detail as possible, a particular social context.

The possible benefits to participants in this study were many. Potentially, students would benefit from receiving science education that has been shown to be more meaningful and effective than traditional textbook-based instruction. Given the racial make-up of Westdale School, improvement in science instruction could help to close the gap between the achievement scores obtained by White and minority students, and male and female students.

In addition, this study explored an alternative to traditional teachers' professional development, which has consisted mainly of detached, one-shot workshops. Study groups could pose the possibility of a more effective way of supporting sustained teacher growth and development based on teachers' own goals and efforts to improve their practice. Finally, this study fit the national, state, and local reform efforts in constructivist science teaching and offered the possibility of serving as one model for helping teachers develop the attitudes, knowledge, and skills they would need to be successful in changing traditional practices in science teaching.

CHAPTER FOUR

Roots of the Ojibway School District Elementary Science Curriculum

A Recent History of the Ojibway School District Elementary Science Curriculum

The formation of the Ojibway Public Schools K-12 Science Committee in the summer of 1992 was a milestone for science education in the district. Prior to that time, the elementary science curriculum was limited to the Silver-Burdett science textbook series (1987, Mallinson, Mallinson, Smallwood, & Valentino) and an accompanying box of “hands-on” materials for each grade level. By 1992, the boxes of materials were in a sorry state. Items were missing, broken, depleted, and unorganized. The expiration date for the chemicals had long since passed. There were no funds earmarked for the purchase of replacement materials or for any type of experiments that teachers wanted students to do. The blackline masters for tests and worksheets were yellowed, dog-eared, and misfiled. The text and accompanying materials were very didactic in nature, geared toward a “lecture, read, seatwork, and test” style of instruction. Very few experimental activities were incorporated into the curriculum, and those that were included consisted of “cookbook” procedures that left little room for student creativity, critical thinking, and problem solving.

In addition, the breadth of the curriculum at each grade level left little opportunity for the in-depth exploration advocated by the new science reforms. For example, fifth graders were expected to “cover”: plants; vertebrates and invertebrates; communities of living organisms; stars; the respiratory, circulatory,

excretory, muscular, and skeletal systems of the human body; atoms; physical and chemical changes in matter; electricity and energy; weather; and geology and environmental conservation. The sheer scope of topics to be taught severely limited the time students had to meaningfully learn any concept, and the emphasis placed on presentation and retention of facts gave students little opportunity to learn and apply scientific processes. This superficial form of instruction is typical of pedagogy that the new science education reform movement was seeking to replace and improve on.

However, as superficial as the former curriculum was, I observed many teachers who either did not teach science at all or gave it minimal time in comparison to other subjects. This was typical of many American elementary classrooms (Jones, et al., 1992). These teachers could not be faulted for ignoring district policy; the administration also placed a low priority on science, and teachers had no need to fear reprisals if they spent little time on science instruction. The district did place heavy emphasis on math and reading, with several consultants employed to assist teachers in improving their teaching in these areas. In addition, the school system conducted district-wide assessments in math and reading. No such assessments, resource personnel, or other forms of support were available from the district in the area of science.

For those few teachers, such as myself, who were interested in teaching science, the old curriculum was unfulfilling, and the lack of district support frustrating. I personally spent quite a bit of time and effort developing my own classroom curriculum and attending workshops such as Activities Integrating

Math and Science (AIMS) in an effort to provide my students with a more engaging science experience. I knew of several other teachers who did the same. The district's Office of Instructional Services did pay the registration costs for attendance at these types of workshops, but teachers were responsible for taking the initiative to seek out opportunities for their own professional development. The district provided no follow-up to these workshops. Those attending were assumed by the administration to be making individual efforts to expand their own teaching repertoires.

Therefore, it was with much enthusiasm that I joined the K-12 science committee when it was convened in the summer of 1992, grateful that the district was finally devoting time and energy to a long-overlooked segment of the curriculum. However, over the course of the next three years, the committee itself often proved to be a source of frustration as it struggled with changes in leadership and direction.

At its inception, the science committee was chaired by a veteran elementary principal. In June of 1992, a team of elementary and secondary science teachers, along with teams from several other school districts, attended a week-long Science Education in Michigan Schools (SEMSplus) workshop designed to give the team a framework for designing and developing its new curriculum. This workshop was process-oriented rather than content-oriented. The SEMSplus program provides a series of "modules" (guide books) to help districts work through the curriculum renewal process in science.

In the long run, this workshop had very little impact on the committee's actions. The fact that a great deal of time and energy was spent on familiarizing a team with a set of materials that were not adopted was an early indication of the curriculum committee's lack of direction and focus. The committee never discussed the value of the SEMSplus materials. They just weren't used, and I never learned why.

In August of 1992, the local intermediate school district (ISD) held a three-day, workshop retreat at a local summer camp to kick off a countywide science curriculum collaboration project. The goal of this project was to bring local districts together in a common effort to align their science curricula with the new reforms and the Michigan Essential Goals and Objectives for Science Education. Ojibway schools sent a team to this conference, which consisted of the district curriculum director, several elementary principals, and several elementary and secondary teachers. The only two people who attended both summer workshops were the principal who served as the committee chair and myself. At the time, I wondered why a consistent group membership had not attended both workshops. As it turned out, the committee was still in the process of member formation. Most of the teachers who attended one of the workshops became permanent members of the science committee, although some did not.

The workshop was led by Terry Farmer, the math and science consultant for the county ISD. A variety of informative presentations by several speakers gave attendees a broad overview of the new science curriculum reform efforts. Special focus was given to the Michigan Essential Goals and Objectives for

Science Education document. This document, published by the State Department of Education, listed 216 science learning objectives broken down into elementary, middle school, and high school levels. The goals were categorized under Life Science, Physical Science, and Earth and Space Science. Also included were two process-oriented categories entitled Reflecting On Scientific Knowledge and Constructing Scientific Knowledge.

Over the next two years, the districts participating in the curriculum collaboration project would work to assign responsibility for teaching the learning objectives listed in the document to various grade levels, with mastery designated at a certain grade level. Care would be taken to ensure that students had an opportunity to master those objectives tested on the Michigan Educational Assessment Program science tests at the fifth-grade and eighth-grade levels before students took the test. By eleventh grade, students also would need to have adequate exposure to the objectives tested on the science portion of the state's, high-school proficiency test.

For the small districts in the county that did not have access to curriculum development support on a regular basis, participating in the project made their job easier. Ojibway's curriculum director decided that the collaboration project was based too strongly on Outcomes Based Education. As he told our team at the time of the summer workshop, he felt participating in the project took too much control away from Ojibway, which is the largest district in the county. He also felt that the result of the project would be a curriculum that was too structured to allow for individual teacher creativity. For Ojibway, which had long

avored a decentralized approach to curriculum development that allowed teachers a great deal of autonomy, this alignment initiative would be a radical change. The curriculum director made the decision for our district to pursue its own science-curriculum development path separate from that of the ISD collaboration project.

Although Ojibway was not an official partner in the ISD's project, I was sent to the work sessions that were held during the course of the 1992-93 school year. The principal who served as the committee chair attended most of these sessions, also. While I was able to pick up a great deal of information to enable our own efforts, it was very awkward attending these sessions as an "outsider." The other teachers and staff members were there with their teams, actively engaging in redesigning their science curricula. I felt like a third wheel, not part of any team, and just there to listen, not truly participate.

During the 1992-93 school year, nothing much was going on with our own committee in Ojibway. Until May, when the committee was finally reconvened and the membership solidified, it was extremely frustrating to know that other districts in the county were making such great progress while we were stagnating. I also felt angry that I had given so much of my time and effort over the course of the summer and school year, and nothing was happening in my own district or school as a result. At times, it felt as though I was the only one in the district who really cared whether our students had a meaningful learning experience in science. I also felt extremely frustrated at my lack of power in the

district. As a “mere” teacher, I was not a natural powerbroker, and I felt I had to sit idly by waiting for those above me to make their move.

During the course of the 1993-1994 school year, the activities of our local committee picked up. The leadership also changed. Our curriculum director retired at the end of the 1992-93 school year and was replaced by the former Director of Compensatory Services. She was given the new title of Assistant Superintendent for Instructional Services and served as chair of the committee for that school year. We met monthly during the school day, with substitutes taking over our classrooms. We spent the year listening to several guest speakers: science “gurus” hired to come and enrich the committee members’ knowledge of constructivism, hands-on activities, the MEGOSE objectives, and the new science reforms that had prompted their conception, etc. Two of the consultants shared examples of other science programs they had helped develop to give us an idea of what our finished product might look like. We did not copy any other program, however, because it was important for our committee to have ownership of its efforts.

With the change in curriculum directors also came a change in philosophy. The new assistant superintendent brought in Terry Farmer to work with the committee, and we ended up doing the exact same thing the rest of the districts in the county had done the previous year. A huge matrix was made out of poster board, listing the grade levels along the left side, and the MEGOSE categories (Life Science, Physical Science, etc.) along the top. Each of the 216 MEGOSE objectives was cut out and stuck on a Post-it note. As we determined which

objectives would be taught at each grade level, the Post-it notes were attached to the board at the proper grade level and category coordinate. Often a specific objective was assigned to more than one grade level, with student mastery expected at the highest grade assigned responsibility. In this way, just as the rest of the districts had done, we were able to determine the scope and sequence of our science curriculum and ensure that all the MEGOSE objectives would be taught by the time students were assessed on the MEAP or state high-school proficiency tests.

The efforts of the district science curriculum renewal project were definitely sparked by external forces. As I have stated earlier, I perceived very little interest in revamping our science curriculum among the vast majority of other teachers and administrators. The new MEGOSE objectives and the knowledge that these objectives would be tested (and the scores published) provided the major impetus for change. The Ojibway Public Schools had long struggled with mediocre MEAP test scores in many of its schools. This struggle was one shared by other Michigan school districts serving inner-city, urban populations with high numbers of socially and economically-disadvantaged children. The political climate in Michigan placed increasing pressure on school districts to improve their MEAP scores. The executive and legislative branches of the state government cast an accusatory eye on those districts whose test scores were unsatisfactory. All schools were mandated by the state to develop yearly School Improvement Plans as district accountability became a major focus of attention.

Whereas previous assessment emphasis had been placed on the reading and math tests, the State Department of Education was preparing a remodeled science test. Scores on this new test, as well as the reading, writing, and math tests, would determine whether schools received state accreditation and full financial support from the state. For the Ojibway system, the fear of not making accredited status and thus being financially penalized was a real concern for some of its schools.

The new test, which would make its debut during the 1995-96 school year, was based on the science reform movement. The old test consisted of multiple-choice questions assessing students' content knowledge in the areas of life, physical, and earth and space science. Students took the test in one untimed sitting. The new test also would include multiple choice questions in these three areas but placed more emphasis on constructing knowledge and reflecting on scientific ideas, and less emphasis on regurgitating memorized facts.

Several short-answer (paragraph-length) questions were interspersed throughout the new science test. These questions challenged students to think and allowed somewhat divergent responses. In addition, each classroom of students would conduct a directed experiment during the two weeks preceding test administration. Students would take notes in a log, which was preprinted and provided for them, and then use this log to answer a series of questions during the actual MEAP testing time.

As this type of test required students to demonstrate proficiency with scientific thinking and with scientific processes, Ojibway needed to provide students with the type of science instruction that would enable them to perform well on the test. I do not believe that the district would have placed such a priority on revamping the science curriculum were it not for the MEGOSE objectives and the advent of a new MEAP science test. While we were working on developing the new curriculum, the MEAP test was frequently mentioned by the district curriculum director as well as by Terry Farmer, the ISD consultant.

The approach to developing the new science curriculum was technical (positivist) in nature. The committee designed the curriculum to meet a given set of objectives. Although this new curriculum was intended to expand students' opportunities for critical thinking and problem solving, the administration was more concerned about MEAP scores. Every year, meetings were held in each building in which the school's MEAP scores were displayed on overhead transparencies. District curriculum consultants working out of the Office of Instructional Services analyzed the areas where weaknesses appeared (according to the test scores) and presented those areas as the foci for improvement. There was rarely time for discussion of better teaching strategies. We scrutinized specific test questions and were told to address "this kind of question or objective" *more*. No one ever seemed to have any real ideas for how to address the apparent weaknesses *better*.

Grundy (1987) summarized the kind of technically-oriented curriculum development espoused by Tyler (1949) and Rowntree (1982) this way:

The product of a learning process designed in this way will be judged according to the fidelity with which the implementation of the curriculum design realizes the objectives, thus producing the desired outcome. If the 'product' of the learning experience 'measures up' to the pre-specified objectives, it will be judged 'good'. If too many of the products fail to reach the standard implicit in the objectives, the whole learning process will have to be looked at (though not necessarily the objectives themselves). Some parts of the process will have to be honed up so that the desired outcomes are obtained. The technical interest which exhibits itself in the language and practice of the curriculum design has important implications for control of the curriculum. (p. 29)

Such a technical paradigm influenced the science curriculum development process at Ojibway. Although the district curriculum consultants and director espoused a constructivist method of science teaching, they were most concerned about achieving satisfactory MEAP scores. This may have been due more to outside political pressure than to their true, personal educational philosophies, but the result was the same.

A traditional method of curriculum development was put into process, with the MEGOSE objectives as the guiding influence. These objectives may have been worthy in their own right, but the fact that students would be assessed on their achievement on a state-wide standardized test severely compromised the constructivist nature of these objectives. Teachers could not achieve both goals: teach to the test, and give students more open-ended questioning and self-directed, problem-solving opportunities. These two goals were incompatible. At the time, I worked out a personal compromise by downplaying the MEAP emphasis and concentrated on the fact that the new curriculum would be a big improvement over the old one. It wasn't going to be perfect, but it was sure

going to be better. I was doing what I could under political circumstances over which I felt I had no control.

By the end of the 1993-94 school year, the scope and sequence of objectives had been determined. Now the committee needed to determine how these objectives would be taught and what materials would be selected. It had long been determined that a new textbook series was not the solution. Four units were created for each grade level with an emphasis on depth over breadth. For example, fifth grade, which previously was responsible for a myriad of topics, now had just four units: Animals and Animal Classification Systems; Changes in the Earth; Human Body Systems, and Changes in Matter. Similarly, each grade level included one unit each from life science, physical science, and earth and space science, as well as one unit from the Michigan Model Health Program (this was a mandated, prescriptive, state health curriculum in which teachers were trained and certified by grade level).

During the summers of 1994 and 1995, as well as over the 1994-95 school year, committee members worked in grade-level teams to select materials and write the actual unit plans and specific lessons. We were responsible for reviewing available kits, books, and other materials, and making the decisions about which resources the district would buy for our grade level. For some units, we purchased a prepackaged kit.

In other cases, we designed the entire unit ourselves, writing some of our own lessons and also pulling lessons from sources such as the AIMS resource lesson books and newsletters. This was a very rewarding experience for me.

Working with two other dedicated, fifth-grade teachers, it was very fulfilling to see our visions finally coming to fruition. I had been waiting and working for so long to see science take a priority in our district. I felt confident that the fifth-grade curriculum we were creating was a vast improvement over the previous one, and I couldn't wait until fall to see it enacted. Each grade-level curriculum was typed up over the summer and bound in a three-ring binder. The materials, kits, books, etc. were to be ordered in time for the fall. It was an exciting time.

Introduction of the New Curriculum

Unfortunately, the three-years' worth of time and planning that had gone into the design of the new science curriculum were not respected when it came time to introduce staff to the new program in the fall. Leadership of the committee's efforts was delegated to the upper-elementary math consultant, Carol Tate, who was temporarily reassigned to the role of science consultant. Although she was truly an asset for her expertise in mathematics, the same could not be said for her science education knowledge. She was not prepared to direct the new science program, and her activities over the course of the following year demonstrated that she did not recognize the dramatic instructional changes the new curriculum represented. As will be seen in this and following chapters, she did not facilitate a constructivist approach to science teaching, and like other central office personnel, often continued to promote a "delivery" instructional model, both in teacher and student learning opportunities.

In August of 1995, staff members received their obligatory "welcome back" letters from the superintendent. Listed on the agenda of opening events

was a meeting for all elementary teachers regarding the new science curriculum. The meeting was to be held in one of the district auditoriums -- not a good sign. This indicated that the new curriculum would be presented in a superficial, generalized manner, in a large-group setting that would be inconducive to an interactive discussion.

Upon arrival, the primary teachers were directed to sit on the left-hand side of the auditorium, while upper-elementary teachers were directed to the right. In charge were Carol Tate and the primary-level math consultant. The three-ring binder notebooks were distributed en masse, and a brief introduction to the new curriculum was given.

The presentation was very general, followed by a question-and-answer period. During the question-and-answer period, it became obvious through the overheard grumblings that teachers knew they were not being adequately prepared, were not pleased, and were confused regarding the new curriculum. Some of the more militant and vocal teachers began grilling Mrs. Tate. Teachers wanted to see the student materials. We learned that only some of the experiment materials and kits had been ordered, and she did not know when the rest would arrive. We also learned that due to budget constraints, each building would be sharing one set of materials, so teachers would have to share with their grade-level colleagues. This was a major inconvenience that would necessitate the scheduling of science instruction to avoid time conflicts with other teachers.

Following this presentation to the whole group, Mrs. Tate asked the teachers to reseal themselves by grade level in different sections of the

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auditorium. She asked those of us on the science committee to make a presentation to our respective grade-level groups regarding the specifics of our grade level's four units. We had not been asked to do this prior to the meeting, and I really felt she was putting us on the spot by expecting us to make an extemporaneous presentation. At this time, I was feeling very angry and frustrated at the slipshod introduction the teachers were getting. The pride I had felt in being responsible for developing the fifth-grade curriculum was quickly disappearing as I felt I was being put on the defensive. I couldn't blame some of the teachers for being unimpressed, and I was concerned that this shallow approach to professional development would only give some of the teachers a new reason to avoid teaching science.

Since the MEAP science test would be given to fifth graders, our group drew several principals into its ranks that morning. Although they were careful not to criticize, the questions that were asked made it clear that teachers and principals were going to need much more intensive, personalized guidance as they struggled to enact this new curriculum. Students would be required to construct their own meaning as a result of the questions they posed, and they would need to reflect back on their experiences to help them do this. I sensed a growing feeling of panic from some of the more vocal teachers.

I was fearful that this curriculum was going to sit on the shelf in many rooms. As Grundy (1987) states: "The learners can, however, exercise a reactive power, by being unwilling or unable to participate in the learning environment" (p. 30). While most of these teachers were not part of the

curriculum development process, they could still play a role in its enactment by closing their classroom doors and teaching as they felt comfortable. In this way, teachers held a reactive power to make the enacted curriculum very different from the intended curriculum.

My other concern was that given the lack of assistance, many teachers would teach the new “topics” in the old didactic style the textbook series promoted, not realizing they were missing the boat. I had a sneaking suspicion that we committee members likely were being badmouthed by more than one person under their breath as they left the meeting. Grundy (1987) comments further on the ways in which curriculum developed in a technical way can rob teachers of their voice and their footing. In discussing the 1980’s shift from phonics and basal textbook-based reading instruction to “whole language” instruction, she states:

No matter how sound the theoretical basis for this change of method might be, the fact remains that many teachers were de-skilled by such curriculum policy changes. They may in time have become just as expert in the new methods, but the point is that, as teachers, they did not control either the knowledge from which the change in policy followed or the policies which dictated that they change their teaching practices. (pp. 30-31)

The shift from textbook-based science instruction to constructivism had the potential to leave many teachers feeling as if the rug had been pulled out from under them. Suddenly, most of what they knew about science teaching was being thrown out, and no one was helping them make the shift to this new vision of constructivist science teaching. Given that science was already the weakest subject in many elementary teachers’ content-knowledge bases, I believe the

change in the science curriculum was a frightening prospect. The science textbook offered a “safe” reference for the teacher to work from, while the new unit-based, constructivist curriculum required pedagogical skills and knowledge that most of the district’s elementary teaches were unfamiliar with.

Much of the problem stemmed from a mix of philosophical approaches working at cross-purposes. While the new science curriculum was interpretivist in nature, encouraging students to formulate and pursue their own questions, think critically, and construct their own understandings, it was developed by a traditional curriculum committee using a Tylerian (1949) approach with specific learning objectives designated, and specific lessons and materials presented in binders and instructional kits. The teacher binders were dispersed at the initial meeting as if they were “teacher-proof” directives that provided all an instructor needed to do the job. Those responsible for this mass distribution seemed to be operating under a technical paradigm just as they were supposedly promoting a more interpretivist science curriculum. In my mind, this was an invitation to trouble. However, it was unlikely that either Carol Tate or the district curriculum director were aware of this mixing of paradigms. I myself had only been introduced to positivism, interpretivism, and critical theory at the doctoral level.

The curriculum director was a former secondary English teacher and reading consultant who had risen up through the ranks over her years working in the district. Carol Tate had only taught for two years before leaving her elementary classroom for the math consultant position. In my talks with them at the time and since, I never got the impression that either had a great deal of

theoretical expertise in the area of curriculum discourse, development, and deliberation. The curriculum director admitted to me more recently that she knew the teachers did not have enough “training” or support as the new curriculum was introduced, but that the district did not have sufficient financial resources or resource personnel at its disposal to provide the necessary professional development.

The 1995-96 school year began, and I worked on teaching the new curriculum with the other two fifth-grade teachers at Westdale Elementary. As I busied myself with the start of a new school year, most of my attention focused on my own teaching. I spent little time worrying about how other teachers were faring beyond our little grade-level group. We were fortunate at Westdale to have a half-day of release time each month to spend on grade-level planning. During that year, most of our time was spent working on science. We would coordinate our sharing of the materials and plan a time-line for each unit. We spent quite a bit of time discussing our experiences with teaching the new curriculum. Since we also had the science paraprofessional to gather, set up, and clean up all the experiment materials, we felt relatively unstressed.

Both of my fifth-grade colleagues were excellent teachers. One was a 25-year veteran who had won the district’s Excellence in Teaching award. The other had been a science major in college and had served the district as a middle-school math consultant for several years before choosing to return to the classroom. Her experience with constructivism in math education made the transition to the new science program easier and clearer for her. Since I had

designed the curriculum, I certainly felt comfortable with it. The students seemed to be really enjoying and benefiting from the new fifth-grade program, and so for the first couple of months, I naively assumed that everyone else was enjoying the new curriculum as much as my fifth-grade counterparts and I were.

The next real signs of trouble came later in the fall when the district brought in another outside, science consultant to present a series of three half-day workshops on constructivist science teaching for each grade level at the central office building. While the consultant had prepared the three workshops to progressively build one upon the other, budget constraints dictated that each building could send only one teacher to each workshop. While Ojibway had one small elementary school with only one section of each grade-level, most of the buildings were larger and had two or three classes at each grade. Thus, my fifth-grade colleagues and I were each allowed to attend only one session. We were instructed to "share" what we had learned with our counterparts.

Most of the "sharing" took place in the teachers' lounge over lunch, and it was then that I began to sense the frustration most of the other teachers were experiencing. The content of the inservices had centered on a discussion of constructivist science teaching, but the consultant did not model this type of teaching or make connections with specific curriculum objectives. During the session I attended, the consultant lectured the entire time, and while she had a vast array of hands-on materials sitting behind her on a table, she never made use of them with us.

During these lunch-time discussions, teachers expressed disgust and disappointment that the district was “too cheap” to provide enough substitutes so that each teacher could attend all three sessions. Those who had attended the first session felt they had just gotten a taste of what constructivism was but were unable to build on that starting point. Those who attended one of the second two sessions felt they had missed something by not attending the introductory meeting. A feeling of despair was apparent as teachers noted the irony inherent in a consultant who *lectures* teachers on *constructivist* teaching. I think the general feeling was “If the *expert* can’t do it, how am I supposed to do it?”

Another difficulty lay in the fact that those who arranged the inservice seemed to feel that much of what the participants learned could be “delivered” to non-participants when they returned to their buildings. While many teachers expressed their disappointment with the limited participation allowed at each session and seemed to recognize that hearing second-hand information from the participants was no substitute for being there, a great irony lay in the fact that a “delivery” model of professional development was employed to assist teachers in familiarizing themselves with constructivism.

This further illustrates how challenging it was for those involved to make a paradigm shift away from traditional teaching and learning to constructivism. Hosting release-time professional development activities that truly provided all teachers with constructivist learning opportunities may have been beyond the district’s financial capabilities. But to not even recognize that the substitute activity provided fit the traditional teaching paradigm the district was hoping to get

away from indicated that deep, fundamental changes in thinking still needed to occur at the administrative level as well as the instructional level.

At the time, I believed that the skimpy support offered led many teachers to feel unsure of how to practice constructivist teaching. I also felt that while others may have believed that they had a good grasp of the concepts and practices advocated in the new curriculum, the minimal amount of professional development and support provided made it likely that they would face difficulties. Grundy (1987) suggests the “real” curriculum will be the one enacted in the classroom, no matter what great plans have been created for them to implement:

There is a very real sense in which curriculum development takes place at the level of classroom practice, despite what might have been designed elsewhere. This is, of course, why so-called curriculum developers often tear their hair in despair. All their careful work of designing a curriculum can come to naught unless the classroom operators can be persuaded to adopt their recommendations.... Ultimately, however, the curriculum is that which students experience in the learning environment. No matter how sophisticated the plans might be, it is through the transactions of the classroom that the real curriculum is developed. (p. 42)

Several teachers I spoke with had clear suggestions for professional development they would have liked the district to provide, and which they felt would have enabled them to practice an enacted curriculum that aligned more closely with the intended one. There seemed to be agreement that the teachers would like to have had the new curriculum introduced earlier in the summer when they could have had more time to familiarize themselves with it. However, as all new curriculum materials, textbook series, and programs were introduced during the work days at the beginning of the school year, it was not surprising that the science curriculum had been introduced at this time as well. This pattern of

handing teachers a new curriculum and accompanying materials several days before they were to begin teaching further indicated that the curriculum director and curriculum consultants were operating from a "delivery" model of instruction and learning, which was not conducive to constructivism.

There also seemed to be some consensus amongst the teachers that they would have liked the opportunity to meet several times throughout the year with their grade-level counterparts from other buildings, going through each of the units just as the kids would. They wanted to have the teachers who developed the units walk them through the lessons, engaging in the actual hands-on activities as much as possible. Teachers wanted the opportunity to dialogue with their peers. There was also a great deal of confusion about the nature of constructivism, which the half-day inservices had not helped to clarify. Some of the professional development opportunities teachers were expressing a need for were in keeping with the spirit of constructivist learning, such as dialoguing with peers and learning through doing the experiments themselves. Other requests, such as a desire for more role modeling, illustrated that the "delivery" model was still the operational teaching paradigm for many teachers. Overall, much frustration was expressed by the teachers.

Cohen and Barnes (1993a, 1993b) have stated that meaningful policy recommendations that advocate radical changes in teaching practice require learning on the part of teachers. The new science curriculum was certainly a radical change from what was previously in place. Teachers needed to learn how to teach in the manner advocated by the new science reform initiatives, and

the binder was not a teacher. Some sort of long-term, professional development would be necessary if teachers were to move from a textbook-based, didactic program to a more constructivist form of pedagogy. Teachers needed an opportunity to become constructivist teachers through a process that enabled them to become constructivist learners. They needed an opportunity to develop an internalized, intuitive sense of the nature of constructivism.

As was discussed in Chapter 2 in Snyder, Bolin, and Zumwalt's (1992) review of the literature on curriculum implementation, three perspectives are at play in the discussion of curriculum innovations. The fidelity perspective, which enjoys the longest history as a lens for examining curriculum implementation, looks at the degree to which innovations are enacted as planned. Obviously, the teachers in the Ojibway district, including myself, were influenced by this paradigm. We wondered how we would be able to implement the curriculum as it was intended without additional professional development, role modeling, or support. Although the lack of prescriptive professional development ensured that all teachers would have to adapt and negotiate the curriculum individually, there was lingering uncertainty and even some guilt on the part of teachers, who wondered whether they were doing it "right." The teachers in the study group adopted a perspective of mutual adaptation as well as an enactment perspective as we assumed control of negotiating the new science curriculum in the ways that worked for us at the time. As will be seen, however, even the teachers in the study group experienced varying levels of discomfort with the approach we took.

Figure 2 on the following page illustrates the ways in which the new elementary science curriculum was intended to differ from the previous textbook-based curriculum.

As the chart illustrates, the expectations for teachers inherent in the new curriculum represented quite a departure from the demands of the previous curriculum. Guiding students through constructivist, inquiry-based, science experiences would demand a different set of abilities and proclivities from teachers.

Carol Tate was of little help. She served more as a watchdog than a resource to teachers. Every other week she'd stop by in the morning before school, never bothering to take her coat off to check on how we were doing. Her main concern seemed to be making sure that teachers were "doing" the new curriculum. She may have felt she lacked the expertise in science to really help anyone. Or she may have naively assumed, as I once did, that teachers would be able to easily make changes in their practice with minimal professional development and support, if they just had an open mind and were willing to put in enough effort. For whatever reason, the fact remained that Mrs. Tate became a target of resentment instead of a resource for teachers.

	Ojibway's "Old" Textbook-based Curriculum	Ojibway's "New" Constructivist Curriculum
Classroom practices or activities	• Textbook based • Learning objectives were determined by textbook scope and sequence • Emphasis on breadth and memorization of facts • Based on "delivery" instructional model • Student activities emphasized reading, worksheets, and post-tests • Externally-produced curriculum • Low level of teacher accountability	• Based on state standards and reform movement recommendations • Emphasis on depth and conceptual understanding • Based on "constructivist" learning paradigm • Students engage in a variety of activities with textbooks and other books used as resources • Students construct meaning through inquiry process • District-produced curriculum • High level of teacher accountability
Material Resources	• Commercially created • Few hands-on materials required; funds available for purchasing and replenishing varied from building to building per each principal's budget • Teacher and textbook were the authorities • Students expected to learn individually • Teacher and text-directed questions; students respond	• Many hands-on activities included in curriculum • Each elementary building had a science paraprofessional to order, buy, and set up materials; funds allocated at district level • Teachers and students all bring knowledge and insights • Students learn collaboratively and individually • Teacher is a facilitator and guide • All parties have a voice and ask questions
Human Resources	• Teacher manual provided only necessary background knowledge • Teacher needed to know how to help students read and comprehend informational text • District would pay for outside inservices at teacher's request	• Teachers needed to have deeper scientific content knowledge and pedagogical content knowledge to enable them to facilitate inquiry-based instruction • District would pay for outside inservices at teacher's request

Figure 2 Comparison of Activities and Resources Required for the Textbook-based Curriculum and the New Constructivist Curriculum

This lack of trust interfered with her ability to be a true resource for teachers and identified a lack of social capital in the district. The lack of a supportive, collegial relationship between Carol Tate and the teachers she was supposed to help created an unfortunate barrier. Had the relationship been better and teachers felt that Mrs. Tate was there to facilitate the curriculum, teachers may have felt more comfortable communicating problems and needs to her. As it was, teachers felt obligated to give a “thumbs up” when they saw her. This combination of cursory visits and obligatory positive feedback may have given Carol a false impression that “all was well” and further served to prevent teachers from receiving the professional development and support they needed.

In June of 1996, the science curriculum committee reconvened to revise and fine-tune the grade-level units we had developed. We were encouraged to bring feedback from other teachers in our building. All the fine-tuning was done with the curriculum materials themselves. The agenda for our work sessions had been predetermined by the Assistant Superintendent/Curriculum Director. Three days had been budgeted for us to complete revisions of the units. We were rushed in our efforts to finish the task in that amount of time. Nothing was done about the requests for more teacher support and professional development, either that summer or over the course of the following school year. Once again, it felt like the district powerbrokers were ignorant of the need for sustained professional support that is necessary for significant changes in elementary science teaching to occur.

This context set the stage for the work of the five members of our study group. We would be experimenting with a model of professional development designed by us, for us. This group would work as novices in many areas: as constructivist science teachers, as teacher-researchers, and as professional developers. While I provided the research framework, it would be up to the group as a whole to determine the specific direction our work would take as we identified our own learning needs and professional strengths.

CHAPTER FIVE

An Initial Portrait of Each Teacher Participant

Each of the other four teacher participants study was interviewed in June of 1996 using a semi-structured interview protocol (see Appendix C). The purpose of this interview was to establish an initial portrait of each teacher's background, experiences, feelings, and needs regarding science and science teaching. The responses given in these interviews would allow me to plan our activities for the first few group meetings, based on the needs expressed by the participants. I also was interested in establishing a "baseline" profile of each teacher's perception of her own practice. What did each of these particular teachers need to learn and be able to do to practice constructivist science teaching? What kinds of supportive experiences, abilities, and knowledge did they already possess? The purpose of the final interview would be to elicit any changes and growth the teachers felt they had made over the course of the group's meetings. This would be important in analyzing the potential of a study group as a means of professional development.

Cindy Ward

Cindy Ward had just finished her second year of teaching at Westdale Elementary at the time of the first interview. After teaching on the East Coast from 1966-72, she left the profession to raise her children. She began substitute teaching in the early 1990s and was hired by the Ojibway school district in 1993. After teaching for one year in another building, she transferred to Westdale. She

reentered the profession with gusto, often staying late in the evening to work in her classroom. I was impressed with the variety of interesting activities she provided for her students. She seemed to spend a great deal of time and energy ensuring that her students had a well-planned, exciting year. I also observed that she took more field trips than any other teacher I knew. Her assignment for the 1996-97 school year was a grades 3/4 split classroom.

Cindy described her own science background as weak, especially in the physical sciences. She enjoyed science as a student, especially biology and botany, and at one time contemplated becoming a physician. However, she did not feel that she'd be able to handle the chemistry and math involved. She felt that she was a victim of gender stereotyping as she grew up and was made to feel that she "didn't have the head" for those subjects.

Cindy described herself as a "verbal-linguistic" learner (Gardner, 1983, 1993). She enjoyed learning "facts" about scientific topics, not doing hands-on experiments. For example, she loved learning about and still loves teaching astronomy. She felt that this was a topic geared more toward memorization, not experimentation. She seemed to feel more comfortable with learning a known body of information as opposed to posing questions aimed at investigating the unknown and constructing your own knowledge. At the same time, however, she stated that she was a strong advocate of constructivist science teaching based on her early teaching experiences. These early experiences made a major impression on her, and she returned to discuss them several times during the interview.

These comments were the first indication that Cindy was struggling to form a personal definition of exemplary science teaching by interweaving what she read about the current science reform movement with her own teaching and learning experiences. Throughout the year, Cindy expressed conflicting opinions about the learning value in discovery-oriented science activities and more verbal-linguistic activities such as reading, learning vocabulary, and doing research reports. She seemed to be trying to mesh together her definition of constructivism (discovery-oriented, very child-centered, with minimal teacher guidance or direct teaching) with her personal preference for verbal-linguistic learning activities. She also felt that our students often needed background information that might be difficult to convey via an experiment, but she struggled with whether direct teaching was “appropriate” given her definition of constructivism as “child-centered discovery with little teacher direction.”

The school in which Cindy had begun her teaching was heavily involved in implementing the science reforms of the 1960’s. The suburban school served children from professional families, and the academic standards were very high. She described the school as progressive with a cutting-edge curriculum. The parents were very involved, and she often received feedback regarding her science instruction and additional content-related background information from those who were engineers or scientists themselves.

Cindy had hoped to teach first or second grade but instead was assigned to sixth. She felt very unprepared for this, especially since she was assigned responsibility for math and science due to a team-teaching arrangement. The

school was using new, National Science Foundation-developed units that required the students to engage in self-directed experimentation. Teachers were directed to “not say a word,” beyond posing questions during experiments and discussions. Students were given unlimited time to work with the materials in an effort to construct their own knowledge and reach their own conclusions. For example, in one activity students were given a battery, a light bulb, and some wire, and were told to “make it light.” They were to draw pictures of the set-ups that did not work as well as those that did, which would then lead to a discussion in which the children would generate the idea of a circuit from their own experiences.

Cindy would take the materials home the night before each lesson and conduct the experiment herself under the direction of her husband, who had a Ph.D. and eventually became head of research and development for a large chemical company. Under her husband’s tutelage, she learned science as she never had before. She came to feel quite comfortable with the units she was responsible for teaching, but felt that beyond those units, her knowledge was still very limited.

Cindy learned the importance of hands-on science as she watched her students interact with the materials. Although she had enjoyed reading and memorizing as a student herself, she began to acknowledge that most students preferred experimentation. In fact, she found reluctance on the part of both her former and current students to engage in the accompanying reading and paper-and-pencil activities each unit included. One of her goals as a member of the

study group was to help students go beyond “playing” to understand important scientific concepts and learn how to formulate and communicate their ideas verbally and in writing.

Cindy was amazed to discover that the same “Batteries and Bulbs” unit was part of the new fourth-grade science curriculum at Ojibway and had remained largely unchanged in 30 years. She therefore felt fairly comfortable with her content knowledge for this unit as well as for the Solar System and Human Body units. However, she felt that some of the materials in the Solar System unit were not as impressive as some other resources she had seen for that topic. She also felt that the life sciences unit was very unorganized and the teaching objectives unclear. Cindy expressed a sense of dismay that the “new” materials were either the same ones she had used 30 years ago or were not as good as those were. She was shocked that more “progress” had not been made in the past three decades. The materials she had used 30 years ago were so powerful in her mind, she thought we’d all have the “answers” by this time, and the science curriculum would be honed to perfection. She said she’d like to go back to her old district and see what they were doing now.

Cindy was quite critical of the new fourth-grade curriculum, which in her mind was not up to snuff when compared with the highly constructivist curriculum she’d used before. She felt we should work during the year to get away from paper-and-pencil activities and figure out a way to give kids more time to work with the materials, and develop their own thinking and their own questions, especially given the tightly-scheduled access to the science lab. However, she

also felt that the students needed to become comfortable communicating in substantive ways (not on worksheets) what they were learning, both verbally and in writing. She found that many of her students were reluctant to do this, or found it difficult due to a lack of prior opportunities.

Cindy's other goal for herself was to expand her own content knowledge, especially in the physical sciences. She was enthusiastic about my suggestion that perhaps Terry Farmer could come and work with our group, as she felt he could be instrumental in expanding her knowledge base. Overall, Cindy expressed clear opinions and had definite ideas about what she needed from the study-group experience. She wanted us to set a specific agenda of goals and activities to help us make the most of our time together.

Karen Carr

When it came to teaching science, Karen Carr was a self-proclaimed fish out of water. Her science background was very minimal. Although she did remember taking biology and chemistry in high school, she had trouble remembering any other science instruction prior to that. What she did have was very textbook-based with little hands-on experimentation. Although she grew up on a farm, Karen said that she "still can't grow anything" and that she felt very inept in her attempts to teach science.

Karen majored in history in college. After teaching for a short time, she went on to get her master's in library science and became an elementary school librarian. For the nearly 20 years she spent working in this capacity, her focus was on reading, with very little exposure to science beyond helping students find

related books for reports and projects. However, budget constraints in the Ojibway school district caused the elimination of the elementary librarian positions at the end of the 1993-94 school year. Paraprofessionals were hired to staff the libraries, while the librarians returned to classroom teaching. Karen chose a fourth-grade classroom at Westdale, one of the buildings where she had formerly served as librarian.

After being a librarian for so many years, it was difficult for Karen to return to classroom teaching. She had to reacquaint herself with the many tasks of elementary teaching, as well as familiarize herself with the curriculum and current pedagogy. Reading and social studies were the easiest for her, while math and science presented more of a struggle. She also stated that reading and math instruction received the highest priority in her classroom, mainly as a result of these subjects' assessment on the fourth-grade MEAP test. Science, which was tested in fifth grade, and social studies received less emphasis.

Karen admitted that for the two years she had been back in the classroom, her science teaching centered on reading the Silver-Burdett textbook. She would take the students down to the science lab, but gave authority to the science lab paraprofessional, Donna Workman, to select activities and instruct the students while they were there. Mrs. Workman's role officially was limited to material procurement, set-up, clean up, assisting the teacher, etc. But unofficially, she welcomed the opportunity to take over and teach for those teachers who felt uncomfortable teaching science. In fact, Carol Tate confided to me at one point that she was always on the lookout for teachers abdicating their

science teaching responsibility to Mrs. Workman. This abdication was a closely-guarded secret, and while Karen admitted to it in the interview, my guess was that this was common among other teachers beyond our study group.

This guess was partially founded on the fact that when I first came to Westdale, Mrs. Workman, a strong-willed person, automatically took over on our first two trips to the lab. After a friendly discussion with her, she relinquished control on future visits. However, I was rather amazed that I had to assert myself at all to maintain my role as teacher. As time went on, and I began to learn more about the Westdale culture, I surmised that she was teaching science for quite a few teachers.

Karen displayed a lack of self-confidence about her teaching in general, but she especially felt she was a novice in science. She was beginning at the ground floor and expressed her need for a great deal of help. Unlike Cindy, who was able to evaluate the new curriculum and offer criticism, Karen felt that her experience was so limited, she couldn't begin to offer an opinion. During the interview, she mentioned Cindy's criticism of the fourth-grade materials: "Cindy says that she doesn't like the materials that we have, and of course she's been teaching long enough that she can see. I mean I just look at them and think, well..." This was an interesting comment, considering Cindy had just returned to teaching about the same time Karen was transferred back to the classroom.

Although Karen expressed a strong lack of confidence in her teaching, she also had a real desire to improve. I gave her a lot of credit for agreeing to participate in the study group, knowing that she would not have much to offer

anyone else in the beginning. Given that most of the other members felt quite proficient in teaching science, she even stood the chance of being embarrassed as her novice status in teaching science became more apparent. But she was willing to risk this in her efforts to improve. She stated, "I think that seeing somebody else teach that way will help, and I'm sure that the experienced teachers will have some suggestions of how to improve, of maybe a different place to start, or a different way to organize things."

Karen said that she was nervous about being videotaped because she felt that her inexperience would show. My impression of Karen was that although she outwardly expressed a sense of personal ineptness, she must have had a strong core to agree to participate in the project at all. After the interview, I felt that I was going to have to make a point of nurturing Karen during the course of the study group. I wanted this to be a source of support for her, and I wanted to ensure that she didn't feel uncomfortable or alienated to the point where she'd want to drop out.

Beth Owens

Beth Owens was the youngest member of the study group. She also had the most experience in constructivist teaching methods and the strongest science background. Beth graduated from college in 1988 with an elementary group-science major. Her emphasis area was biology. She remembered that she had loved science since the seventh grade when she had had an exceptional science teacher. During the six years she had been with Ojibway Public Schools, she had participated in many science inservices offered by the local intermediate

school district. During the interview and in working with Beth as a fellow fifth-grade teacher, it was obvious that she really enjoyed teaching science.

Beth's room was full of experiments in progress. In math as well as science, she organized learning around "big ideas." She used challenging questions and problems as a launching pad for learning, following up with many opportunities for inquiry activities in cooperative groups. Beth and I taught next door to each other and collaborated in our science teaching throughout the year. Along with the other fifth-grade teacher, we coordinated our lessons and informally reflected together on how our lessons went, especially those that took place in the science lab. We generally taught lessons in the lab twice a week and would discuss how they went so that the person who taught each lesson first could help the other teachers make improvements when their turn came.

Beth had spent two of her years at Ojibway as the middle-school math consultant. In this role, she had become very well-versed in constructivist methods of teaching mathematics advocated by the NCTM. It was not difficult, therefore, for her to apply this knowledge to the new science curriculum. She felt quite comfortable with her ability to incorporate constructivist science teaching into her practice. While Karen was a self-described novice, Beth was at the point of fine-tuning her science teaching.

During the initial interview, she expressed few concerns about her own teaching but was very concerned about how those with weak science backgrounds were faring with the new curriculum. She acknowledged that the new curriculum presented a challenge, even for her, and she seemed to think

that less prepared teachers would be unable to meet that challenge without a great deal of professional development and district support. Beth felt that the amount of material in the fifth-grade binder, along with the direction given to teachers that they had some freedom to pick and choose the lessons they wanted to teach, based on their professional opinion of what students needed (and their own personal preference), would overwhelm teachers who had weak science backgrounds. She felt competent to make decisions about which lessons would help her students learn objectives, and was confident in her scientific background knowledge of the key concepts to be learned, but also found that negotiating the curriculum required her to continually reflect on her knowledge and her students' needs. She was concerned that many teachers in the district, with weak content knowledge in the sciences, would be unable to make appropriate decisions regarding lesson choice, and would have a difficult time assessing whether students had learned a given concept, or if/why they were having difficulty.

Beth felt that the district had mismanaged the introduction of the new science materials. Rather than holding a mass meeting, she felt that the teachers from each grade level should have met with their counterparts on the science committee, with these committee members leading the other teachers through the activities of their assigned units. She stated:

It was just so badly presented. I could tell that a lot of work had been done, but it wasn't presented that way. It would've been nicer if the science committee presented....I still think the district's giving science a lick and a promise. They are not committed to it as much as they are committed to reading and math, and this is kind of the way to say, "Okay, we took care of things." But they haven't.

In addition to expressing some legitimate concerns about the inappropriate staff introduction, I believe that Beth already carried a sense of disillusionment regarding professional development in the district. She had decided to leave the math consultant position and return to the classroom because she felt her attempts to help middle-school math teachers change their practice had been met with rebuffs on their part. She described the teachers as a “good old boys club” and was frustrated in her efforts to gain entry into their classrooms. After a frustrating two years in which she felt she received no support or “back up” from the administrators above her and as the teachers she was supposed to be helping ignored her, she returned to the classroom in disgust. No one was hired to replace her, and the position was eliminated.

Beth was concerned that if she had some questions regarding various aspects of the curriculum, then what questions might less experienced teachers have? She made a connection between this concern and the major goal she had set for herself: “How do I help students make the leap from experimentation to understanding important scientific concepts?” She acknowledged that the kids enjoyed doing the experiments but often seemed reluctant to go beyond the “playing” to develop connections with real scientific concepts. This required a great deal of thinking and discussion, which Beth noted that many students were either unwilling or unprepared to do. As a member of the study group, she was interested in exploring new ways of helping kids connect experimenting with meaning-making (Cindy had expressed a similar interest herself). Beth stated:

I'm concerned that many people are going to do the activities and not

help children make the connections that they need. If they're just doing the experiments, going through it, and then not taking the children through that one step beyond of how to put it all together....

She added:

Students want to just do the activities. The activities are fun, they're exciting, and their reactions when they see them, they're like, "Ooh, Wow," and I don't want them to come away with the impression that a miracle just occurred, or this was a magic show. They need to learn to be able to sit down, and they need to be led and helped, led to conclusions, so they can put it all together, so they really do understand what's going on. This year it took a while to get kids so they would do that. They don't do it naturally in math, either. They just want to do the fun game and not talk about why did you do this.

Beth was hopeful that the study group would offer some help to her as she worked toward the goal she had set for herself. I felt that Beth would play an important role in the group. She brought expertise but also was unintimidating in her expression of that knowledge. Having our classrooms right next door to each other had given us the chance to have many after-school discussions regarding pedagogy, curriculum, and classroom management. She struck me as a "thinker." She took the time to examine a situation deeply and seemed genuinely concerned with what she could do to make things better.

Pat Stevens

Pat Stevens was the lone primary teacher in the study group. She had been teaching for almost 30 years at the time of the initial interview. Pat and I had first met as "cabin mates" at the ISD's science curriculum collaboration project's initial meeting at the summer camp four years before. Since that time, we had worked together on the Ojibway science curriculum committee. She had co-developed the second-grade curriculum units with one other teacher. I

respected Pat as a veteran teacher who still had a tremendous drive to improve her practice. Pat attended a myriad of conferences and inservices every year, and was often encouraging other teachers to join her.

I assumed that Pat had a strong background in science because I knew that she made it a priority in her classroom, which is unusual for a primary teacher. However, she told me that she had had very little science in either her K-12 or college education. Like Cindy, she felt sexism existed in her high school science classes: "I think the boys dominated the class. The girls knew you tried to get a boy as a lab partner because he knew everything. So I always felt kind of inept in science." Because she felt unprepared to teach science, she went out of her way to attend many science inservices in an attempt to improve her background knowledge. She was about to attend Activities Integrating Math and Science (AIMS) for the fourth time that summer, had attended many of Terry Farmer's ISD science workshops, and had even gone to the Michigan Science Teachers Association conference that year.

Even before the new curriculum was put into place, Pat had tried to create an exciting science program for her students. She had developed eight units for the year, to along with or replace the Silver-Burdett textbook series, and had organized the materials in separate boxes. She also set up science centers in her classroom. Pat remembered that the best lessons were the "teachable-moment" ones in which the class would design an experiment to try to answer some question the children themselves posed. She acknowledged that "planning

for spontaneity” was a contradiction in terms and that those moments were hard to create.

As a co-creator of the new curriculum, she felt comfortable with the four units in second grade. As a result of feedback received from other second-grade teachers, she and her partner included background information pages for teachers when they revised the curriculum that June. Teachers had expressed a sense of unpreparedness, and Pat hoped that these pages would help somewhat. However, she felt (as I did) that the district had done an abysmal job of introducing the new curriculum to teachers. She stated:

I don't think enough time and effort was put into introducing it.... If I would've been coming new into the [curriculum], like some of the others at my grade level, they just felt like it was kind of dumped on them. They weren't instructed in how to use it or how to get the materials for it, so I don't think it was introduced very well.

Pat also was unimpressed by the half-day inservice presented by the hired science consultant. She had attended the second of the three sessions and was disappointed in the lack of instructional modeling:

She gave an overview of what the constructivist type of teaching was. It was a lot of theory and a lot of talk. Not much actual doing or modeling for us to see what it was. And that was the only session that I attended, and I didn't find it very helpful at all. The only thing I got out of it was some observation methods which were forms that you used for observation. That's basically what I got from it. I thought, "Is this all there is?" I was really dangling...very disappointed.

Pat also felt that over the years, the Ojibway school district had not provided enough inservice opportunities in science. She had taken it upon herself to seek those opportunities personally elsewhere.

For Pat, the study group seemed like a good opportunity to bounce ideas off other people. She was disappointed that none of the other primary teachers shared her enthusiasm for science. Pat previously had shared units with another second-grade teacher. Since that teacher's retirement, however, she had no one to work with. She missed that collegiality and exchange of ideas. She was disappointed that another primary teacher could not be recruited for the study but was still eager to participate.

Pat especially was looking forward to the videotaping experience. She had participated in a series of videotaping workshops held at the Ojibway high school a number of years before and felt that the experience helped her improve her teaching and presentation skills. She also felt that participating in the study group would hold her accountable for finishing her science units on time and not letting them "drag on." As a veteran teacher who was quite comfortable with her practice, Pat did not express many needs. I believe she was eager to participate in the group because she was a "joiner" who truly enjoyed interacting with other teachers and eagerly accepted any opportunity for learning.

Reflection and Analysis

Each of the teachers participating in the study group brought a unique set of experiences, opinions, and needs. Figure 3 on the following pages shows an Initial Profile chart of the participants, which was created to give the reader a brief summary of each of the teachers' responses to the initial interview protocol. During the summer of 1996, the initial interviews were transcribed and analyzed in an effort to identify common and unique experiences and needs among the

Profile Areas	Cindy	Karen	Beth	Pat
Science background, teaching assignment, years teaching	Taught 1966-72; just recently returned to teaching. Taught a 3-4 split classroom. Weak knowledge base in most science topics.	Recently reassigned to 4 th grade classroom after 20 years as an elementary school librarian. Weak science background.	Science/biology major. Began teaching in 1988. Spent two years as the district middle school math consultant. Was currently assigned to 5 th grade.	Weak formal science background but had participated in many science-related workshops and conferences. Co-designer of 2 nd grade science curriculum. Taught 2 nd grade.
Familiarity/ comfort level with teaching science	Comfortable with her particular units, because they happened to be the same topics she previously taught. Years 1966-72 were spent in a progressive, constructivist school.	Very uncomfortable with science and feels overwhelmed by returning to classroom teaching in general. Relied on lab paraprofessional to do the science teaching the previous year.	Felt very comfortable with content and processes, because she was a science major.	Has worked hard to improve her science teaching and background knowledge. Designed units with recently retired 2 nd -grade colleague. Used science centers extensively.
Opinions of the new curriculum, introduction of materials, and half-day inservices	Electricity unit great, Plant unit disorganized, Solar System could be better. Would like to see constructivism role-modeled, which consultant didn't do.	Felt overwhelmed by new materials. Needs a lot of support in working through the curriculum. Disappointed with half-day inservices, felt she only got a partial picture since each 4 th -grade teacher could attend only 1 of the 3 sessions.	Even as a science major, she had to put a lot of effort into understanding and implementing the new curriculum. Wondered how less prepared teachers are coping. Felt district was still giving science a "lick and a promise."	Felt comfortable with the content of the curriculum because she helped write it. Was disappointed with the large-group, impersonal presentation of the new curriculum and the "unconstructivist" half-day inservices.

Figure 3 Initial Profile Chart of Each Participant

Figure 3 (cont'd).

Profile Areas	Cindy	Karen	Beth	Pat
Familiarity with constructivist model of teaching science	Definition of constructivism from previous teaching experience in a progressive school – science instruction should be based on conceptual-change, but felt she didn't have the science background to go beyond the discovery approach.	Very basic definition of constructivism. Wanted to see modeling of this type of teaching. Was currently didactic in her science practice; wanted to work toward a "hands-on" discovery approach.	Became well-versed in constructivist techniques in math instruction. Science practice often based on conceptual-change model, although discovery and processes approaches are also evident.	Was currently refining a discovery-oriented methodology, and was trying to lessen her didactic instruction. Goal was to have kids talk more and talk less herself.
What does this person want/need from the study group experience?	Identify 2 or 3 major focus areas/obstacles and work as a group to identify and try out solutions. Also wanted to learn how to connect "playing" during experimentation with building solid scientific understandings.	Help in all aspects of science teaching: expanding knowledge base, teaching methods, classroom management, etc. Hoping to get a lot of help and ideas from more proficient teachers in the group.	Wanted to refine her practice, become more constructivist. Wanted to learn ways to motivate kids to go beyond the "hands-on" and become more "minds-on."	Wanted to refine practice, hoping videotaping will really help. Wanted to continue to work on making her classroom more "child-centered," with kids asking more questions and designing their own experiments.
Thoughts about videotaping	Nervous	Nervous	Somewhat nervous	Was looking forward to it. Previously participated in similar professional development activity.

Figure 3 (cont'd).

Profile Areas	Cindy	Karen	Beth	Pat
Gender Issues	Felt gender discrimination as a science student; still felt she doesn't have the "head" for math and science. She did not take many formal science courses.	Felt inept at science when she was a student; these feelings still present to some degree. She did not take many formal science courses.	Felt frustrated by the lack of cooperation she received from the "good old boys club" of math teachers when she was the middle school math consultant. Was a science major in college.	Boys dominated science labs when she was a student and were perceived as being more knowledgeable, but this did not seem to significantly impact her personal opinion of her own science learning capabilities. She did not take many science courses in college, but had since enrolled in many professional development courses in science content and pedagogy, and was an active member of the Michigan Science Teachers Association.

teachers. Identifying the commonalities in our science-teaching backgrounds would provide a partial basis for planning our year's work and help me in planning the activities for our first meeting.

While there was some common ground on which to begin work in the fall, it was important to note that each teacher was an individual. This individuality led each teacher to have her own strengths and weaknesses, her own goals, and her own disappointments and successes as she struggled with the new science curriculum. As well, each brought a personal definition of constructivism to the group, based on prior knowledge, experiences, and exposure to this theory of learning. To varying degrees, these personal definitions affected each teacher's current science teaching and influenced the goals they had for changing their practice. To help analyze each teacher's initial expression of their practice, I found it helpful to use a framework for describing different forms of science teaching first outlined by Anderson and Smith (1987) and used by Smith and Neale (1991) in their work with eight teachers in the year-long professional development/coaching study described in Chapter 2.

Anderson and Smith (1987) identified four orientations toward science teaching and learning: didactic teaching, activity-driven teaching, discovery teaching, and conceptual-change teaching. Of these four types, Anderson and Smith state that "only the pattern that we have labeled conceptual-change teaching generally produces conceptual change in students" because it is the only approach that significantly addresses students' prior knowledge and aims to change the misconceptions students have formed through prior learning and

observation. However, teachers who are adept at conceptual-change teaching are rare, and the other forms of science teaching are much more prevalent. Each of these four orientations will now be described in more detail.

Anderson and Smith (1987) claim that they have encountered didactic science teaching far more often than any other at all grade levels. Didactic teaching rests on the belief that knowledge can be conveyed and memorized, hence teachers practicing this orientation tend to “turn discussions into lectures, delete investigative activities, and transform problem-solving exercises into objective tests” (Smith & Neale, 1991). Since didactic questions tend to elicit students’ recall of facts instead of probing for student thinking and understanding, didactic teaching generally fails to expose or address students’ misconceptions or personal conjectures (Anderson & Smith, 1987).

Activity-oriented teachers share many of the same assumptions about science teaching and learning, but they spice up their reliance on texts and lectures by incorporating such activities as demonstrations, videos, and experiments into their teaching. There is still a focus on content mastery, however, with the hope being that the additional sources of information will ensure that more students learn (Smith & Neale, 1991). Activity-oriented teachers try to follow the teacher manual and experiment procedures as closely as possible, and Anderson and Smith (1987) state that they have observed this type of teaching most frequently among elementary teachers who are uncomfortable teaching science. I would associate this approach with “cookbook” style activities, in which children follow a given set of procedures,

answer questions on accompanying worksheets, and are supposed to arrive at a predetermined conclusion. These are the type of activities that cause teachers to sweat when they don't "work right" because most elementary teachers lack the scientific background knowledge to explain variations or errors during student experimentation.

The discovery-oriented approach aligns closely with Cindy's description of the constructivist teaching that was practiced at the progressive school where she began her career. Smith and Neale (1991) state that those who hold a discovery orientation appear to assume that

scientific claims rest on the empirical discovery of the truth that lies in the sensory world. For these teachers, children learn by "hands-on" experience with phenomena in open-ended experiments; if enough experiences are provided, teachers assume that children will assimilate the intended science content directly. In lessons, children are encouraged to come to their own conclusions, and their ideas are accepted without challenge. (p. 193)

There is also a sub-group of discovery-oriented teachers that focuses on students' understanding of scientific processes, such as the scientific method of investigation. These teachers place more emphasis on students' attainment of procedural knowledge, assuming that conceptual knowledge will follow hand-in-hand (Anderson & Smith, 1987). As will be seen, Beth often expressed an interest in having her students understand the process of designing experiments and considered this an important goal for her teaching.

Conceptual-change oriented teachers assume that students bring a variety of prior experiences, thoughts, and conceptions to each science lesson. These teachers focus on "children's explanations for phenomena, the predictive

adequacy of alternative explanations, the use of evidence in supporting and justifying claims, and the role of discussion and debate in establishing knowledge and making progress in understanding" (D. Smith & Neale, 1991). Teachers must continually diagnose children's conceptions, determine the extent to which challenges to students' misconceptions are successful in changing students' understanding, and design lesson plans accordingly (Anderson & Smith, 1987).

If we consider conceptual-change teaching to hold the ultimate potential for science learning, then we must acknowledge the challenges this type of teaching presents. The teachers in the Ojibway study group were currently oriented toward didactic, activity, and discovery-oriented modes of teaching. All of the teachers understood that something was "missing" in their teaching, and Beth was actively seeking to connect solid meaning-making with the discovery-oriented approach she practiced. They all were in the process of negotiating the science curriculum in ways that worked for them, based on their prior knowledge, attitudes, available time, and the priority they placed on teaching science. Anderson and Smith (1987) state that the ability to practice conceptual-change science teaching rests on a teacher's knowledge of scientific content, knowledge of students' misconceptions, and knowledge of teaching strategies that can effectively address these misconceptions. This presents a challenging learning agenda for elementary teachers.

In acknowledging the sustained learning efforts required to implement teaching reforms, Spillane and Thompson (1996) conclude:

Most teachers will have to unlearn much of what they already know as well as learning new things. For most teachers (indeed, most people),

such reconstructive learning requires sustained, honest, substantive interaction about the new ideas with other people who understand these ideas at least as well as they do. These discussions must also make connections between the new ideas and actual classroom practice, not just once but over and over again, with particular students and particular pieces of subject matter in particular classroom contexts. (pp. 31-32)

It was my hope that this study group could be a means for fulfilling this need for sustained learning through interaction with knowledgeable colleagues. As a group, we would be meeting for almost an entire school year, giving us the opportunity to discuss our frustrations and progress in a way that is impossible in a brief workshop. This would not be a generic inservice generalized to a wide audience. We would be teaching specific children in our own specific classroom contexts, and this would influence our work as we brought those contexts into the group meetings and the subject of science. By videotaping ourselves teaching in our classrooms and sharing these tapes with the rest of the group over time, we would have the opportunity to recognize the facets of our teaching we needed to “unlearn” and focus on what we wanted to improve.

The needs expressed by the teacher participants in the initial interview aligned with several components of Ojibway’s “New” Constructivist Science Curriculum shown in Figure 2. Cindy and Karen both felt they needed to deepen their content background knowledge in science. Karen and Pat had goals of making their science teaching more “hands-on” and child-centered. Karen felt she needed to move away from dependence on the science textbook and the science lab paraprofessional, while Pat felt she currently was too didactic. She wanted her students to do more discovering and talking as opposed to doing most of the talking and telling herself. Both Cindy and Beth sought to make more

solid connections between hands-on activities and scientific concepts so that children developed deeper understandings and could explain what they experienced with the materials. As the study group began meeting, these needs were discussed in an effort to create some common ground upon which to begin our work together.

CHAPTER SIX

The Exploratory Phase:

An Account and Analysis of the Study Group's Initial Meetings

The First Meeting

The first meeting of the study group was held on August 22, 1996 in the Westdale Elementary School library. Teachers were due to report back to work the following week. Everyone seemed well rested after summer vacation and eager to return to the classroom. I brought refreshments for the group, and we broke the ice by catching up on the summer's gossip over snacks. This was followed by a brief "housekeeping" session in which we determined that Tuesdays seemed to be the best day for everyone to meet once school started. We decided that we would try to meet every other week after school through the end of March, making allowances for breaks during busy times such as parent-teacher conferences, the holidays, and MEAP testing.

For this initial meeting, I prepared an agenda of activities based on the dissertation proposal. The selection of activities was amended somewhat as a result of the needs expressed during the first interviews. Over the summer, I had transcribed the interviews and analyzed them in a search for individual as well as group needs. From this analysis, I compiled a list of five key points that emerged from the initial interviews and passed this list out to the participants, along with a copy of their own interview transcript. I asked them to read both documents in preparation for discussion and goal setting. I reminded them that I would not

refer to anyone's individual interview responses in the interest of confidentiality, but that I hoped that rereading their own personal transcripts would help refresh their memories after the period of time that had elapsed over the summer.

After allowing about 15 minutes for them to skim over their interviews, which they were eager to do, we discussed the following list of understandings I had summarized from my analysis of the initial interviews:

1. We have a range of comfort levels in teaching science. Some of us feel comfortable creating and critiquing the curriculum, while others feel relatively unprepared to teach science due to limited background knowledge in this subject and its pedagogy. The majority express a desire for more scientific background knowledge in order to feel fully prepared to teach the concepts in the curriculum, especially in the physical sciences.
2. All of us feel that the district has not done enough to prepare us to teach the new science curriculum:
 - Teachers express predominantly negative views of the three, half-day consultant inservices (especially the first two sessions).
 - Some of us desire help in classroom management of hands-on activities and learning centers.
 - There are some concerns about the lack of enough materials and the appropriateness of some materials.
3. Several of us wonder how to effectively bridge the gap between playing/exploring/experimentation and meaning-making without resorting to "telling" kids. How do you lead kids from making discoveries to building solid scientific understandings?
4. How do we create an atmosphere that encourages children to take the time to engage in adequate, pressure-free experimenting, given the tightly scheduled nature of the science lab?
5. Most are nervous about videotaping. We need to create a trusting, comfortable, confidential atmosphere for sharing our videos.

I also numbered the summary with a blank 6, 7, and 8 to leave room for the participants to add more points as these might come up in the group's discussion.

As we discussed the list, most of the teachers opened up and offered their thoughts on each point. Karen was rather quiet throughout the discussion, while Beth, Cindy, and Pat had more to say. Cindy was determined that we focus on a finite number of specific goals for the year so that we would avoid aimless activity when time was of a premium. To that end, the group decided on two important needs. The first was to expand the scientific knowledge base of the participants, especially in the physical sciences. The second grew from the third point on the list: How do you lead kids from making discoveries and playing with the materials to building solid scientific understandings? In other words, kids might be meaningfully engaged in working with materials and exploring questions, but when the state MEAP science test rolls around, the group felt that students also needed to be familiar with an agreed-upon, scientific vocabulary and the basic body of scientific knowledge and processes presented in the Michigan Essential Goals and Objectives for Science Education document.

The teachers were concerned that constructivist teaching might allow too much freedom for exploration and discovery. They worried that the process of constructivist science teaching was fraught with unknowns: students might take too long "playing and exploring," the teacher may not have time to cover all the necessary objectives, and students might not be able to transfer the discoveries they made into the language of the test questions. None of the teachers was

questioning the value of inquiry learning, but they taught in a political world where the high-stakes MEAP test placed pressure on schools to help their students do well with this testing format. Concern was voiced that constructivist teaching and standardized testing presented a mismatch between instruction and assessment.

Over the summer, I had contacted Terry Farmer, the ISD science consultant, to see if he would be interested in acting as a resource person for our study group. He found this type of professional development an intriguing idea and told me that he would be pleased to help us. All of the other members of the group were familiar with Terry and respected him for both his science expertise and his ability to effectively communicate that expertise without condescension to “scientifically-challenged” teachers. We decided to invite him to our next meeting in order to seek his advice and assistance regarding the two main goals we had set for ourselves. Terry also led inservices at the ISD designed to help teachers connect MEAP testing to instruction, so we felt he could offer advice with this concern as well.

The next activity on the agenda was an idea that came from a course called “Contemporary Theories and Discourses” I had at Michigan State. My professor, Dr. Wanda T. May, had us fill out a “definitions” paper and bring it back to the second class session. We were asked to give our definitions of such words as “curriculum,” “knowledge,” and “learning.” When we looked back at our initial definitions at the end of the semester, we were able to see how our own educational philosophies had become clearer. I found that I had written definitions that did not really match my belief system but instead were very

prescriptive. I wanted to have the group members engage in a similar activity at the beginning of the year and again at the end of the nine months we would spend working together. I hoped that their own definitions and understandings would become clearer as we worked together to explore constructivist science teaching. The words I asked them to define were: "curriculum," "knowledge," "constructivism," "science," "comprehension," "hands-on," and "minds-on."

I passed out the papers to the group members (including myself) and explained the history of the activity as well as my purpose for having them complete it. However, much to my disappointment, the activity bombed. None of the group members would share their responses. In retrospect, I think they felt put on the spot, as if I were testing them to see if they knew the "right" definitions.

If I were to do this activity again, I would not have included it during the initial session where I was trying to establish trust and collegiality. In my doctoral class, we had all been on relative par with each other. In this case, however, while I was a teacher-peer of the other group members, I was also a doctoral student engaging in my dissertation research, and there may have been some concern on their part that their definitions would be "incorrect" or too simplistic. This feeling of intimidation may have been exacerbated by the fact that the activity came from my doctoral coursework.

While the definitions paper may have indeed sparked some thought, I do not think this compensated for the discomfort it seemed to cause the other participants. I think it would have been an effective tool if I had waited until after we had met for a couple more sessions or discussed our ideas more informally.

The experience did point out to me how indoctrinated we are to seek the one right answer, and that this would be one hurdle we would have to work to overcome in our attempts to teach science in a more constructivist manner. To varying degrees, we had all been indoctrinated in a positivist approach to learning, which depicts students as “empty vessels” waiting to be filled with facts and right answers.

Our efforts to adopt a more constructivist teaching methodology would require us to reexamine our past learning experiences and teaching practices, grappling with how this baggage may interfere with our good intentions. Were we still unconsciously expecting kids to come up with the one right answer? Were we still expecting ourselves to come up with the one right answer? I was disappointed that the teachers were uncomfortable engaging in discourse that could have helped us identify some operational definitions for our work as well as clarifying our own thoughts and theories about constructivism.

After taking a break, I passed out some reading material for the group members to peruse before our next meeting. I tried to choose some pieces that combined academic descriptions of constructivist science teaching with real-life vignettes of teachers engaging in this type of practice. One of the pieces, “Inquiry at the Window: The Year of the Birds” (Whitin & Whitin, 1996), was written by an elementary teacher and her education-professor husband. It described their successful year working together to provide her fourth graders with meaningful experiences in science. They had set up a bird feeder and a hummingbird feeder in a tree outside a classroom window. A journal was placed

on a table by the window, and children were encouraged to observe the birds, take notes, and write questions in the journal. A different child was given a turn each morning, and this child would report his or her observations to the class before lunch. The observations and questions spawned a whole year of discovery, experimentation, research, and child-led learning opportunities. I thought that this was an excellent example of constructivist science teaching born of simple materials and children's natural curiosity.

The other pieces I asked the group to read were several chapters from the book *Elementary School Science for the 90's* (Loucks-Horsley, Kapitan, Carlson, Kuerbis, Clark, Melle, Sachse, & Walton, 1990), which is a very readable text describing the new science reforms through both description and anecdotes. I asked the group members to read the pieces before our next meeting so that we could discuss them. I also invited them to bring any pieces of writing they came across and wanted to share at any time.

The last activity I had prepared for our first meeting was the viewing and discussion of a videotape. Although I had originally intended to use Kathy Roth's (1991) "Science: Science For All" tape focusing on photosynthesis, I decided over the summer to postpone that tape for a later session in favor of another video I had come across that summer. While the Roth tape centers more on children and their understandings, the "Teacher to Teacher with Mr. Wizard" (Herbert, 1994) video series focuses on the teacher and his or her thinking.

I chose a tape featuring a sixth-grade teacher from Anchorage, Alaska teaching a unit on structures. The hour-long video features the teacher teaching

a series of lessons over time, leading classroom discussions and brainstorming sessions, connecting direct teaching with hands-on activities and research, and encouraging children as they worked in groups to make load-bearing structures out of straws, paper clips, and pins. At various points throughout the tape, the teacher is interviewed regarding her thoughts as she taught the unit. She explains her feelings of frustration and success, her rationale for doing things in a certain way, her attempts to rework the lessons when she senses that something has gone wrong, etc. The tape is an excellent example of a teacher negotiating constructivist science teaching, but it also makes it clear that this type of teaching is challenging, even for those who may be viewed as master science teachers.

The group was quite energized by viewing the tape. The comments made during and after the viewing made it clear that all of the members could see the value of this type of teaching. The students were obviously invested in learning about structures, and this was apparent through the intense classroom work and discussions they engaged in during the program. This group of teachers wanted to learn to bring this type of science teaching to our students. The fact that even the master teacher shown in the tape struggled with her science teaching made the group feel less intimidated. If it was okay for this teacher to be less than perfect, then it was okay for us to be less than perfect. This tape provided some of the role modeling that several group members felt they needed to see, but it also gave them permission to take their time and make mistakes as they struggled with constructivist science teaching themselves.

Even though we did not know this teacher, we knew her struggles. The group discussed how we were often unsure of how successful our lesson plans would be. We too experienced frustration and reflected on how certain lessons could be improved before we presented them again (Schön, 1983). Given the year that generally passes before elementary teachers teach the same lesson again, Beth noted that reflection and improvement on content was something she valued but often overlooked. In the course of the day, preparing for the next activity took precedence over improving a lesson for the next year. Day-to-day reflection on science teaching tended to focus on process and pedagogy; things that we could improve on and that might impact this year's teaching. I believe the videotaped teacher role-modeled more than constructivist teaching to our study group; as she explained the process of negotiation and self-reflection she went through, she helped to legitimize risk-taking and mistake-making as a way of reflecting and learning.

The Second Meeting

After our first meeting, I contacted Terry Farmer and asked him to begin working with the study group. We arranged for the group to meet with him the next week during the afternoon of one of the teacher work days before students came back to school. This time, we met in Beth Owen's room. Beth and Pat already knew Terry quite well, either through his work with the science curriculum committee or through attendance at some of his inservices. We introduced the other members of the group and began our meeting.

I shared with Terry the two main goals that the study group had set for itself: the need to expand our background knowledge, and our desire to learn how to connect student-led discovery with important scientific understandings. Over the next hour, Terry addressed each of these areas in turn.

Terry began by telling us that a weak background in science content knowledge is a very common problem for elementary teachers. He felt that the two goals we had set for ourselves were quite “heady” and that the type of teaching we were aspiring to fit with his description of a master science teacher. Cindy commented that she didn’t feel she’d ever be able to become a “master” science teacher; she just wanted to improve as much as she could. In response, Terry used the analogy of new football coaches who are typically given five years to turn a losing program into a winning one. He felt that we should give ourselves five years to become proficient in constructivist science teaching because it required such an investment of time and energy to engage in a radically different type of teaching, for which most elementary teachers were unprepared.

To begin to address our need to become more familiar with physical concepts, Terry invited the group to participate in a monthly series of workshops held at the intermediate school district, entitled “Michigan Operation Physics: The Wonders of Physical Science.” For several years, Terry (a former high-school physics teacher) and a local elementary teacher had led the workshops, which were designed to acquaint both elementary and secondary teachers with physics in a hands-on format. Each of the 14 sessions highlighted a different

topic, such as Electricity, Astronomy, Light, and Forces. Seven topics were taught monthly throughout the school year in alternate years. Although teachers could sign up for all 14 sessions over a two-year period, it was also possible to enroll in individual sessions, as some teachers were only interested in certain topics. The sessions met from 4:00-8:00 p.m. on a school night, with dinner provided.

Beth and I had first met each other several years earlier when we participated in the workshops over the course of one year. Since we had found the sessions to be an excellent learning experience, we encouraged the others in our present group to participate. Karen and Cindy expressed a great deal of interest in participating, whereas Beth felt she probably didn't need to re-enroll. Pat thought she might look at the schedule of topics and pick those sessions that applied to the second-grade curriculum. After further discussion, we all decided to attend the first session in October in which the topic was Mass. After explaining the situation with our science lab, Terry also invited Donna Workman, the lab paraprofessional, to attend without charge. We felt that the experience might help channel her energies in a more supportive and less authoritarian direction.

Terry next turned his attention to the topic of constructivism itself. He described it as a new term that described an old way of teaching and learning. In his mind, constructivism is the most natural way of learning, but this method had gradually been stifled by institutional forms of schooling which required one teacher to instruct a large number of students in an environment removed from

the real world. He gave a brief description of the difference between an empirical, prescribed philosophy of teaching and learning (he used the “empty vessel” analogy) and an interpretive philosophy, which supports a constructivist approach.

By his definition, constructivism helps children develop “intuitive understandings” by giving them concrete, hands-on opportunities to see principles of science in action. From these concrete experiences, children should first be able to describe what they observe in their own words. Abstract scientific terminology and formuli can come much later. When these abstractions are linked to students’ explorations at the high-school level, children will then have the prior knowledge to see intuitively how the formuli and vocabulary fit with what they have already experienced.

Because constructivism builds on a child’s prior knowledge, Terry told us that pretesting at the beginning of a unit is a vital piece of this type of teaching. It is imperative that the teacher understands what personal hypotheses the children bring with them so that any misconceptions can be “attacked” during the course of instruction. As an example, he cited the work of a Michigan State University researcher who was teaching a group of elementary children about heat. During the course of preparatory interviews with the students, it became apparent to the researcher that the children believed that a hat kept them warm in the winter because it *produced* heat. She asked the children how they could prove that a hat actually produces heat on its own. They placed one thermometer inside a hat and one on the table next to it and checked them periodically to see if there

was any difference in temperature. When it became apparent that there was not, one child said, "Wait, maybe you have to put it on your head for it to turn on!"

They next used a mannequin with hair because the children felt that the hat wouldn't "know" the difference between a fake head and a real head. In this way, the children were able to investigate and disprove their own naïve hypotheses.

Terry modeled this type of teaching by leading us through a hands-on experience of our own. He opened by saying:

I brought something here, not a hat....The wonderful thing about constructivism is that you can introduce concepts to kids that a traditional teacher wouldn't even think about introducing until maybe high school. And this is one example.

From his bag, he pulled out some devices and distributed one to each of us. Each device consisted of a clear flexible tube nearly filled with water. Connected to each end of the tubing was a plastic syringe. The two syringes were of different diameters, one quite thin and the other quite wide. By pushing on the plunger of one syringe, the water would force the plunger on the opposite end of the tubing to partially eject. Terry asked us open-ended questions as we began to play with the devices, "Tell me what you're experiencing with this. What do you think is going on? Not necessarily what you think is going on, but what do you feel?" A back-and-forth conversation resulted in which we offered our observations, and Terry probed us further.

Pat: The little one gets pushed out a lot further than the big one does.

Terry: The little one goes out a lot further than the big one moves.

Cindy: And I like doing the little one better.

Terry: Why do you like doing the little one better?

Cindy: It feels nicer. It's harder to push the big one. It's not as much fun. The other one goes so nice and easily.

Terry: Oooh. The little one is easy. The big one is hard. Wow. Well, I tell you, in about a minute and a half, you've already identified two of the most important principles in hydraulics.

Terry explained that in high school, these principles typically would be introduced through formulae or "magic math": the diameter of the pistons compared to the distance traveled. The force with which each piston is ejected can be predicted by the diameter of the pistons. With no connection to the real world, however, few students will form an "intuitive understanding" of hydraulics. Terry told us that the most important thing for elementary teachers to do is offer hands-on experiences for students to reflect back on and build upon. Later on, the mathematics won't seem like "magic"; the formulae will be a natural extension of their prior knowledge.

The group, unfamiliar with the principles of hydraulics, was quite intrigued by learning something new. Terry explained that this is the same system used in disc brakes. He demonstrated how he would make that connection for students: "Now when your parents came home last night and pulled up to the garage, they stuck their foot out on the pavement to stop the car, right?" He suggested taking kids out to the parking lot and showing them an actual disc behind a tire. Cindy exhibited a great deal of interest in the topic and continued the discussion by asking Terry more questions about how the model hydraulic device related to real-world mechanical devices.

Terry Farmer's presentation to the group was a great success. He provided us with the kind of introduction to constructivism that we had hoped to see at the three, half-day inservices the previous year. He clearly articulated what this type of teaching looks like, both through his explanation and his actual teaching during the lesson on hydraulics. He got the group excited about learning science during the lesson, and it was obvious that the group gained confidence as it felt comfortable grasping what previously would have been an intimidating concept. In addition, he took some of the pressure off the more novice members of the group by acknowledging how difficult constructivist science teaching is. Rather than making us feel we had to "catch up" to the rest of the teaching profession, he lauded us for setting a challenge for ourselves and working so hard to improve.

It is interesting to note that as we worked with Terry throughout the year, it became apparent that he often used masculine analogies, such as the football coach analogy discussed earlier in this chapter and the hydraulic brakes connection discussed above, to demonstrate real-world connections and to explain his ideas. I don't believe that this alienated any of us, but it is interesting to note how the language, analogies, and metaphors he used never made connections to real-world contexts that were more familiar to the women he was trying to assist. Personally, I had little interest in taking my students out to the parking lot and crawling under the car to show them where the hydraulic brakes were located (even though I'm sure it would have been a meaningful experience for some of my students)! But I also know that there was some method to Terry's

madness: he told me that he often chose the hydraulic syringe devices as a method for introducing constructivism, because so few people have had any exposure to how they work. We had to construct our own explanations for what we observed, because we had little prior knowledge of the principles of hydraulics. No one could give the secrets away, or jump to sharing the formula. We were all exploring, observing, and constructing knowledge together.

During the discussion at the end of this meeting, the group decided that we needed to make some changes in our time-line of activities for the year. After Terry offered his opinion that this type of teaching could take years to master, it seemed inappropriate to begin videotaping and critiquing each other early in the project. I suggested, and the others agreed, that we spend the first few meetings familiarizing ourselves further with the new science reforms and watching more professionally-prepared videotapes that modeled this type of teaching. We would wait until later in the fall to begin the videotaping. I hoped that this would help reduce any nervousness the members felt and also reduce the pressure some of us might still feel to "perform" constructivist teaching the "right" way on camera, after such a short time working together.

We also realized that our plan to concurrently teach life science, earth and space science, and then physical science would not work. Due to an integrated thematic curriculum in second grade, Pat would be doing her units in a different order. Thus, we agreed to familiarize ourselves with constructivist teaching methods in general for the first few sessions, at which time I would conduct a second round of interviews. Part of the purpose of this set of

interviews was to ascertain the extent of the group's progress in familiarizing itself with constructivism. I was also interested in hearing each member's opinion of the study group's effectiveness along with suggestions for improvement. In addition, I was trying to determine our readiness and willingness to begin videotaping and sharing our own individual science lessons.

At the time we made the decision to delay videotaping, I felt that I was enabling the teachers to feel more comfortable. Delaying the videotaping would allay some of the nervousness and fears a few of the group members had about being filmed and exposing their teaching to others. In retrospect, however, I feel that I inadvertently contributed to the notion that this professional development effort would be modeled on more of an Instructional Theory Into Practice (I.T.I.P.) paradigm (Hunter, 1982) than a constructivist paradigm. This was certainly never my intention. Still, it appeared at the time that we first needed to see "models" of constructivist science teaching, then "practice" it ourselves, and finally have our peers "check our understanding." If we "got it right," we'd be free to practice independently the next year. We were having a great deal of difficulty breaking away from this more prescriptive instructional model in our own learning.

Looking back, I'd like to be able to say that I was cognizant enough of this irony at the time to be able to guide the group away from a Hunter model toward one of learning that more nearly approximated what we were trying to do with our own students in science. It is hard for teachers to break away from feeling that they should be seen as knowledgeable and having all the answers, at least by

their students, and instead embrace the notion that we are all works in progress, lifelong learners who are always refining our ideas and practice. But at the time, I was not cognizant of this irony. I learned through my experience and through my reflection, and in the process became further enlightened as to how difficult it is to recognize and shed the trappings and habits of mind we are indoctrinated with.

The Third Meeting

Our next meeting was held in the library after school on September 19, 1996. Once again, we had snacks and chatted while we waited for all of the group members to arrive. A couple of us began spontaneously sharing positive experiences we had had in teaching science during the first three weeks of the school year.

Pat told us that her second-grade class was studying the life cycle of the butterfly, and she had ordered Painted Lady caterpillars from the Carolina Biological Supply Company. The caterpillars arrive in small plastic cups covered with a porous paper and a plastic lid vented with air holes. Each cup holds two caterpillars along with a supply of food, which looks something like firm, grainy peanut butter. Over a span of two weeks, the caterpillars consume all of the food. As they grow, they expel small round fecal pellets. Once the food has been consumed, the caterpillars crawl to the top of the cup where they attach themselves to the porous paper. There they hang by one end, curled into a "J" shape. At some point during the day, they form a pale green, shiny chrysalis. It happens very quickly. After having raised these caterpillars several times in my

own classroom, I have never actually seen the chrysalis forming or the adult butterfly emerging from the chrysalis. In order to catch one of these magical moments, I feel a series of student “observers” would have to be stationed near the containers throughout the day. I have spoken with other teachers who have also been frustrated by “missing” the key moments of metamorphosis.

Much as the Whitins (1996) had in “The Year of the Birds,” Pat stationed student observers near the cups and asked them to report what they saw. She shared a humorous story with us. One boy who had been observing said, “Mrs. Stevens, I figured out which end is the head.” When she came over and asked him how he had determined this, he replied, “Well, I was watching this end, and I thought it was the head. But then something came out, so I knew that that was the poop end, and the other end was the head!” Pat expressed some lament that we were not starting the videotaping yet, as she felt she was missing some moments that she would like to have shared with us. This was not surprising, as she had looked forward to the videotaping as the component of our study group that she felt would be of the most benefit to her.

This situation presented an instance in which the formal structure of the project interfered with an activity that would have been helpful to one of the participants. As a novice researcher involved in doing a dissertation study, I did not feel comfortable veering away from the study parameters we had set. In retrospect, I would have liked to have had Pat feel free to begin videotaping her teaching when she felt it was appropriate for her, as opposed to when the rest of the group reached that point. Since she had already participated in another

professional development project that involved videotaping, and had positive memories of this experience, she already had overcome some of the anxiety this activity produced.

The fifth grades were building “ecocolumns,” which consisted of a terrarium and an aquarium stacked on top of each other made with two 2-liter pop bottles. The aquariums needed duckweed, an aquatic plant, as a food source for the guppies. We were having trouble getting duckweed from The Carolina Biological Supply Company, the usual supplier, so Beth decided to go out and get some from an original source. She headed to a marshy spot off the Ojibway River with her golden retriever and collected a good supply of duckweed and water.

Our class was the first fifth grade scheduled to assemble our aquariums in the science lab. What followed was a genuine “teachable moment.” Unlike the duckweed we received from the company, our sample was “contaminated” with a myriad of aquatic organisms. We found planarians, which we had just been reading about, along with many new creatures heretofore unknown to the kids. A great deal of excitement followed, completely unrelated to the planned lesson, as we got out magnifying glasses, microscopes and slides, and a field guide to identify pond life. We even sliced the planarians and took the specimens back up to the classroom to observe regeneration. I shared with the study group how thrilling it was to see the students’ curiosity sparked as they bustled around the lab, enthusiastically asking questions, and gathering materials for their investigations of the little creatures.

Following this sharing, our group went over some “housekeeping chores” in the meeting. I related that I had talked to our principal about funding for the Michigan Operation Physics workshops. He was checking with Carol Tate to see if we could use Eisenhower funds (federal funds all districts receive annually to support science and math professional development) to cover our attendance costs. I passed out a photocopy of the workshop flyer that listed the dates and topics for each month of the school year. We talked about which topics tied in with our own grade-level science curricula. With time being a premium during the busy school year, most of the group was only interested in attending the sessions that directly pertained to their own grade-level units.

I asked the group to return the consent forms they had collected from their students. The teachers reported that everyone had given their consent, so we had no need to exclude any children from videotaping. I gave each of the teachers extra forms and reminded them that they would need to give one to any new student who enrolled during the course of the school year.

In other business, Pat shared with us that she had received information on the Michigan Science Teachers Association convention, which would be held in Detroit the following February, and that she would bring the information to our next meeting. We also discussed the fact that Tuesdays were getting a bit too complicated for meetings. The ISD inservices were to be held on those days, and Beth had volunteered to be the teacher’s union representative for the building. The monthly union meetings were scheduled for Tuesday nights. We decided to schedule our meetings session to session, as it seemed to be too

difficult to pick any one other night of the week that would always work. It was important for our group that every member participate in each meeting.

I discovered that not all of the group members had read the literature pieces we had planned to discuss at this meeting, so we postponed the discussion until the following session with a joke made about making sure they got their "homework" done this time. I offered to pass out a "reminder note" a couple days before each session, which would include the date and time of the next meeting, along with an agenda of our planned activities. This suggestion was welcomed by the other members.

I was getting concerned about the level of commitment that each teacher brought to the group. I didn't want to have to hound them about doing the readings. I was also worried about the amount of effort they were going to put into making substantive improvements in their science teaching if they were having trouble finding enough time to read a couple of short pieces. When I recruited the members, I was specifically interested in teachers whom I perceived to be dedicated and hard-working, as well as committed to personal growth. If this group of teachers, who were concerned and had volunteered their own time, was finding it difficult to make a commitment, how were those faring that I didn't even approach? How realistic is it to expect teachers to have the time, energy, and resources to engage in sustained reform? As Anderson (1999) states: "Even if the answers to these questions are discouraging, I think that realistic answers are preferable to false hopes based on superficial analyses of how teaching for understanding can be sustained."

We decided to invite Terry Farmer to our next meeting. We would bring our curriculum binders and ask him for suggestions on how we could introduce our second science units with a “bang” in an effort to really spark the students’ curiosity and excite their interest.

The rest of this meeting was spent viewing and discussing the Kathy Roth (1991) “Science For All” videotape, which I had originally planned to share at our first session together. In contrast to the “Teacher to Teacher with Mr. Wizard” video, this production focused on the *children’s* questions and understandings. In the video, Kathy is seen introducing a unit on photosynthesis by brainstorming with the students a list of substances they think provide food for plants. At the end of the 25-lesson unit, several of the students are interviewed on tape as they explain what they learned, answer questions about their science experiences in general, and talk about how they learn best in science. The students’ responses provide a powerful confirmation of the benefits of constructivist science teaching, both in terms of learning achievement and student interest. During the course of the tape, the student interviewees repeatedly stress their opinion that hands-on, engaging science activities, such as those experienced in the photosynthesis unit, help them learn more than traditional, didactic methods ever did.

The Kathy Roth tape provided another excellent example of constructivist science teaching in action, but it offered our group another perspective: that of the students. After hearing the students describe the positive attitudes they had about this type of science instruction, the group discussed how important it was for us to work toward this type of teaching. The group also was impressed with

Kathy's introduction of the unit. Wearing a "plant" costume, she engages student interest and activates prior knowledge through the brainstorming session. The lesson presented a vivid example of the misconceptions, opinions, and ideas children bring to their learning experiences, and how vital it is to tap that prior knowledge before planning lessons. Pat expressed special interest in getting ideas for starting her next unit in a similar fashion.

The Fourth Meeting

The fourth meeting of the study group was held on October 7, 1996. Everyone had done her "homework," so we began by discussing the "Year of the Birds" piece and the chapters from *Elementary School Science for the 90's*. Beth commented that she saw a lot of connections between the powerful science teaching described in the chapters and the type of mathematics teaching she was espousing in her previous position as middle-school math consultant. She stated:

As I read through it, a lot of it I could apply to what I knew about math because that's where my strength was. And math went through the same stages. At first, everything was hands-on, hands-on, hands-on, and all of a sudden it was, "Ooh, we're not making those connections." So we started talking about how do you transfer that over, and how do you combine it all together.

I saw that in this also when it said that exemplary science learning is promoted by both hands-on and minds-on instructional techniques – the foundation of constructivism. And it just talked about the importance of not just doing the hands-on activities, but to really talk to students about whether they learned and to really pull that together, and to add it to their preconceived notions that help them restructure what they believe. And unless we do that, they don't seem to "get it." And they don't even listen to what we're instructing if we don't do hands-on and help them apply what they've done to the real world.

Pat agreed, explaining that the second-grade math curriculum was non-textbook based. The primary teachers had been trained in constructivist mathematics teaching in which they probed student thinking with a lot of questions. Manipulatives were used to a great extent. She also admitted that having two curricula that required a great deal of material set-up and higher-level teacher thinking and planning was very difficult, given the number of other subjects elementary teachers are responsible for teaching.

Karen and Pat both liked the vignettes of “real” teachers that the chapters included, which they felt brought the practice of constructivism to life. Karen said:

I liked those because I think it made it clearer what they were trying to get across. It was interesting to me, that man teacher, he'd taught that unit for how long? So he really knew his material, and I think you really have to know your material before you step into it. And know enough to modify it. You have to really know what you want them to learn from this. He could sit down and do that because he knew what he wanted.

Karen was making important connections back to one of the perceived personal deficiencies she expressed during the initial interview: her weak background knowledge in science. She relied heavily on the Silver-Burdett science textbook and the science lab paraprofessional because she felt unprepared to develop and guide her own lessons. By working toward her goal of improving her content knowledge, she felt she'd be better able to critique and modify lessons, and ask students appropriate guiding questions.

The group discussed how important subject-matter, background knowledge is. Without a strong familiarity with the science concepts included in the curriculum, it would be impossible to ask appropriate questions or to develop

a series of activities because the teacher would be ignorant of the understandings he or she wanted the children to develop.

Following this discussion of the readings, Terry Farmer arrived to offer us guidance on kicking off our next units. We had each brought our science curriculum binders and shared with him our specific unit topics for the year at each of our grade levels. Each of us had started the year with life science. The third through fifth-grade teachers were moving on to earth and space science for their next unit, while Pat planned to teach physical science. She was focusing on integrating her curriculum with other subject areas, and the choices she made for sequencing her science units made the most sense to her given this other goal.

At the fifth-grade level, the earth and space unit was called “Changing Landforms.” The bulk of the unit consisted of a Scholastic Science Place kit which included student textbooklets, trade books, an introductory video, reproducible black line masters to accompany the many experiments, assessment materials, a teacher’s manual, and a large laminated K-W-L wall chart.

The unit began with the video, a fast-paced, glitzy production in which a group of preteens has discovered a perfect cast of an extinct miniature rhinoceros set inside a large rock they have cracked open after a rock-collecting expedition. They are mystified as to how this perfect shape could be contained inside the rock and set out to interview various experts to find an answer. Each person gives them a different explanation. Without a firm answer, the video

students as well as the students watching are challenged to find out for themselves a solution to this puzzle.

The rest of the unit leads students through activities focusing on volcanoes, earthquakes, plate tectonics, rock formation and identification, glaciers, and erosion. After having taught the unit the year before, Beth and I had some concerns about the unit's sequence of activities. The unit begins with rock identification, but Beth pointed out to Terry that the students had not yet had an introduction to how sedimentary, igneous, and metamorphic rocks are formed because the unit does not teach about layering and volcanoes until later. Therefore, we wondered how to start this unit so that students would not be confused about rock identification due to a lack of prior knowledge about the rock cycle and the causes of rock formation. We felt that it was inappropriate for kids to learn how to identify rocks as sedimentary, igneous, or metamorphic without having an understanding that these labels originate from the way in which the rock was formed.

In response, Terry asked us this question: "If kids spent a year traveling around the United States, would they understand about different landforms?" When we agreed that they would because they would have firsthand experience observing volcanoes, mountains, glaciers, etc., he told us that we need to recreate that experience for them as much as possible. On his way into the building, he had noticed the large piles of dirt associated with the new classroom-wing construction excavation. He suggested that we create a real-life archeological dig outside from the piles of dirt. For example, he advised that we

create several layered piles, and place marine fossils at the same level in each group's pile. From that, students could conclude that water had covered the land at that particular point in time. This activity would be a reconstruction of what a real geologist would actually do in a dig to determine a geologic timeline.

Although we realized that this would be a great learning opportunity for the students, Beth and I admitted to Terry that we were a little leery about the practicality of working on such a large scale. Beth reminded him that this unit would be taught during the winter, and I asked if we could set up the activity on a smaller scale indoors, in tubs or some other type of containers. Terry was quite excited about the unique opportunity presented by the construction piles, however, and urged us to do it on a grand scale. I also felt that he had evaded our original question about the sequencing of studying rock formation and rock identification. While the large-scale archaeological excavation might be a great way for students to engage in a close approximation of real-life geological work, it didn't directly address the problem we were having with sequencing the rock lessons. At the time, I didn't really see this because I was distracted by the thought of Beth and I taking on this proposed activity, which seemed rather daunting to me. This is an instance in which Beth and I negotiated what was to us an unreasonable suggestion, and made a conscious choice not to follow Terry's advice.

The rock dilemma continued to plague us. We ended up teaching the lessons in textbook sequence again for that year, but we still were not satisfied with the amount of confusion the children experienced in the rock identification

lesson. We recognized that there were difficulties for children created by the sequence of lessons the science kit laid out, but we really didn't have enough scientific expertise in earth science to redesign the unit for better student understanding. Although Beth and I had both had several courses in earth science during college, which helped us recognize the problem, we did not have a strong enough knowledge base to resolve our dilemma.

Time was also a factor that kept us from expanding our knowledge base, investigating alternative sequences, and then working to redesign the unit. As elementary teachers, we were generalists. Devoting a large amount of time and energy to redesigning one unit was not a high priority, given the other demands the elementary curriculum placed on us. We also were constrained by a prepackaged kit and accompanying materials that were difficult to adapt. In the long run, it was much easier to simply use the kit and accompanying books and materials in the sequence prescribed.

We next turned to a discussion of the fourth-grade Earth and Space unit, "The Solar System." Cindy expressed her dissatisfaction with the unit based on her previous year's teaching experience. She felt the teacher-created, district unit overemphasized the concepts of rotation and revolution simply because the fifth-grade, standardized, science MEAP test assessed students' understanding of these planetary movements. The problem lay in two areas. First, the terms sounded so similar, it was easy for students to confuse the two words, even if they understood the differences between the two types of movement. While both motions needed to be understood, Cindy wanted a better, less confusing way of

teaching the terms so that students could keep them clear in their minds.

Secondly, the little moon, planet, and sun models that depicted revolution and rotation when the students turned a crank didn't work very well. These concerns arose again when Karen videotaped herself teaching the lessons on revolution and rotation and shared them with the study group. The group's further discussion of this dilemma will be presented in Chapter Seven.

Terry explained that many misconceptions can arise from a poorly taught unit on The Solar System. He advised against using the little earth, moon, and sun models because it complicates the teaching of eclipses. As the crank is turned, and the moon and earth move, it looks like a solar eclipse occurs every month because the little moon aligns perfectly between the sun and earth, blocking the sun from view. The little model does not accurately depict the true sizes and distances between the sun, earth, and moon, or the true path of the moon around the earth. The misconceptions that form in students' minds after using this oversimplified (and thus inaccurate) model are difficult to alter once they become enmeshed in students' understandings.

Other misconceptions occur as students are taught to underestimate the sizes of and distances between bodies in outer space. It is common for science textbooks, student astronomy books, and solar system models to show inaccurate and disproportionate measurements in solar system illustrations due to the impossibility of illustrating accurate sizes and distances on two adjoining pieces of text in a standard size textbook. The true size differential between the sun and the earth is mind-boggling: the sun is 1.3 million times greater than the

earth. Only a portion of the sun would be able to fit on an 8 1/2" by 11" page, in comparison to even a tiny-sized earth. Books that show all the planets lined up in a nice little row extending out from the sun are inaccurate and fuel misconceptions.

Terry felt that one of the most powerful experiences a unit on the solar system could provide is to give students an accurate picture of the true distances between the planets. He described an activity that Beth and I had participated in a few years before during the astronomy session of Michigan Operation Physics. Using a half-mile long stretch of sidewalk, it is possible to pace out groups of students, holding signs that represent each of the nine planets at the correct proportional distances from the sun. The students representing the inner planets stand almost right next to each other. It then takes a half-mile to illustrate the distance to the outermost planet. Students can then see for themselves how the sun would look like a little star from a viewpoint on Pluto or Neptune, and they can appreciate how cold it would be with so little of the sun's warmth reaching it. Terry offered to give Karen and Cindy a copy of the directions for this activity, and also offered to come out and help conduct it with them if they would like. They agreed to take him up on this.

The presentation of this activity led to a group discussion about the uses of measurement in science, after which we discussed Pat's next unit. She would be moving on to her physical science unit where the topics were Heat, Light, and Sound. Terry felt that this was too much material to address in one unit and commented that the inclusion of all three concepts threatened to compromise

depth for breadth. After looking over a scope-and-sequence matrix for the elementary science curriculum, we discovered that Heat, Light, and Sound are not taught again until seventh and eighth grade. Terry felt that this was something that needed to be revised, since another concern was that it would be developmentally inappropriate to address some of the more difficult material at the second-grade level.

In the meantime, Terry had some suggestions for Pat for teaching the Sound portion of the unit. He advised us that the most important understanding for the children to grasp is that all sounds are caused by vibrations. He had several activities to offer for teaching this concept, such as rapping a tuning fork and letting the children dip it in water to see the waves produced by the vibrations. To illustrate how wave length affects sound, and to demonstrate how pitch can be raised or lowered, he explained how to make some homemade "guitars" out of boards, screws, and guitar string. By connecting guitar strings to screws at each end of the board and letting children experiment with the sound produced as they tighten the screws, they would hear, see, and feel firsthand how pitch rises with a thinner string. A tighter, thinner string cannot vibrate as much, thereby creating a lower wavelength and a higher-sounding pitch.

Pat asked if it would be possible to demonstrate this with just one apparatus, but Terry responded that it was very important for each child to experiment with tightening the screws themselves. He commented:

If you hold one up and show the kids how the sound changes as you tighten the screws, they'll learn that the pitch changes as the string gets tighter. But unless they do it themselves and try tightening it themselves, they won't remember whether the pitch rises or falls. They'll just

remember that it changes. Kids need to feel it themselves, feel the screws tightening and the string stretching and twanging, and then they'll never forget it.

While it may not be a certainty that all children will remember everything they learn from hands-on activities, I think that Terry was trying to emphasize the importance of putting the materials into children's hands as much as possible. I know a teacher (known for his enthusiasm and energy) who does many neat science demonstrations in front of his class. He feels that these are just as effective and much less work than setting up the same activity as a hands-on student experiment. The problem is, he's always the one having fun, while the kids just sit there and watch. Reflecting back on my own experiences learning something new, I always remembered more when I had to do it myself the first time, as opposed to when someone had just shown me.

Given the historical nature of elementary science instruction, perhaps Terry was emphasizing the importance of letting kids muck about and get their hands dirty. Conducting a demonstration still places the teacher in the role of "all-knowing" dispenser of knowledge. Placing the materials in children's hands places them in the role of experimenter, demonstrator, and self-guided learner. When children are given the opportunity to be scientists, they are more likely to raise thought-provoking questions and discover new things on their own. While "knowledge retention" may be better as a result of hands-on experiences, a more important benefit is the children's opportunity to engage in scientific behavior and personal experimentation and meaning-making.

Our discussions regarding the appropriate pedagogy to use when teaching science links back to the four orientations toward science teaching discussed earlier (Anderson & Smith, 1987; Smith & Neale, 1991). We were all convinced that strictly didactic forms of science teaching were ineffective and often alienating to students, but we struggled with our wavering orientations to activity-based teaching and discovery teaching. We were engaged in a conceptual-change model of learning ourselves, as we addressed our previous and present conceptions of what constructivist science teaching entailed. During the year, we negotiated these changing beliefs with ideas about how we wanted to change our practice. It was often difficult to clarify what we believed excellent science teaching looked like, and at times we were so pressed for time we wondered what “good enough” science teaching looked like as well.

We wrapped up the meeting by discussing the Michigan Operation Physics workshops. I had received approval for the group to attend at the district’s expense. Donna Workman, the science lab paraprofessional, eagerly agreed to participate. We discovered, however, that the October session fell during conference week, so none of the teachers would be able to attend. Therefore, we all registered for the November session when the topic would be Matter.

At this point, I decided to take a break from the meetings and schedule a second round of interviews. The group had covered a lot of ground, and I felt it was time to step back and assess what we had learned. I also wanted feedback from each participant regarding our activities so that we could continue to meet

everyone's needs. After meeting together four times, some of the needs each member had initially expressed may have changed. I also wanted to ensure that the study group was indeed a beneficial experience for each teacher. If it wasn't, I needed to know where the trouble lay before we proceeded further.

I made arrangements to schedule individual interviews over the next month. We would meet again at the "Matter inservice" in November. This would not be audiotaped as an official group meeting because this was a public meeting involving teachers from many school districts who may have felt uncomfortable being recorded during discussions, and who had not consented to being audiotaped. In addition, Beth would not be in attendance, as she had decided not to enroll in the sessions for what would be a second time.

The Second Set of Interviews

The second round of interviews (see Appendix D for interview protocol) revealed some obstacles to implementing constructivist teaching. The gung-ho enthusiasm exhibited during the summer interviews had given way to the harsh reality of a new year of teaching demands. As a whole, the teachers expressed frustration in having to cope with these obstacles. They did not seem to be listing excuses but appeared sincerely bothered by their inability to give less than their best to students.

Time was a precious resource for elementary teachers in the Ojibway School District, as it is for most teachers. All of the teachers complained that lack of time was an obstacle in improving their science teaching. Several years before, when Karen and the other librarians had lost their positions to

paraprofessionals, other cost-cutting measures had been taken as well. The three-year teaching contract between the Ojibway Board of Education and the Ojibway Teachers Education Association for 1996-1999 detailed the cost-cutting changes that had been made. Physical education, art, and music had been reduced from a full year of instruction to only semester-long courses. While physical education had since been reinstated to a full-year program, the time had been cut from 40 minutes to 30 minutes in length.

The teacher lunch "hour" also had been reduced from 40 minutes to 35 minutes. In addition, legislative action at the state level had increased the required number of instructional hours. Fifteen minutes were added to the elementary day at the beginning of the 1996-97 school year, and fifteen more were to be added in 1997-98. Therefore, teachers were now responsible for planning for a longer day, while at the same time seeing special subjects (art, music, physical education) reduced from four periods a week without students to only two periods. Teachers were having a difficult time coping with increased student contact time along with decreased planning time, and reflected back longingly for the former schedule.

At this stage, the teachers were all hoping that the current contract negotiations would restore the special-subjects program and hence their planning time. This topic dominated lunch-hour discussions in the teachers' lounge. A letter was fired off to the negotiation team expressing our hopes. Many Westdale teachers attended a negotiation team forum, which became rather heated. Elementary teachers and secondary teachers (who still enjoyed a planning hour

each day and had not had their instructional day lengthened) were in heated contention: while we wanted planning time restored, their priority was a pay raise.

This was the context in which the study group was attempting a voluntary, major professional development effort. Lack of preparation time was affecting our teaching in general, not just this project. I personally felt that I was more stressed due to the fact that I had to be “on” for hours at a stretch with no break. I needed time off from the kids to relax, to set up materials for hands-on lessons, to talk with colleagues, duplicate materials, etc. I know that the kids missed their special subjects, and I’m sure they missed having a break from me as well.

While other obstacles were mentioned, lack of free time to plan, set up materials, and reflect was the major issue that arose in the second set of interviews. At this point, I think the group was dwelling on this issue to the point where it created some immobilization. Due to the district cuts and the legislative mandate, the teachers were in a period of transition that happened to coincide with this project. They had not yet accepted the reality of their situation and were determined to fight it. It was a reality that I still feel should not be accepted. The question was then and still is: “How can teachers be expected to do more and do it better with less time to prepare, plan, and collaborate?”

Although the current obsession with time probably had a negative effect on the teachers’ predisposition to dig into a change effort at this point, I feel the stand they were taking had a positive effect. The teacher empowerment they were initiating as they made their voices heard to the negotiating team and to the

school board mimicked the actions we were taking to provide ourselves with the professional development, collaboration time, and support the district had failed to provide us.

Beth's Story

For Beth, time was a concern, with respect to how she wanted to resequence the curriculum unit on landforms. She had ideas for how the landforms unit should be changed, but she was having a great deal of difficulty finding the time to plan for making these changes in her actual instruction. She said:

We had the meeting with Terry Farmer, and he talked a little bit and gave us some things to think about, but when do you find the time to plan for those things?... Like I said, a lot of it is the time issue, of not being able to have enough time to really think about it and prepare. I'm really frustrated in that I don't see this thing [lack of planning time] changing. I see us having to adapt to it, and I find myself spending a lot of time after school trying to keep up with the management things, but it's not making my *teaching* any better.

Beth wanted to rework the landforms unit to address the concerns she had had the year before. She had decided that instead of teaching about the three types of rocks and rock identification at the beginning of the unit, she would teach the students about each type of rock as they studied how it was formed. For example, she would include igneous rocks during the lessons on volcanoes and sedimentary rocks during the lessons on layering. She realized, however, that the task of reworking the curriculum was much greater than it first appeared. Breaking away from the sequence of instruction the unit kit laid out would create a domino effect of problems. If certain lessons made reference to activities the children had not yet done, then that lesson would need to be

reworked as well. Beth simply didn't have the time to devote to reconfiguring the entire unit, especially when that reconfiguration might lead to the materials being so overly compromised they would be too difficult to use. Therefore, she decided to use the materials in the prescribed kit sequence after all.

The dilemma Beth faced in the Landforms unit illustrated how difficult our task was. The further we dug into this project, the more we realized that our goal of becoming more constructivist science teachers went way beyond changing the way we acted in front of a group of students. We were beginning to find that many of the materials and lessons in our science curriculum binders were less than ideal. This was something that Cindy, with her previous experience teaching in a very progressive district, had pointed out in the initial interview. As a member of the Science Curriculum Committee who helped create these curriculum materials, I think that pride kept me from fully agreeing with her at the time. However, there were difficulties with the teacher-created curriculum materials, (although many of these difficulties have surfaced slowly over the past few years that the curriculum has now been in place, and were not as apparent at the time). They were created by teachers in the district, many of whom have limited scientific background knowledge and little familiarity with designing conceptual-change-based lessons and units, and little experience with selecting externally-created science materials and kits.

Looking back, I believe that I really had a naive notion of how big our task would be and how much we would be able to accomplish during one school year. None of us had ever participated in a long-term project like this before, and none

of us really knew what to expect. Now we were all coming to the same realization as we spent quite a bit of time amongst ourselves, and with Terry, talking about how to improve our lessons and make them more constructivist.

Beth felt that, so far, most of her actual instructional progress had been limited to becoming more aware of when she was engaging in constructivist practice. She seemed to be catching herself in these moments more often, but they seemed to be just “haphazard, by accident.” She found that she was asking more questions of the students and trying to avoid “giving answers.” Still, she was frustrated that factors beyond her control were slowing her progress toward her goal:

At times, I find myself just getting really stressed about the fact that I know I’m not doing the very best that I can for the students. Actually, I’m doing the best that I’m able to at the time.

While Beth was trying to give herself permission not to feel guilty, at the same time she was determined to overcome the time issue:

So what do we do? Do we roll over, play dead, and say, “Can’t do this,” or do you rise to it and say, “I have to do this because this is what’s best for our children. Now how am I going to do it”?

Beth brought up an interesting point when she commented that she had to make herself find the time to improve the curriculum and her science teaching, even though the context for doing so required that she do that on her own time. I think this is typical of society’s current expectations of women: we can have a career, raise children, do the grocery shopping and the laundry, take care of the home, and teach. We’re expected to do it all, and if we can’t, we organize the delegating of responsibilities to day care centers, cleaning ladies, helpful

husbands, and relatives. Some of the lounge talk regarding our planning time had focused on the fact that the elementary teachers in our district who were predominantly women had always been “doormats.” While the secondary teachers would file grievances and “stand up for their rights,” few elementary teachers ever complained in a political way to the power-brokers in our district. The negotiating team was almost entirely made up of secondary-level men. The one elementary teacher representative was a friend of mine, and she would often comment on how isolated she felt in this group. Elementary teachers’ needs seemed to take a backseat. For example, no one in the study group ever mentioned asking our principal or Assistant Superintendent for release time from our classrooms to work on this project until the final interviews.

The time issue also was on Beth’s mind as she thought about which of the study group’s activities had been helpful and not to her. She was having a hard time giving up her own free time to discuss the curriculum at the other members’ grade levels. She said, “Isn’t that terrible? I don’t really want to hear what you guys are doing. I just want to concentrate on what’s going on for me!” She suggested that we spend part of our meetings breaking up into grade-level partnerships to work on our own but realized that Pat would be left by herself in such an arrangement. She had come to the conclusion, then, that “I just have to deal with it to help these people out.”

As she had begun teaching the life science unit again this year, Beth had set a new goal for herself. She was having a hard time assessing what the individual children were learning and had asked herself, “How do I keep track of

what the children really know? What are their responses?" She was interested in developing some authentic assessments for the unit that would go beyond the paper-and-pencil tests included with the kit.

Cindy's Story

Time for planning also was affecting Cindy, as she stated:

If you asked us what would be the three major -- no, no, make it one, one or two major problems that you find with constructivism, like, "What do you have the most difficult time with," and I will say that I have the most difficult time with planning time.

Like Beth, Cindy was determined to find a way to cope with this obstacle and felt that the study group should zero in on this problem, as well as one or two others we might be able to collectively identify:

That would be the most helpful to me because I've talked about this [obstacles to implementing constructivist science teaching] for 30 some odd years, and there's still the same kinds of problems over and over and over again, and I haven't thought of solutions for them. And maybe with some other people [the group members], we could brainstorm together and think of some ways and try them to see if they work or not.

Cindy was troubled by the fact that the Solar System unit was difficult to teach in a constructivist manner. She felt that this unit just did not lend itself to this type of instructional approach because it's impossible to get "hands-on" with objects in outer space. I told her that Terry Farmer had just told me about a team research project that he would be happy to share with her. The small groups of students who represent the planets in the "spacing out" activity each conduct a research report project on their respective planets and then prepare an informational presentation for the class. Cindy thought that sounded great, but questioned whether doing a research report was a constructivist activity. This led

to a debate/discussion between the two of us that probed our individual definitions of constructivism:

Cindy: Now, is that constructivism, or is that research?

Ellen: I think it's a little of both. I mean, if you have to construct your own report....I kind of look at researching as some of both....

Cindy: See, I don't. I consider constructivist science as scientists learning, totally coming out of your head with manipulatives and not using books. 'Cause once you start using books, it's just another way of teaching science the old way.

Ellen: Mmmm...,but you can't go to Saturn.

Cindy: Exactly! But that's what I'm saying. There are some units that do not lend themselves well to constructivism.

Ellen: So you have to...what do you do? It's as close as you can get.

Cindy: Unless they came up with..., somebody can come up with some wonderful [Solar System] units that would be constructivist. Nobody has bothered to do it. I mean, when they came up with Batteries and Bulbs, they did a wonderful, wonderful, wonderful thing. You could do something like that.

I was thinking on my feet when Cindy asked me whether the research reports were an example of constructing knowledge. At the time, I wasn't really sure whether or not they fit into my definition of constructivism, but I was sure that I valued them as a teacher. My experience having kids do library and computer research had taught me that both individual and group reports were an effective learning activity. Although books and computers do not fit into the general definition of "hands-on manipulatives," when used as research tools they still present a means of student-guided inquiry. As students delve into these sources, they use guiding questions to help them search for and select pieces of relevant information. They find answers to questions and often form new

questions based on what they've found and read. Students can use the research of others to launch their own questions and investigations. These are higher-level activities that many elementary teachers underestimate their students' potential to perform, but ones that have enormous learning potential. Scientists themselves read and write, they manipulate questions and ideas into forms of systemic learning, and they engage in inquiry pursuits that go far beyond manipulating materials and attending to bubbling beakers of chemical concoctions.

Cindy obviously was firmly committed to constructivist science teaching, but I felt she had a narrow definition of what constructivism entailed and was overlooking the ways in which certain instructional methods could be incorporated into meaningful science learning. There are times when direct instruction may be the most appropriate means of accomplishing your learning objective, and there may be times when trying to use a "discovery" approach is like trying to fit a square peg into a round hole. I felt that the planet research report was a worthwhile activity for the students to engage in because the students couldn't go to the primary source (the planets) for direct observation and experience. A field trip to the local community college's planetarium was possible, but engaging in activities similar to what astronomers do would also be difficult, given our lack of sophisticated equipment. In this instance, gathering information through books, computer discs, or the internet would be an effective way of learning both content knowledge and research process skills.

At times, it seemed like the group was throwing the baby out with the bath water. In trying to become more constructivist science teachers, some of the members seemed to feel they eventually should dispense with all direct teaching and textbook/trade-book reading. While all of the members had a goal of making their science instruction more hands-on as they weaned themselves away from the Silver-Burdett textbook, there seemed to be confusion about the appropriateness of some other learning activities. A teacher who is trying to employ a conceptual-change approach should be interested in having students engage in whatever learning activities might contribute to students' understandings and address the misconceptions they hold, but this was a notion that was lost on us at the time as we struggled with what activities fit into the box labeled "constructivist teaching." I wanted to acknowledge Cindy's opinion, however, so I suggested a possible activity for her to try.

We discussed something I had done at the end of our Landforms unit the previous year, which she might modify for her use. The kids had built space probes designed to travel to another planet and survey the terrain for various landforms, rock samples, water, etc. The kids had brought in such items as old phones, wire, cardboard boxes, and tin foil, and had assembled "spacecraft" equipped for exploring another planet. They were able to describe what each part was designed to detect, photograph, transmit, or collect.

Cindy said that she had done a similar activity in which students were to design a spacecraft capable of supporting life. She found, however, that many of

the students lacked the background knowledge necessary to complete this task successfully and required instruction on basic human survival needs. She said:

There's a lot they don't know. See, that's the other thing with constructivist knowledge, when you're teaching in a school system that has a lot of children that haven't had a lot of prior experiences. A lot of our kids don't know that I could feed you all the dried food in the world, but if I didn't give you any water, you're not going to make it. You know, they don't know that. Whereas somebody who's been camping wouldn't think of going camping with dried food but no water. You have to have a water supply or know where to get it.

Cindy's comments suggest that she was still grappling with her own definition of constructivism. She was trying to sort out what the "experts" said and what she knew to be effective teaching from her own experience. She was also thinking about her specific teaching context and trying to understand what forms of direct instruction and other experiences our students might need that other students might not. There were times, such as in the astronomy unit, that a hands-on approach was not entirely feasible, but she felt that there must be some way to make it so -- if only someone with expertise in curriculum development took the time to design the activities. However, other comments she made, such as sharing her opinion that our students needed more exposure to scientific vocabulary, suggested that she valued reading and direct instruction as well. Perhaps Cindy was having a difficult time using her own expertise to craft a personalized definition of meaningful science teaching out of the policy dictates she had been exposed to.

I had interviewed Cindy right after the November Michigan Operation Physics class. Terry told the workshop participants that the most important thing elementary teachers can do is provide kids with a lot of hands-on experiences

because many of the children from inner-city neighborhoods do not have these opportunities to build prior scientific knowledge. While he felt that hands-on learning opportunities are important at all age levels, he advised us to worry less about making connections and learning terms at the elementary level, and focus more on providing plenty of concrete experiences. As middle and high-school science teachers address increasingly more difficult scientific concepts and vocabulary, students need to have relevant, hands-on background experiences to reflect and build on.

Cindy understood this, but she felt there was a lot of pressure not to let kids take the time to explore. The report card, the MEAP state assessment test, and the time limits in the science lab all conspired to squelch the freedom to “play.” But she was trying to remain positive as she concluded:

There’s a way to do it. We just need to...first of all, we’ve got a number of things that ...we have a wonderful resource as far as we don’t have to go to the store every time we have to get something for an experiment. So we do have some very, very neat things. We have it at our hands now. We just need to get it into our heads and our hearts.... That sounds like a 4-H slogan!

Cindy’s comments and our debate illustrated how complex our task of improving our science teaching was. We couldn’t even agree on exactly what constituted best practice. Even when we thought we had our hands on an excellent lesson, our particular teaching context presented problems we needed to take into consideration. Our year of working together was entailing much more than simply following a predetermined path to success. We were learning that there was not one right model of science teaching, just as we

wanted to get away from emphasizing one right answer in science class. We needed to find what worked for us and for our kids. This was a difficult process.

Cindy mentioned many obstacles that were interfering with her ability to improve her science teaching: lack of planning time, lack of lab time, the report card was too constricting, the Solar System lessons weren't constructivist, etc. However, it's important at this point to mention that Cindy had been diagnosed with breast cancer in September. During the course of the year, she would undergo several weeks of radiation as well as two rounds of chemotherapy. Through all of this, she barely missed any school, and she never even considered pulling out of the study group. The treatments were taking their toll, however: she went to bed early every evening. For someone who often had stayed at school until well into the evening, this made a major impact on her teaching. She had a fraction of the energy she had had before.

Knowing what a committed, energetic teacher she had been and was still trying to be, I feel that many of the obstacles she mentioned throughout the interview would not have been factors for her if she were not battling cancer. She herself told us in one of our group meetings that it bothered her greatly that she was unable to perform at her usual high standards. This was probably the most difficult year of her life, and I gave her a great deal of credit for continuing to participate in the group and come to school every day under circumstances I feel would have incapacitated most of us.

Pat's Story

Unlike Beth and Cindy, Pat was quite pleased with the progress she had made so far in adapting her science teaching. As a co-creator of the second-grade curriculum, she felt fairly comfortable with the materials and concepts she was responsible for teaching. Since the study group had begun meeting, she had been focusing on improving her questioning skills in an effort to help the children learn more by discovery. She found she was naturally disposed to give children the answers when they asked questions, so adapting this part of her teaching required some effort. She said:

I try to remember it a little bit more when I'm doing my own lessons with the kids. And maybe stating things differently, or trying to get them more involved, or letting them do more talking and questioning, and not putting so much of my own two-cents worth in there -- which teachers tend to do.

I think I've tried to plan my lessons so its more of an inquiry thing for the kids...give them more time to talk. I think that I am just more aware of trying to do more discovery, letting the kids find their questions and ask their questions, and discover things without me jumping in and saying, "All right, this is how it's going to be and this is what's going to happen, and look for this and look for that." And letting them find it out for themselves. I was pleasantly surprised many times. Things went better than I thought they would.

Pat found that aside from the formal curriculum, she was also looking for those "teachable moments" that would give students the opportunity to engage in scientific discovery. After an unusual early snowfall, she had noticed several of her students eating snow as they waited outside for the school bell to ring. She asked one of the students to bring in a bucket full of the snow. They let it melt in a bowl and then strained the water through a coffee filter to see what was left on top. In this supposedly clean, white snow, they found "all kinds of dirt and cruddy things." The children looked at what they had found under a microscope. When

Pat asked the question, "Do you still want to eat snow?," she heard a resounding chorus of "No!" This created a memorable learning experience for her second graders and helped them see for themselves the additional materials that contaminated the snow they thought was pure, clean, frozen water. It addressed their prior misconception about the purity of fresh, white, snow and was certainly more effective in preventing them from eating it than a lecture would have been.

Because Pat was feeling good about the progress she felt she was making, she was anxious to start videotaping some of her lessons. She had already taught several lessons that she said she wished she had caught on tape. After discussing how we could accommodate her, we decided to move the school camcorder to the science lab. Donna Workman could be in charge of the videotapes and the camcorder, and could easily do the filming in the science lab while the members of the study group taught. We discussed how her role as videographer also would prevent Donna from trying to take over the actual teaching, while at the same time fulfilling her apparent desire to direct the teaching. The study- group members could indicate on the lab scheduling calendar whether or not they wanted to have the camcorder ready during any particular time slot they reserved. This arrangement also would allow any member who wanted to film in her own room the ability to check out the camcorder and tripod from one locked central location (the science lab).

Pat also was feeling the constraints of time, but it was impacting her in a different way than it was the other teachers. While she agreed that she could use more planning time, she was more concerned about actual teaching time.

Both the second-grade science and math programs required a great deal of hands-on materials and manipulatives. It was very time-consuming to set up the needed items for each lesson. She explained:

Yeah, the planning, and actually, you know, to do it. Because we have to do the same sort of thing for math. You know, we're doing all hands-on math. We have no books. So you're setting up all these activities and then talking about them, so that takes forever, too, and it's just [that] there's no time in between to put one thing away and get the next thing out. So I think it's a big time constraint, it's the biggest problem. And then getting the materials and putting the materials away when you're done. So I don't know how that's ever going to change. We'll have a longer day in the future, but it won't make it any easier.

Pat was continuing to feel isolated being the only second-grade teacher in the study group. None of the other second-grade teachers had been interested in joining us, and she missed the sharing relationship she had had with her former colleague who retired. She wanted the study group to make a conscious effort to discuss lower-elementary concerns. She expressed:

I think its helpful to get together and just talk about things that we're doing. Share common concerns, we feel we're all kind of in the same boat. Um, me being the lower-el. person, things tend to get more "upper-elish", so I know that when we had Terry there, you know, everybody got theirs in, and by the time it was time for me, there was no time left. So, it would be nice if there was another person who was lower el. to bounce things off of.

Pat suggested that one way we could address the problem of her isolation as the only primary teacher would be to focus more on the scope and sequence of the curriculum across the grade levels, and how each grad-level's content supported or was based on the other grade-level's. Pat's feedback was an important point for the entire group to consider as we planned our activities for the months

ahead. I was glad that she shared her concerns at this point when we could try to do something to address them.

Pat's isolation illustrates one instance where the formal, dissertation research interfered with the endeavors of the study group. While I had not been able to recruit any other primary teachers at the outset, it was possible that Pat and I may have been able to recruit another member or two now. We could have invited some primary teachers to attend one of our meetings on a trial basis so that they could get a taste of what went on before deciding if they would like to join. However, because this was a formal project with a sequence of activity phases and interviews, it prevented me from attempting to recruit anyone else, even though Pat continued to mention her isolation throughout the year.

I really didn't want anything to "mess up" my little arrangement. I didn't want anyone to quit, and I didn't want to hassle with any new members joining midstream, either. If this had been an informal project, which I would not have been responsible for reporting, I think I would have gone out of my way to include another primary teacher, even if we had to look outside our building. I think the contrived constraints that came with this study group being a dissertation project led to the experience being less fulfilling for both Pat and myself than what it might have been.

Karen's Story

Karen chose not to participate in the second round of interviews. We scheduled an appointed time twice, and each time she canceled the interview appointment. She had been the least active participant in the study group

meetings to this point, listening attentively, but speaking very little during the discussions. I think at this point she was still coming to terms with her role in the group and possibly deciding whether or not to continue participating. I didn't want to put any pressure on her, as it was her right to refuse to participate in the interview. I also didn't want to make her uncomfortable or have her opt to quit the study group. After she canceled the second appointment, I left it in her court. I told her that it was fine if she didn't want to be interviewed at this point, and if a date opened up that would work for her, she could tell me, and I would be happy to interview her then. However, she chose not to do so, and I never brought it up again to her or anyone else.

Reflection and Further Analysis

After completing and transcribing the second set of interview responses, I created a data analysis matrix for the purposes of identifying themes of negotiation among the group members. Through analysis conducted during the course of the study and after data collection was completed, I identified three major themes of negotiation that the majority of the study group members' work, thoughts, and experiences fell into. Figure 4 displays a brief summary of each participant's responses to the questions asked during the second set of interviews, categorized within one of these three major themes of negotiation: negotiation of constructivism and the new science curriculum; negotiation of support relationships with others (study group members, Donna Workman, Terry Farmer, district administrators and the science consultant); and negotiation of

Themes of Negotiation	Cindy's Views	Beth' Views	Pat's Views
Negotiation of Constructivism and the New Science Curriculum	Rigid definition of constructivism as completely discovery-oriented, focused on hands-on investigation with little teacher direction or use of printed material or texts. Certain topics lend themselves or don't to constructivist teaching. Certain assignments are constructivist, and others are not. Felt that some of the new curriculum materials were of low quality or did not fit into a constructivist perspective.	Teacher is the facilitator who guides students to conceptual understandings as they engage in investigations and focused predicting, discussions, related readings, etc. Teacher should let students make mistakes, and then help them think through what happened. Teacher tries not to "tell." Was dissatisfied with the sequencing of the Landforms unit, but encountered a domino effect of difficulties when she attempted to rework the unit.	Lessons should be more inquiry-based, with more "kid talk" and less "teacher talk." Teacher asks more questions and does less "telling." Focused on changing teacher-student interactions so that learning is more child-centered. As the co-designer of the new 2 nd grade science curriculum, she was satisfied with the materials, and was not engaged in any significant negotiation of the curriculum.
Negotiation of Support Relationships with Others: Group Members, Donna Workman, Terry Farmer, District Administrators and Science Consultant	Enjoyed working with others, especially beneficial were sessions with Terry Farmer, ISD science consultant. Meeting in a positive light to work out problems was helpful.	Experience was helpful. Feels guilty that she often was impatient during meetings as we spent time listening to other participants' grade-level concerns, as her time was so limited to deal with her own issues. She had a commitment to help her colleagues.	Wished there were another lower-el. person in the group; felt some discussions over-focused on upper-el. concerns. Found it helpful just to get together and share common concerns and bounce ideas off each other.

Figure 4 Data Analysis Matrix For The Second Set of Interviews *Karen did not participate in this interview

Figure 4 (cont'd).

Themes of Negotiation	Cindy's Views	Beth's Views	Pat's Views
Negotiation of External and Internal Resources, Obstacles, and Constraints that Influenced Teachers' Attempts to Practice Constructivist Science Teaching	Not enough time for planning and lab work. Kids had difficulty making connections between hands-on experimentation and minds-on learning due to students' lack of prior knowledge and experiences. Solar system unit not constructivist. Personal illness. Did not feel she'd made as much progress as she had hoped to; faced lots of discouraging obstacles that she felt slowed the progress she is tried to make. Certain obstacles appeared to be overwhelming.	Not enough time for planning. Sequence of Landforms unit was problematic, but resequencing and redesigning the unit would require an expenditure of time that she didn't have or wasn't willing to spend.	Not enough time for planning and setting up for two subjects (math and science) that were both inquiry-based. Felt isolated at lower-el. in that other primary teachers did not share her interest in science and felt little attention was given to her or lower-elementary curriculum/issues in the study group. She was planning lessons to be more inquiry based and was working on improving questioning skills. Tried to increase opportunities for kids to ask their own questions and follow up with experiments to address those questions.

external and internal resources, obstacles, and constraints that influenced teachers' attempts to practice constructivist science teaching.

As mentioned earlier, lack of time was cited as the number-one obstacle facing this group of teachers in their efforts to incorporate constructivist science teaching into their practice. After analyzing the responses at this stage of the study group's work, it was apparent that while there were some shared opinions, there was also a great deal of diversity among the group members, especially in their suggestions for the group's future work. While Cindy wanted to focus on identifying and overcoming a couple of major obstacles, Beth was more interested in authentic assessment, and Pat wanted to look at how our individual grade-level science curricula supported each other, and how conceptual understanding is built through the years. These were all good suggestions but very different from one another. At our next two meetings, which provided a transition phase to videotaping and critiquing our own practice, we needed to work out some type of compromise. Time would not allow us to focus on each of these issues in depth.

Pat, Cindy, and Beth all felt the group was a supportive venue for sharing concerns, bouncing ideas off each other, and working out problems. However, I think that Beth and Pat's comments about "wasting their time" when we talked about concerns that didn't directly relate to their grade-level responsibilities showed that the group was still struggling to form a nurturing, truly supportive environment for dialogue. Their own personal needs were more important than the needs of the whole group. As time went on, I believe this began to change.

Comments made by the members during both the interviews and group meetings indicated to me that the members were now familiar with the general theory of constructivism, but had begun to refine and negotiate the definitions they articulated in the initial interview. Pat, Beth, and Cindy each expressed a similar definition of constructivism, but one that was individualized to their own teaching philosophy, experiences, and style. While we had some individual differences of opinion regarding its practice, I felt the group was now asking additional types of questions from levels of concern that went beyond, "What is this?" They were now asking, "How do I do it?", "How do I do it better?", and "How do I overcome the obstacles I face as I try to teach this way?" Hord, Rutherford, Huling-Austin, and Hall (1987) outline seven levels of concern teachers experience during innovations:

<u>Stages of Concern</u>	<u>Expressions of Concern</u>
6 Refocusing	I have some ideas about something that would work even better.
5 Collaboration	I am concerned about relating what I am doing with what other instructors are doing.
4 Consequence	How is my use affecting kids?
3 Management	I seem to be spending all my time getting materials ready.
2 Personal	How will using it affect me?
1 Informational	I would like to know more about it.
0 Awareness	I am not concerned about it (the innovation).

(p. 31)

Levels 0-2 are termed *self-concerns* and are frequently experienced by teachers during the planning or early stages of an innovation, such as the questions and concerns raised by the teachers at the mass-meeting for introducing the new Ojibway science curriculum. Level 3 represents a *task concern*, but one that continued to plague the members of the study group during the entire year. The top three levels depict *impact concerns*. Although many of the discussions and actions of the study group members related to impact concerns as they negotiated the new curriculum, we wavered through several of the lower-level concerns during the year as well.

Examining the concerns expressed by the teachers throughout the year illustrated to me that teachers do not proceed through these 7 levels of concern in a lock-step continuum; the process is much more complex and teachers fall back to self-concerns as they learn more about the innovation and attempt to weave it into their practice. As this group of teachers began to explore constructivist science teaching and teach the new science curriculum, new concerns and new questions repeatedly arose from their practice. Some concerns, such as lack of time for planning and set-up, never went away. These concerns remained problematic even as teachers wrestled with higher-level issues such as exploring ways to connect student experimentation with the development of solid scientific, conceptual understandings.

In the initial interviews, several of the group members had expressed unfamiliarity with scientific concepts due to skimpy educational experiences. This was still a problem for them, but the reasons why were beginning to change.

It was no longer necessary to be an “expert” so that all the children’s questions could be answered with the “right” answer. It was important for us to have an understanding of the “big-picture” scientific concepts we wanted children to eventually grasp. This also required a great deal of familiarity and expertise with scientific concepts and processes.

In a science classroom that operates on a constructivist methodology, it is impossible to plan a completely prescriptive lesson for each day. The interaction that takes place between the students and the teacher is more negotiated and equitable than in a traditional classroom, requiring that all parties play an important role in meaning-making. The teacher must have a strong idea of the scientific concepts he or she wants the students to understand, but the process of learning these concepts is somewhat unpredictable and varies with each individual class. As students play a larger role in guiding the learning process, through asking questions, designing experiments, and taking risks, they “muddy” the teaching process. A constructivist science teacher must be responsive and flexible, guiding each group of students toward the learning goal along each group’s different path. While teachers must still have both long-term and short-term goals for learning and accompanying plans, they also must possess an intrinsic familiarity with the concepts being taught, which will allow them to “think on their feet” and adroitly guide and redirect students as they pose questions and formulate hypotheses.

For some of us, expanding our knowledge base would be a big undertaking. Learning how to use that knowledge base to guide children through

meaningful learning experiences based on their prior knowledge and personal hypotheses presented another major challenge.

The group members were struggling with the dilemmas they faced as they were challenged by a new teaching paradigm that caused them to think, plan, and teach in new ways. They were groping with which instructional strategies and activities “fit” with their developing definitions of constructivism and should remain a part of their teaching repertoires, and which needed to be replaced with something better. They were also identifying the teaching behaviors they wanted to work on replacing or improving in order to develop more inquiry-based science instruction. The next two meetings provided a transition phase between exploring the nature of constructivist science teaching and personalizing its practice in our own teaching.

The Fifth Meeting

Our next meeting was held on December 4, 1996, following completion of the second round of interviews. I opened our study group meeting by commenting that everyone was finding the time crunch to be a major obstacle in our attempts to modify our science teaching to a more constructivist approach. I suggested that we spend some time discussing how we could address this problem. Perhaps together we could find some ways to alleviate the problems we were all having.

Cindy said that one way she had found to allow kids more time to play and explore was to set up science centers. She would set up materials for them to experiment with, such as magnets and a variety of objects for the children to

test to see if these would be attracted to magnets. She allowed children to go to the center when they were finished with their regular assignments. However, she had a couple of concerns with this approach.

First, time at the centers was inequitable. Only the children who finished their work quickly and had free time to spare before the next directed activity were getting a chance to participate. Cindy wanted to find a way to schedule center time so that all of the children could have an opportunity to spend time experimenting. Second, she was concerned about the management of center materials. Some of the magnets had disappeared and were expensive to replace. She wanted to provide interesting materials to work with but didn't want things to get lost, stolen, or broken.

Pat shared that she had been using science centers for some time and had worked out a scheduling system that might alleviate Cindy's equity concerns. She, too, had had problems with items getting lost or broken and had found that certain years were worse than others. The previous year's group was rather "wild," and she said she was unable to offer as many center experiences. This year's class, however, was able to keep the center equipment in good order.

Beth had another suggestion for allowing students more time for exploration. She suggested teaching science only two days a week, but allotting a three-hour instructional block on those days. On the days that science was not taught, reading and math could receive more emphasis. I added that my own high-school science classes had operated that way. Biology, chemistry, physiology, and physics were taught on alternate days for two-hour blocks, with a

one-hour session on Friday. The M-W-F group would then have study hall for two hours on Tuesdays and Thursdays, and one hour on Friday. This arrangement allowed more time for experimentation and also made material set-up easier for the teachers. Most of the group agreed that this seemed like a good approach to try. Pat felt, however, that these time blocks would be too long for the more limited attention span of a second grader.

No one had any answers for increasing our planning time. As Pat said, "You stay until 11 o'clock at night!" We all laughed, but there was definitely a sense of frustration with an arrangement beyond our control. Contract negotiations had failed to win back any of our lost planning periods. To help alleviate the situation, beginning next year "floating substitutes" would be hired for each school to provide biweekly planning periods of 45 minutes for each teacher. However, we would be responsible for planning the lesson the substitute would teach while we were out of the room. Being out of the room would also make it impossible to use this time for lesson set-up. This was the compromise that had been worked out, and the group seemed to feel resigned to the situation.

We next turned to a discussion of the Michigan Operation Physics "Matter" inservice we had just attended. Cindy was still very interested in finding ways to introduce her units "with a bang," as she was finding that some of her more "verbal-linguistic" (Gardner, 1983; 1993) students who preferred reading, listening, and discussion activities were less interested in hands-on exploration (a personal learning preference she expressed earlier as well, and that may have

affected her sensitivity to these students). She wanted to ensure that *all* her students would be eager participants as they delved into a new science unit. This was something she felt Terry was adept at: asking the right questions and presenting the right activities that really lured kids in. As Cindy had had to leave the inservice early, I shared with her a demonstration Terry had done for the class at the end of the evening's session.

The main concept that Terry wanted us to learn was that all matter is made up of "little beaters" (a kid-friendly term for atoms). After spending an evening facilitating experiments and discussion, he set up an activity to demonstrate this further. Without offering any explanation, he placed a meter stick on a large worktable, letting one end project over the edge by a foot or so. He then took a section of newspapers apart and began laying pages down over the section of the meter stick that was lying on the table. As he did this, he very carefully smoothed the newspapers down, running his hands along them toward the outer edges. We were all very curious as to what he was doing, especially since he wasn't giving us any explanation. After he finished smoothing the papers, he looked up and said, "Now, watch this." Placing his left hand behind his back, he made a fist with his right hand and with it struck the projecting end of the meter stick. It broke off right at the table edge, just like a stereotypical karate chop. The papers never moved. We were all amazed as he asked us, "Now, why did that happen?" In our small groups, we all reenacted the experiment and discussed our theories.

The answer the class came up with was that the force of the air molecules (the “little beaters”) placed a greater amount of pressure over the surface area of the newspapers than the fist created as it slammed down on the end of the stick. This pressure kept the table end of the stick in place even as the projecting end broke off. Terry had been careful to smooth down the newspapers so that he would remove as many of the trapped air molecules pressing up as possible. The group’s enthusiastic response seemed to indicate that this was a perfect example of eliciting curiosity as well as helping students develop what he termed “intuitive” conceptual understandings.

Our study group returned to a discussion of the “Year of the Birds” article and mulled over some ways we might do something similar in our own classrooms. Beth said that she was planning to set up an aquarium in her room after the first of the year and thought she might try a similar approach, having students observe the fish and write down notes and questions in a journal. Pat said that she had tried a simple goldfish bowl with her second graders and found that the kids had come up with many interesting questions, such as “Does he blink his eyes?” and “Does he sleep on the bottom of the tank when we’re gone at night?”

We reviewed some of the points that had struck us most in the article. Pat thought it was interesting that the children had decided to observe the bird feeders in partner teams, since they had found it hard for just one person to watch and take notes at the same time. They had solved this problem by working in teams, with one partner dictating to the other what the birds were

doing. The students also had placed a tape recorder outside so that they could record the birds' noises. What was especially appealing to our study group was the fact that the *children* had done the problem solving and thinking which led to these extensions, not the teacher. We wanted to create opportunities for that same kind of self-directed problem solving to develop in our students.

The Sixth Meeting

Our next meeting was a short session held on December 12 in which we took care of several housekeeping issues as we prepared to begin sharing our videotaped lessons during the coming winter months. We each brought our calendars to set up meeting times for January, February, and March. Each of us chose one of the meeting times to present our own videotaped lesson. I volunteered to go first at our first meeting in January. Beth also offered to share that month. The rest of the group would take their turns in February and March. Beth, Cindy, and I had already begun some initial videotaping but planned to do more before we chose a lesson to share. We learned that Pat was not currently teaching science, as she was alternately teaching either science or social studies units in blocks (of several weeks in duration). This was one of the reasons she had been so eager to begin videotaping early in the year; she knew she would be switching to social studies later in the fall. However, she had not shared this planning information with me or the rest of the group, so I had not gone out of my way to encourage her to begin videotaping before the rest of us. She planned to switch back to science in January and would begin videotaping then.

We each gave a brief description of the units we would be working on next to give the other members a general idea of the content they could expect to see during our presentations. Beth and I were wrapping up our Landforms unit during the month of January, and both of us planned to show a lesson from that area. Pat would be working on Heat, Light, and Sound. Karen and Cindy were moving from The Solar System into their physical science unit on Magnetism and Electricity. They each were unsure which unit they would be presenting to the group.

Everyone in the group liked Pat's idea of keeping the camcorder in the science lab. This was working out well for those who had already begun taping. As expected, Donna Workman was eager to take on the responsibility of overseeing the camera equipment and more than happy to do the actual filming during class sessions. She also had readily enrolled in all of the Michigan Operation Physics workshops and seemed to enjoy participating with all of the teachers there.

We concluded the meeting by discussing some of Terry's comments from the November workshop. He had given a mini-lecture urging us to emphasize depth over breadth in our science curriculum. There are basic scientific concepts that elementary children need to become comfortable with to prepare them for advanced study as they move through the grades. The concept that matter is composed of atoms, or "little beaters," was one of those major concepts. Terry advised that the elementary science curriculum focus on developing intuitive understandings of those important, basic concepts that lay a foundation for future

learning. Superficial exposure to a wide variety of topics and concepts undermined this goal. Beth reflected on his comments:

You know, I think that's a key. We really need to start zeroing in on what's important that elementary students need to know. They don't need to know everything. And right now, I think that's the thought. You have to teach them everything. You know, cram, cram, cram. Less is more. Now wouldn't it be nice if we could get old OIS [the district's Office of Instructional Services] to figure that out. For all our complaining, that's not going to change. We need to adjust. We need to find a solution.

Many teachers in the district were upset and overwhelmed with the amount of district directives and assessments. As the pressure increased to improve MEAP scores, the central office staff seemed to have decided that the way to raise scores was to cram more content into the school day. Little time was spent focusing on helping teachers improve their actual teaching methods. Instead, increasingly we were receiving packets of materials from OIS that contained mini-unit science lessons on various topics the students had scored poorly on. In general, the lessons were mimeographed from some instructional magazine and were of mediocre quality.

Teachers were feeling overburdened as they were pushed to teach *more*, while at the same time no one was helping them teach *better*. Beth expressed the sentiments of many of the Westdale teachers who did not feel empowered to change what they recognized to be fruitless efforts. We needed the OIS staff to ask us what we needed and to listen to our requests. None of us felt that their little mini-packets were of much value. Once again, however, none of the teachers suggested contacting our assistant superintendent or any of the consultants and telling them how we felt. In the process of negotiating with

people who could support us as science teachers, no one felt comfortable negotiating with the power-brokers in the district who could have been instrumental in enacting policy-level changes.

An inequitable power arrangement was present in the district. Carol Tate was responsible for distributing the mini-lessons, which certainly did not mesh with the tenets of constructivist science teaching espoused in the current reform movement. They were a step in the wrong direction. Teachers were confused and frustrated with these new lessons, which contradicted what they were trying to do with the new curriculum. However, teachers were reluctant to express that confusion and frustration to Tate or the assistant superintendent, due to a perceived notion that teachers' concerns, requests, and suggestions were often ignored. Therefore, nothing was said or done that could have helped the central office staff recognize the contradiction in the review mini-lessons they were promoting.

Of course, this small example of contradictory policy and pedagogy lies within a larger context. The new MEAP science test itself, though an improvement over the previous version, was still largely an inauthentic measure of students' scientific understandings and skills. As with all standardized achievement tests, it was designed to be "objective" and easy to administer to large groups. It was not designed to give the individualized feedback that interviews, portfolios, projects, or other authentic forms of assessment provide. A test that requires a student to fill in little black ovals does not allow for divergent thinking, and the constructed response portions that allowed some divergency

were a smaller proportion of the total test. At the same time the national reformers were advocating the types of higher-level activities that are difficult to measure on a standardized test, the state was putting heavy pressure on schools to improve test scores. The reform movement and the test required different types of teaching and learning.

The new curriculum was geared toward the national reform initiatives and based on the MEGOSE objectives, a by-product of that movement. The MEAP test was also based on those objectives, but evaluated students' achievement of those objectives through a paper-and-pencil test that many critics felt was linked more to reading ability than scientific achievement and understandings. By presenting the mini-lessons, the district was trying to provide the type of quick review, short-term memory activity that might help the students get a few more questions correct on the fifth-grade science test.

The MEAP test weaves a tangled web. Districts like Ojibway felt powerless to complain when their status and financial support were on the line. Teachers felt powerless and frustrated when faced with these new mini-lessons. Many educators remain critical of the test and the ways in which it is used as a political tool. For the teachers at Ojibway who were struggling to become more constructivist science teachers and at the same time being pressured to raise test scores, the message was confusing and conflicting. This atmosphere was certainly not conducive to a meaningful move toward constructivism. Given the context, teachers had to wonder, rightly, how appreciated their efforts were. In many ways, this group of teachers was on its own.

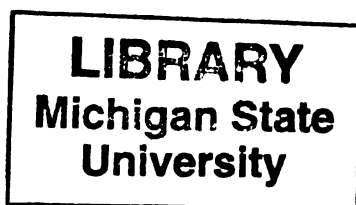
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**THE ROLE OF A TEACHER STUDY GROUP IN
NEGOTIATING CONSTRUCTIVIST SCIENCE TEACHING
IN AN ELEMENTARY SCHOOL**

VOLUME II

By

Ellen Louise Schiller

A DISSERTATION

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CHAPTER SEVEN

Personalizing Constructivism in our own Practice:

Each Member's Videotaped Lesson and Follow-up Interview

I Break the Ice

Beth opened our first meeting of 1997 on January 9 by sharing an account of her class's excitement during a recent field trip to a gypsum mine. The kids were allowed to chip for samples down the length of two mine shafts and bring the gypsum pieces home in tote bags. Their enthusiastic voices had echoed down the shafts as they called to each other, "Over here! I found a whole bunch!" Beth said that this was the best field trip that she had ever been on, either as a student or as a teacher, due to the natural curiosity that overflowed from the kids as they experienced this unique opportunity.

We discussed more ideas to help alleviate our time issue. Beth told us that she was planning out her science units on a calendar. By blocking out time for the whole unit in advance, it was helping her stay on schedule and make the best use of her time. Cindy and Pat shared that they had tried to do the same, but found they still got off track when certain lessons took longer than others or when children needed more time to work through some concepts.

There was a feeling of resignation in the air but also a growing feeling of support. As I listened to the audiotapes of our meetings, I could hear more laughter and camaraderie as the meetings went on. We were learning that we all shared many of the same problems, frailties, and frustrations. Knowing that we

were not alone was helping to alleviate the guilt we felt about not making more dramatic progress in our efforts. At least we could laugh together to relieve the tension, even if we were not making much headway in relieving the workload. For Cindy, the time issue was especially crucial. Staying until 11 o'clock at night was no longer an option. She told us that she was in bed by 8:30 at the latest every evening, because she was so exhausted from her chemotherapy regimen. Beth asked her how this was affecting the way she felt about her job performance. Was she able to let it go? Cindy responded, "No. No. I'm stressed because of it." For someone who had thrown her heart and soul into her renewed career, being physically limited by her own fatigue was extremely frustrating to her.

Before I began sharing my own videotaped lesson, I introduced the Videotape Presentation Feedback Form for Group Members (see Appendix F) to the teachers. The form consisted of two questions with ample room for the teachers to write notes or responses. The two questions were: "Please jot down instances in the video that struck you, either positively or negatively, as you are watching," and "What aspects of the member's teaching did you pick up that will influence your own teaching positively? Negatively?" I suggested that we use this form to jot down our own observations as we watched together. This would help jog our memories as we discussed the lesson afterwards. It would also provide some written feedback for me to keep and think about as I worked to improve my own teaching. The group responded positively to the form, and I suggested that we use it as each of us presented. Cindy laughingly said she

wasn't sure she wanted to read the feedback we gave her. After some discussion, we left it open to each person. If she wanted to use the form and have it openly shared, that would be fine. It also would be perfectly all right to keep the feedback to themselves or not use the form at all when their turn arose. In the end, everyone used the form, and we all welcomed the feedback as the group shared openly during our post-video discussions.

I took a risk in asking for negative feedback as well as positive. I was opening myself up for critique, but I wanted to show the others that I was comfortable with this. If we were to give each other honest feedback, then we could expect to hear negative remarks as well as positive ones. I wanted us to feel comfortable giving criticism to each other, which I thought might be hard for teachers given what the literature says about teachers' isolation and the culture which has contributed to a preference for keeping their pedagogy private (Feiman-Nemser & Floden, 1986; Grimmer & Crehan, 1992). By including a space for negative feedback on the form, I hoped that the others would see that negative feedback would be naturally expected. I hoped that if I opened myself up to criticism, the others might feel more comfortable doing so as well. I was rather surprised that they each decided to use the feedback form for themselves, but the remark was made that it provided them with a written record to reflect back on after the meeting.

I shared a video I had taped the previous month in the science lab. The lesson was an AIMS activity called Peanut Butter and Jelly Geology, which was part of our fifth-grade Landforms unit. Donna Workman operated the camcorder

as I taught. The lesson was designed to acquaint the students with the process by which layers of rock are laid down and how this happens over a very long period of time. The students worked in pairs with slices of white, wheat, and dark rye bread, chunky peanut butter, raisins, and jelly. The activity gave a lyrical description of how the layers of rock in a riverbed are laid down. I read each verse along with the students, and they assembled the layers of "rock" as we proceeded. For example, the white bread represented white sandstone, the dark rye bread was brown sandstone, and the raisins stood for boulders. As they stacked each layer, they made a "rock sandwich." We then used the completed sandwiches to discuss how geologists date rock layers. We also cut the sandwiches in half and used them to demonstrate how sections of the earth's surface move along fault lines during an earthquake.

After watching the tape together, the rest of the group gave me feedback on what they had observed. Cindy felt I had asked good probing questions. She also liked the way I encouraged students to speak up by acknowledging all comments positively. For example, the activity used the word "drought," and I wasn't sure if students knew its definition. When I asked, one girl raised her hand and gave the opposite meaning: she was confusing a drought with a flood. I told her, "You're on the right track." She felt this type of response encouraged students to take risks and offer their thoughts without much fear of embarrassment. Cindy had often voiced her concern over the limited vocabulary of our students. She liked the fact that I often used several synonyms when using unfamiliar words. For example, I had asked the students, "Which layer is

the most recent, the newest, the last layer to be laid down?" My hope in doing so was that each student would be able to comprehend at least one of the terms and add to their vocabulary by hearing all of them.

We turned to a discussion of the instructional methodology used. The group agreed that the lesson was obviously hands-on but not had not necessarily given the students a great deal of opportunity to direct their own learning or investigate their own questions. The students had followed a set of directions, even if they had been phrased in a lyrical, verse-by-verse fashion. Pat thought the lesson included too much teacher talk, but Beth commented that not all lessons suit themselves to a discovery approach. Cindy agreed that direct instruction is sometimes the best approach. Karen noted that much of the teacher talk consisted of me repeating or paraphrasing the students' comments, which she didn't feel was a negative form of "teacher talk." Due to the poor acoustics in the science lab (which was located in the old, soon to be torn-down section of the school), we all realized that we found ourselves doing the same repeating of students' comments while teaching. After further thought, Pat agreed with the observation that the acoustics led her to do the same thing.

Since Beth had taught the same lesson, she focused her observations on specific ways in which we could both teach the lesson better the next year. She thought it would be nice to get some photographs or overhead transparencies of actual rock layers and fault lines. Pat suggested bringing in actual samples of the different types of rocks represented in the sandwich and gave us the name of

a middle-school teacher who sells rock kits and samples at workshops and teacher conferences.

This particular lesson had been preceded by another in the Scholastic Science Place Landforms kit in which students had poured layers of different colored sand into a cup and then taken a “core sample” with a straw. Beth and I had found that the activity didn’t work very well. It was difficult for the kids to get the sand to stay differentiated in the straw. It tended to blend together. Beth thought that the objective of the core sample lesson could be achieved by having the kids take a core sample from their peanut butter and jelly sandwiches instead. I agreed with her that this sounded like a good way of killing two birds with one stone.

I appreciated the honest feedback I felt the group had given me. They pointed out positive features of my teaching that I had not been consciously aware of, such as using synonyms for unfamiliar terms. Being aware of those features would allow me to concentrate on including them in future lessons. However, I also appreciated the constructive criticism the group members offered. Looking at the lesson with a more critical eye, I agree that it was rather “cookbooky” in nature. The students followed prescribed steps that I directed.

However, in looking at the unit as a whole, I think that the lesson did have a place within a series of lessons that had an overall constructivist approach. The ways in which rock layering may have been introduced through a discovery-oriented approach, such as with Terry’s suggestion that we use the construction site excavation piles as miniature archeological digs, seemed unfeasible given

the amount of time we had for planning and preparation, as well as the fact that digging outside in the middle of winter wasn't an attractive alternative. This lesson offered a compromise; it was hands-on but not particularly inquiry-oriented. Given the difficulty in teaching science with a constructivist approach, it is reasonable to assume that classroom teachers may be expected to make many such compromises as they teach science. The context in which elementary teachers do their work is not often conducive to elaborate projects such as the one proposed by Terry Farmer. Time does not allow for elaborate planning for a single lesson; there are just too many other subjects to plan for to allow much time to be spent on one particular lesson.

The discussions that came up regarding whether a particular activity fit the constructivist paradigm like a perfect puzzle piece illustrated that we all held some common understandings yet also somewhat different beliefs regarding the nature of this theory and its distinguishing tenets. At times we became wrapped up in discussions of how perfectly a particular lesson fit that constructivist puzzle, as opposed to looking at the big picture and thinking about whether didactic lessons could on occasion serve a purpose and be the best means of helping students understand a small concept in a larger unit of study.

By this point in the study, I was relieved that the members of the group seemed to be taking our efforts seriously. In the back of my mind, I had worried that everyone would drop out as the group's activities continued to demand their precious time. In fact, the opposite was true. Not only were the members actively engaged in our work, a strong sense of collegiality was developing as we

sought to support each other as professionals and as friends. Some of the teachers' personal goals for professional development had expanded to include goals that would benefit all the members of the group. Beth was concerned with how she could put aside some of her own demands and give her time to helping others. Cindy felt we could overcome some of our common obstacles by selecting two and putting our heads together to address them as a group. As we began the videotape-sharing portion of the study, some of the focus shifted from ourselves to watching and helping our colleagues in the group. It was not until this phase was reached that I think the group realized its potential for becoming a support system for its members.

January 23, 1997 – Beth's Videotape Sharing

Beth also chose a lesson from the fifth-grade landforms unit to share with the group. She began by giving us an overview of the lesson's content and also alerted us to some aspects of her teaching that she specifically wanted feedback on. Beth's strong scientific content knowledge, along with her experience with constructivist mathematics pedagogy, put her further along than other members of the group in terms of already looking critically at her own practice and knowing what substantive questions to raise. The feedback she desired and needed was specifically directed to the pedagogical goals she was focusing on in her teaching.

The topic of Beth's lesson was water erosion. She began her lesson by sharing a newspaper article and accompanying photograph reporting an event from a well-publicized California mudslide the week before. A humongous

boulder (larger than a house) was shown resting on a road at the bottom of a steep hill. Beth asked the class how they thought this huge boulder got there. After many excited guesses, she told them that rainwater had eroded the hill and loosened the boulder, causing it to fall to the bottom of the hill.

Beth then asked questions and gave directions for a simulated rock-slide activity which came from the Scholastic Science Place Landforms kit. Working in small groups, the students were to shape a small, steep mountain out of clay, sand, and dirt and place it in an aluminum pan. They were given small pebbles to press into the mountain. Using a squirt bottle filled with water, the groups simulated a torrential downpour and watched as the pebbles loosened and some rolled down into the pan. The lesson culminated with Beth spending about 5-6 minutes summarizing the experience by asking probing questions designed to help the students make connections between what they had done and observed and the newspaper photograph.

While we watched the videotape, Beth had several points she wanted us to pay special attention to and comment on. First, she wanted us to focus on her questioning skills and offer constructive criticism. She was also debating how detailed the student directions should be before a constructivist lesson. Should she give them step-by-step instructions, or was it more appropriate to let them experiment with the materials and “bumble through and figure it out on their own?” Beth also felt she was moving her hands around too much as she spoke, but thought that might be due to nervousness associated with the videotaping rather than to a regular habit.

As we viewed the tape, Beth pressed pause several times to highlight certain portions of the lesson. At one point, she stopped to comment on how Donna, the paraprofessional operating the camera, was interrupting her. Of the five of us, Beth had had the most trouble reaching a compromise with teaching responsibilities in the science lab. She told us that throughout the lesson, Donna kept reasserting herself and even kept giving Beth “side directions.” She realized that Donna had already been through the lesson twice before when the other two fifth-grade classes had come to the lab, which gave her added insights. But Beth still did not appreciate the “helpful hints.” Beth felt she needed to talk to Donna privately, but she didn’t want to hurt her feelings or appear to be arrogant. She said, “She is organized, she is good. I don’t want to be the arrogant teacher. But on the other hand, I *am* the teacher.”

Cindy and I agreed that that was the problem in a nutshell: Who’s the teacher? Donna wanted to be a teacher, not a paraprofessional, and she was determined to assert her authority. While Donna had stayed behind the camera during my lesson, in Beth’s case, she had set up the tripod and participated in the activity. Beth advised Pat, Cindy, and Karen to ask Donna to please keep filming during their lessons. Donna’s “authoritarianism” seemed to bother Beth much more than any of the other members of the group. Beth also seemed to have the most difficulty appreciating the fact that although Donna could be rather overzealous in ensuring that students used the lab materials “properly,” she also was very dedicated to her job and did have valuable tips to offer. She attended all of the Michigan Operation Physics workshops and went out of her way to do

her best. Beth may have had a hard time getting past Donna's assertiveness in the lab to see the expertise she had to offer.

After we finished watching the videotape, Beth commented that she wasn't sure she agreed with Terry's advice to just let elementary kids do the activities, and maybe she was confused about what he was saying. I asserted that I didn't think he was advocating just letting the students play:

I don't think he's saying just do the activities. He wants them to be drawing pictures and writing about it. He said drawing pictures is very powerful because they have to really understand what they're seeing and really observe it carefully to be able to go through the mental process then of thinking about it to get it down on paper. So I don't think he's saying, "Don't do anything, just play with the activities."

But I think what he's saying is, "Make sure you do a lot of playing. Don't do just textbook stuff. Give them lots of activities." The playing is very important at the elementary level to build an experience base so when they get to the upper grades, when they're going to need to look back at those experiences and then connect it. Because a lot of those concepts are really too difficult to get into the meat of it at this level. But if they just play and do activities now, then in physics and chemistry, they can go on. Because you don't want to give them misconceptions by dummifying it down and simplifying it to the point where in order to help them understand, you think you have to tell them a half-truth. Rather, if it's something difficult, let them play just to build the basis.

Cindy agreed with this opinion, and Beth acted as though this viewpoint made sense to her.

In giving Beth feedback, we all felt that she had asked excellent probing questions and effectively used paraphrasing to help increase the students' vocabulary. Cindy liked the real-world connection Beth had made by bringing in the newspaper article and photograph. Karen was impressed by the excitement Beth had initiated through the use of the photograph and her introductory questions. Beth was concerned that the excitement might have gotten out of

hand and that some of the students might be perceived as misbehaving. Cindy felt this was expected behavior in the science lab where students are generally eager and anxious to be getting their hands into the activity. Karen and I felt, however, that the class did seem to be getting antsy during the directions. I suggested that the introduction and directions might have gone on a little too long. Beth had incited such enthusiasm with the boulder picture, the children were then anxious to get to the materials.

At the end of the meeting, Beth shared her concern that we may be veering away from a textbook-oriented curriculum to a curriculum that includes too many hands-on activities. Almost every lesson in the fifth-grade Landforms unit includes an experiment. She felt we needed more of a balance between informational text and hands-on activities, and that we needed to put more effort into helping students make connections between the two.

I interviewed Beth one week later regarding her video-sharing experience. She conveyed a sense of satisfaction with the lesson and the sharing, and commented on several ways in which the experience had affected her positively. She felt that the group members had given her many compliments on her teaching that she had not been aware of from her own perspective. This made her feel good. She had also had time to reflect on the group's suggestion that she cut down on her introduction time in order to let the kids get started on the hands-on portion of the activity before they had a chance to get too fidgety. She seemed to agree with that assessment and had been mulling this over in her mind since then. She said:

Yes, I accomplished what I set out to do. They came away with understanding the objective. My strengths were that I had them put things in their own words and tried also to insert some vocabulary, but it basically is kid language and kid-generated.

My weaknesses, I think after the discussion, were that I don't let them get in quick enough and learn from their mistakes. That I try to set up things so that they are done right, maybe almost to the point of overkill. From what I understand about constructivism, they need to be allowed to make a mistake and have the whole experiment be botched. And go back and say, "ooh, now I understand what I did. Let me try it again." I think that would've been more effective.

We do learn from our mistakes, but we don't really provide them with all the opportunities to make all the mistakes they need to in science. [Regarding the materials, we say] "Don't touch them until we tell you what to do with them! Exactly what to do with them!"

Beth felt it would be really powerful if we could enable students to learn how to design and set up their own experiments instead of relying so much on "cookbook" investigations in which a set outcome was predetermined. While we were encouraging kids to ask thought-provoking questions, we also needed to encourage them to explore those questions through experimentation. We both felt that this was a high-level skill, but one which would be very powerful for children to learn. She shared some ideas on how her lesson could be reworked to allow for more student input into the hands-on process:

To redo that experiment again, it would have been effective to have said, "Okay, let's go and see, after we saw that picture in the newspaper of the huge boulder." Talk about how can we set up an experiment so that we can really see how much sand goes off of the mountain. You have some clay, you have some sand, you have some dirt, you gave it some water, a sponge so that you can maybe put the water over it slowly, or maybe not even say a sponge.

How are you going to pour the water? Picking up their fingers and trickling it over would've been just as effective. Or a cup. And then to have them build and talk about it in their groups, and then stop them and say, "Okay, let's get some ideas up here on the overhead of the ways we can really do that." Oh, I think that would've been so effective.

One of challenges Beth was grappling with was how to help students begin to design their own experiments. At this age level, most experiments are still rather prescribed. Beth and I both knew that our fifth graders needed to develop the ability to ask questions and design experiments to investigate these personal questions, but we were hampered by our knowledge that our students had become accustomed over their years of schooling to having teachers tell them the questions and the investigation steps they were to follow to answer those questions. Beth wanted to get away from giving these step-by-step directions and was challenging the notion that students needed to be given such precise procedures for the experiment and the materials they would be using.

The district had developed a two-page, fill-in-the-blank, experiment log sheet that listed the steps in the scientific method. Upper elementary and middle school teachers were encouraged to have students complete the sheet as they engaged in classroom experiments, but the impetus behind the sheet was that it mirrored the MEAP science investigation student journal, and using the sheet throughout the year might give students familiarity with the scientific method and raise MEAP scores. Beth and I were more interested in developing students' proclivities to ask questions and engage in inquiry than we were in having them prepare for the MEAP by filling out what we felt was a glorified worksheet.

In Beth's experiment, it really didn't matter what shape the mountain was, how the boulders were placed, or which type of water receptacle was used to reenact a rainstorm. This would have been a good opportunity to give the students some freedom to find their own way, without much chance of missing

the concept she wanted them to learn. In fact, there was potential for additional learning in that student groups could have compared how different mountain shapes, boulder placements, and ways of pouring or squirting the water cause differences in erosion, just as different landforms and the severity of real storms do in the real world.

Beth acknowledged that this type of teaching would likely drive Donna Workman nuts, as she liked to give the students precise directions on material use and often played the role of a drill sergeant as she monitored the students during activity time. Beth suggested that we

need to meet with Donna and say, "Look, this is what we're trying, and we need to really allow the kids to make some mistakes. And in order for them to make some clear understandings about what's the right way and whether they learned, and why this didn't work, what was the mistake here and what happened, and what was the difference when it did work?" Because I don't think right now it's as meaningful for them as it could be.

But, we never did meet with Donna, and to my knowledge Beth never directly expressed her frustrations to Donna on her own either. One of the problems with people who are rather authoritarian is that it's uncomfortable to approach them to discuss their authoritarianism. Donna scared us a little bit, just as she did the kids, and I for one was pretty sure we were never going to enact any radical personality change as a result of a discussion with her. I knew she was hearing the same message Beth wanted to give her when she attended each of Terry Farmer's physics classes, and I hoped this would be a less direct or personal means of leading her to a less rigid attitude in the lab.

This was the first time Beth had ever watched herself teaching on film. She found it harder to watch the tape by herself than with the group. She said:

By myself, I thought, "Oh my gosh am I a flake!" Not related to science at all are some of the little things I do as a teacher to manage the group. I think watching the videotape by myself, it was really hard to focus on what am I looking at here in science. With the group, it helped me focus a little bit more on watching what's going on here in science and not what you're doing as a person. Don't watch what you're doing with your hands, don't watch to see that piece of hair in your face and that kind of stuff. Watching it alone was very hard. Watching it with the group was a little more focused. It gave me some positive strokes in knowing some things that I'm doing right, and it helped me realize some things that I need to change.

The difficulty Beth had in overlooking her personal appearance and mannerisms as she tried to focus on viewing her science teaching brings up an important point. Before we began our videotaping, the group had discussed the vulnerability we might feel about our physical appearance as we shared our tapes with the group. It is difficult for us to realize that others are already familiar with our personal mannerisms and appearance in ways that we are not, because those of us who do not earn a living appearing on camera do not normally have an opportunity to view ourselves from an external perspective.

As we had watched the *Teacher to Teacher with Mr. Wizard* tape, we had commented on the pretty outfits the teacher had worn during the various lessons. After we finished viewing, we laughed about how we may notice similar things when we watch ourselves. It is important to discuss this with teachers before beginning any videotaping activity. Given how rarely we have a chance to see ourselves in this way, it is natural for teachers to focus on personal mannerisms and appearance. We all have a certain degree of self-consciousness that makes videotaping more challenging to do and share. Beth was the only teacher that mentioned her own preoccupation with personal appearance and mannerisms,

but she was able to overcome this and focus on substantive discussion of her practice. If the other teachers felt similar preoccupations, they did not dwell on it and were also able to focus on their teaching.

Overall, Beth felt the videotaping experience had influenced her most by helping her see the big picture of what she wanted to accomplish with her science teaching. She said, "It's really all of a sudden this light bulb going on, and 'Oh, yeah, that's what's important,' and I think that's what has happened."

March 3, 1997 – Cindy's Videotape Sharing

Cindy chose to share a videotape she had filmed of a favorite lesson she had first taught back in the 1960's. This lesson was part of the Batteries and Bulbs kit (Electric Currents, 1991). She thought it was a particularly "constructivist" lesson from the fourth-grade electricity unit and mentioned the lesson several times during the study as one she really felt was particularly good. However, after having taught the lesson several times, Cindy had reworked it slightly in an attempt to alleviate some of the frustrations she had seen children experience during the interactive portion of the activity. Cindy gave us a very brief introduction to the tape before we began viewing and chose to pause the recording several times to explain what was going on and the ways in which she had reworked the lesson.

The lesson was an introduction to electricity in which the students are given a size-D battery, a tiny light bulb, and a small piece (several inches long) of wire with exposed copper ends. The objective of the lesson is for the children to figure out, entirely on their own, how to configure the materials so that the bulb

will light. As a result of their attempts, students discover that a complete circuit is necessary in order for current electricity to flow and light the bulb. Cindy chose to conduct the activity in her own room so that the children would have the unlimited time to experiment, which would not be possible in the heavily-scheduled science lab. She held the camera and focused on the children since it was a very child-centered activity with little direct instruction.

Cindy began the lesson by leading the children through a brainstorming discussion as they sat together on the carpet. She asked them, "What do you know about electricity?" and "What would you like to learn about electricity?" After the students had some time to offer their postulations, she gave them directions for the activity. Regarding the experimentation process, she merely told them the list of materials they would each be receiving and explained that the objective was for each of them to find a way to light their bulb. They were allowed to work in pairs if they desired.

As students worked, they needed to record each of their attempts by drawing an illustration of their design on paper. It would be important for them to record configurations that did not work as well as those that did. Cindy commented to students that "scientists learn more from their mistakes than they do from their successes," and that good scientists keep accurate and complete records when they conduct experiments.

She gave them explicit directions for their drawings, to make sure that they accurately depicted the glass and metal parts of the bulb, and were sure to depict the "little bump on the end of the battery." Taking the time to make careful

drawings as they worked would help them avoid repeating the same errors or trying the same failing configurations over and over. From her past experience, Cindy said she knew that the children all thought they would discover an operational configuration within a very short period of time, so most appeared impatient with this discussion. In reality, Cindy knew that it generally took 1 ½ hours, spread over two days, for the first child to find a method of joining the materials which resulted in a lit bulb. She had added the comments about scientists in an effort to help allay some of the frustrating moments she knew would emerge as the children worked.

As the students began working, Cindy moved around the room filming their efforts. Many of the children quickly became frustrated as they realized lighting the bulb was not going to be as easy a task as they first thought. They asked questions like, "Are you sure these bulbs aren't burned out?," "Are you sure this works?," and "Can you tell us how to do it now?" Cindy encouraged them, reminding them that she had told them this would take a while. As the initial whining continued, she was heard to remark, "We've only been doing this for ten minutes now." As time progressed, the kids settled in to working diligently, and the comments of frustration ceased. Cindy did have to keep reminding many of the students to stop and illustrate all of their attempts, as they were prone to hurry on to try another configuration as soon as they finished each attempt.

In the middle of the lesson, Cindy called one student up to illustrate a configuration she had tried but which had been unsuccessful. This girl was

asked to explain her drawing when she finished. In this way, Cindy legitimized even the unsuccessful attempts and gave the students more incentive to keep trying. Later, Cindy gave the class a “hint” by explaining to them that this type of electricity needs to travel in a complete circuit. They discussed the meaning of the word “circuit” and its similarity to the word “circle,” but the “hint” didn’t produce any sudden sparks of success.

None of the students lit the bulb during the time Cindy was filming, but she said that several students discovered a solution the next day, including the girl who had come up to the overhead to demonstrate one of her attempted configurations. It is difficult to keep solutions a secret in the close confines of a classroom environment, and Cindy shared that once a few students discover a configuration that works, the news spreads like wildfire. In this respect the students also got a taste of what many real-world scientists experience: they may work individually or in teams, and they may compete with other scientists in the world to claim the credit for first discovery. They build upon the work of others who came before them and others who are working at the same time.

During our discussion of the videotape, Cindy told us that the original lesson plans had not called for the children to illustrate all their attempts. Instead, a worksheet was provided for the students to complete after they had successfully lit the bulb. Cindy felt it was vital for the students to recognize that all of their attempts were equally important, especially because the children become so frustrated as they struggled to find a solution. We talked about how much this activity simulates the work of real scientists, such as those who search

for cures and vaccines. They have no way of knowing if they will ever be successful, but they must record what they have done, and either keep trying or give up. This observation led the group into a discussion of several inventions which were made unintentionally but which proved more valuable than the actual product might have been as intended, such as "Silly Putty," penicillin, and Post-it notes. Beth mentioned how Thomas Edison had tested hundreds of materials before he found that tungsten proved to be an effective light bulb filament.

Beth felt that this was one of those lessons that would really stick in the children's memories and be a powerful learning experience. The group also suggested to Cindy that she replay the brainstorming segment to the class at the end of the unit and give the students the opportunity to try to answer the questions they had posed. Since they had recorded what they wanted to learn about electricity on videotape, this would be a unique way to wrap up the K-W-L format she had started at the beginning of the lesson.

When I interviewed Cindy the next week, she expressed her feeling of satisfaction with the lesson. Since the lesson comes at the very beginning of the unit, she explained that the children don't really understand the concept of a circuit until they participate in several of the follow-up lessons. She felt that this lesson is an excellent opportunity to engage in the work of scientists and experience how frustrating as well as rewarding this work can be. She explained:

I could call it "secretivism." I mean, you gave them the problem, you gave them the equipment, you told them it was going to be frustrating possibly, but that failures were as important as successes, so that when they were making their illustrations they could get a little bit of

encouragement that they were doing something.... Because our students don't have many things presented to them in a constructivist way, its difficult for them to get into that mode. It's one of the better lessons in constructivism that I've used, but again if the children had more practice, and if I had more practice and time to use constructivism, I think it would go a lot better.... The children get very frustrated very easily. And also I think, as in all constructivism, you always run the risk of not having whatever hands-on learning experience actually come to fruition, to actually be some kind of meaningful scientific base of knowledge for them.

Although Cindy felt confident enough with this unit to rework the lesson, she still felt that her overall unfamiliarity with the principles of electricity hampered her teaching as she strove to help the students work toward basic understandings. The modifications she had made were due to her experience teaching this particular lesson, not because of her expertise with the concepts themselves. She commented:

I think my strengths are that I've done it before, and I know that they're not going to get it right away. I think that it would be very frustrating for everyone. It was very frustrating for me all those years ago that I tried it 'cause I wasn't quite sure what they were doing right and what they were doing wrong. It was very, very hard. It takes experience to feel comfortable with it.

As I said, I really think that the follow-through to get the basic science concept after doing the experiment is very difficult, and I don't feel that I have the expertise that I should in doing that, in drawing it all together.... I've added the introduction about the scientists failing through my own experience. You have to prepare them for failure. They immediately think they're going to be able to do it — no sweat. And unless they've been given that background that, no, it isn't, it's more difficult than you think its going to be, "You can do it, but you might not get it done today," they don't believe you. And they need that constantly through the lesson, that reassurance that it's okay not to be getting it. All the illustrations that you're putting down, that do not light the bulb, are just as important.

I knew that this was one of Cindy's favorite lessons because she had talked about it during her initial interview when she discussed the science

teaching she had done at the beginning of her career. To her, this lesson symbolized the epitome of her definition of constructivism. It involved student-centered inquiry with little direction from the teacher. The students were left to their own devices to discover how to light the bulb. For students who are accustomed to being passive learners, this type of lesson poses the potential for a great deal of frustration. Cindy and Beth both shared that they had difficulty getting kids to put forth the mental effort to go beyond doing a hands-on activity and think through the connections to scientific concepts and explanations. Didactic instruction certainly looks much easier both for the students and the teacher than a constructivist lesson such as the one Cindy led. However, as Cindy discussed, the learning benefits inherent in this lesson go far beyond understanding the scientific concept of electric circuits: students gain an appreciation for the processes of scientific inquiry and the real-world work of scientists. They engage in a problem-solving activity that challenges their thinking, they learn the importance of recording data and taking good notes, and they have the potential to build confidence by tackling and solving a difficult puzzle.

It bothered Cindy that the rest of the fourth-grade science curriculum was not equally thought-provoking. However, she did not feel she had the time or the expertise to rework more of the curriculum:

I really enjoy teaching science the way that that lesson shows. I'm frustrated there aren't more lessons that are really that much hands-on. Many of them are, "Now we're going to do this, now we're going to do that, now we're going to do this" – step by step, chronological order. Very nice for organizing a child's brain, however, I don't think that's constructivist teaching.... Time is a huge factor in reworking these

lessons...my lack of having a good scientific background, the time consumed just in learning the basic concepts myself, and then reworking the lesson, that really gets terrifically time consuming.... It's almost impossible to do, and we're fortunate that at least our youngsters are doing it cookbook. They could be doing it textbook. So I feel that we've come so far down the road.

Cindy appreciated the complimentary feedback the members of the study group gave her but felt that much of it was sugar-coated. She wasn't sure that we were totally honest with her due to the "nature of the kind of women that are involved here" and thought that we would be reluctant to come down too hard on anyone. I wondered how much of this opinion lay in her own self-esteem, as she was always making jokes about her own ineptness in science and math. At the same time, she expressed a clear, personal definition of the nature of quality science teaching, although as I stated earlier I think there were some incongruencies in that definition. She seemed to think she was incapable of teaching science really well, and so couldn't bring herself to accept our praise. She had told Terry Farmer that she never expected to be able to become a "master science teacher." She was really the only one of the group who expressed such negative self-opinions regarding not only the current nature of her teaching but her potential as well. The other members all seemed to feel that they could compensate for any current weaknesses, given enough effort in the right direction, but Cindy made frequent, joking put-downs on herself.

Some of Cindy's self-perception was due to sexism. While Pat and Karen, who were about the same age as Cindy, admitted that their own science education had been hampered by gender inequities, they recognized these inequities as unfair and unjust. Cindy, on the other hand, seemed to buy right

into these stereotypes. She had made numerous comments that hinted at an underlying feeling of intellectual inferiority (ie. "I don't have the head for math and science," or "The people who know me will be so impressed if I take this physics class. Whoa, you took physics! Ha, ha."). Cindy also was an extraordinarily beautiful woman physically, and I suspect this had an impact on the way she was treated and perceived by others. As an only child, she had once told me that when she gave birth to her son, her father came to the hospital and told her that she had finally fulfilled his dreams by having a boy.

Putting all of this together with the fact that the group had given both Beth and I constructive criticism and points to work on in our teaching, I felt that Cindy was not entirely justified in thinking that the praise we gave her was unwarranted. She was being very hard on herself. However, she also made some important observations that were difficult for me to accept at the time as a researcher who was both a vested insider and designer of the study. We were inexperienced in critiquing each other's teaching and in sharing with each other. In acclimating ourselves to this type of collegial work, it was quite possible that some of us may have held back negative criticism. Given that the group members were allowed to select their own lessons for taping and sharing, most of what we observed on the tapes were good, approximate examples of constructivist teaching. There was still some reluctance to share "bad work" or "mistakes." Cindy herself had chosen to share a lesson that she had fine-tuned over the years and which she was confident represented a constructivist approach. She also chose to focus the camera on the students, which took some of the "heat" off herself.

That the feedback was predominantly positive related more to the type of lessons we chose to share than it did to our inexperience in giving feedback. Given the expertise Cindy felt she had in leading the Batteries and Bulbs lesson, it would have been very surprising for her to receive much negative criticism. Cindy's comments that she still felt unsure of herself in many other areas of science and questioned the quality of many of the fourth-grade lessons, suggest that Cindy may have indeed expected some constructive criticism had she chosen to share other lessons she taught. Cindy's comments illustrated that we were still having trouble accepting a constructivist approach to our own learning: we acknowledged that children entered the classroom with varied experiences, ideas, and questions, and we wanted to them to feel comfortable taking risks, raising questions, and sharing opinions and conjectures during learning, but we were less able to give ourselves permission to do the same. We still felt we needed to have examples of the "right" way of teaching to share with our colleagues. But given the relatively brief time we had spent working together, and that some of us had not shared any videotaped teaching yet, this was not surprising.

March 10, 1997 – Pat's Videotape Sharing

Pat's videotape gave the upper-elementary members of the group a real eye (and ear) into the world of second graders. The noise level of the class was noticeably louder than the other classes had been, although the children were manageable and on task. Their natural enthusiasm bubbled over, and they

excitedly participated in the potpourri of hands-on activities Pat had prepared for them.

This was an introductory lesson on matter. Prior to the taping, Pat had led the class through a brainstorming discussion on their ideas about what constituted matter. With input from the teacher, they had defined matter as any substance which takes up space and has mass. In the lab, Pat led the students through a series of exploratory activities designed to “prove” that matter does indeed take up space and have mass.

The students were working in small groups at tables in the science lab, with Donna Workman doing the filming. In the first experiment, the children dropped golf balls into graduated beakers half-full of water. They measured the mass of the golf balls first to determine that they did indeed have mass. They read the beaker’s volume before and after adding the golf ball and were able to see that the golf ball did take up space. One little girl said, “The golf ball pushed the water up.” Pat encouraged the kids to make predictions as they began each activity. As simple as many of the experiments seemed to us as teachers, the children were visibly amazed as they proceeded through each phase of the lesson.

To show that the space that matter occupies cannot be shared, the groups poured colored water and oil into the beakers and tried to stir them together. As hard as they tried, the substances separated and formed layers. Pat then asked the students if they thought light was a form of matter. After a heated discussion, she passed out a flashlight to each group and asked them to

shine the beam into their beakers. The children saw that the light shone through the space which the water and oil occupied. They determined that light was not a form of matter.

While it was easy for the children to see that solids take up space and have mass, Pat knew that it would be difficult for them to see that the same rules apply to gases as well. She asked the class, "Is air matter?" She was answered with a resounding chorus of "No's." After some discussion about balloons, most of the class agreed that air did take up space, but many of the students still held firm to their belief that it had no mass or weight. Pat set up a demonstration in which she taped an inflated balloon to one end of a meter stick and an empty balloon to the other end. She fashioned this apparatus into a balance scale by placing a fulcrum in the middle. Theoretically, the inflated balloon end is supposed to dip lower, illustrating that air does indeed have mass. However, Pat had some difficulty getting the device to work correctly in the lab. She said that once she brought it back to her classroom and let it sit for a while, it did indeed perform correctly.

I had seen Terry Farmer have the same trouble in one of his inservices. I told Pat that I had used a spring-scale with my class and inflated a plastic Hefty bag instead of a balloon. The larger volume made a more drastic difference and helped illustrate the point more effectively. Later, Pat had the children sit on the balloons to further illustrate the fact that air takes up space. They couldn't squish them totally flat. At the end of the activity, the kids popped the balloons to show the air exploding out.

As we discussed the lesson amongst ourselves, some differences between the younger and older children became apparent. As upper-elementary teachers, the rest of us noticed that not only did the children display more natural excitement, they also felt very comfortable taking risks and making mistakes. Karen noticed that they asked “Why?” quite often as they worked and offered many of their own conjectures and postulations during the discussions. There did not seem to be any pressure to provide the “right” explanation or answer. We wondered at what point or age this became a more prevalent factor in children, as the rest of us had noticed that many upper-elementary students are tentative during discussions and in making conjectures.

We also talked further about the hampering effect Donna Workman had on squelching student enthusiasm in the science lab. While she had been eagerly attending all of Terry Farmer’s physics workshops, she had not yet picked up on the point that children needed to be free to explore through trial and error as they worked during experiments. She continued to be very directive, especially regarding the treatment of the lab materials themselves. Beth felt that this type of attitude in a teacher could be a major cause of the tentativeness we were seeing in the older children. If students had been trained in the lab to carefully follow step-by-step instructions under a watchful eye, they would not feel comfortable designing their own experiments and posing their own questions. Beth felt that Donna was predisposing the students to feel comfortable with didactic teaching, and this was hampering her ability to have the children feel comfortable with discovery teaching and conceptual-change

teaching. While the students need some direction and teacher guidance, we wanted them to feel comfortable taking risks, making conjectures, asking questions, and engaging in active learning. We did not want them indoctrinated into a passive learning mode in the science lab.

I noticed that as time went on and the group had met for a longer period of time, we were becoming more and more open with each other. A level of trust had developed between us. We felt free to discuss our own personal thoughts and share our real frustrations. There was a lot of laughter at our meetings and a sense of growing easiness in our conversations.

As I interviewed Pat, she conveyed pleasure with how the lesson had gone. She was disappointed that the balloon/meter-stick, balance demonstration had not been more effective. Some of the children still were not convinced that air had mass and weight. On the other hand, she felt that this flop illustrated the fact that all experiments don't result in a "perfect" product or process:

One of the experiments with the balloon, we ran into some trouble setting that up, but that can happen to anybody, I guess. It just shows that things don't always go perfectly the way you want them to. And that you have to keep trying things because they don't always work the first time.

Pat brought the apparatus back to the classroom and worked with it, and she did eventually get the meter stick with the balloons attached to each end to balance correctly on the fulcrum so that the end with the inflated balloon dropped lower. She did not want the children's previous misconception that air has no mass to go unchallenged. Once she got the apparatus to work, she left it on display in the room so that the children could look at it and manipulate it.

Pat also felt that she had encouraged the children to explore and make predictions. She thought that this lesson was a good example of how she was trying to incorporate more constructivist methods into her science instruction:

Well, I tried to. First of all, it wasn't [just] paper and pencil, although I did have them write down some things that they saw and predict what they thought was going to happen. Then I did try to have them do some hands-on activities and discover some things, and let them talk about what they were seeing and doing.

Pat was encouraging her second graders to get into the routine of recording predictions, data, and conclusions as they conducted investigations. She distinguished this type of science writing from stand-alone worksheets that did not accompany hands-on activities. While she felt that writing could be an important part of constructivist science learning, even at grade levels where students are emerging writers, she saw little value in worksheets as an activity in themselves.

Pat had some ideas for extending the videotaping. She wanted to set the camcorder up on a tripod in her room, focusing on one of her science centers. She wanted to record pairs of students rotating to the center over a period of time to observe their actions and comments. She thought this would be an interesting way to gain insight into their thinking. Pat had shared this idea during the study group meeting as well. The other members of the group were quite intrigued by this idea and curious to see the tape if she acted on her idea. Pat felt that she had missed quite a bit during this particular lesson because the acoustics in the science lab were so poor, it was difficult to hear the comments from each individual group of students. She was also interested in taping one table of

students as they worked during some future lesson to give her a better understanding of their group discussion and ways of working together.

April 2, 1997 – Karen's Videotape Sharing

For her videotape sharing, Karen chose to bring a recording of the second day of a two-day lesson from the fourth-grade astronomy unit. She had planned to show us both days, but a camcorder malfunction prevented the recording of the first segment. Karen and Cindy previously had discussed the concerns they had about this lesson with Terry Farmer and were eager to hear what the rest of the group thought.

During the lesson, the students worked in pairs in a darkened room with a small illuminated model of the sun (a round, translucent, yellow ball placed over a flashlight) and a model of the earth. The models are not in correct size or proportion to each other, but the objective of the lesson is to show the movement of the planet earth as it orbits around the sun. During the first day's lesson, the children were introduced to the concept of revolution and used the models to illustrate how the earth travels around the sun. During the second day, they use the models to depict the rotation of the earth on its axis as it orbits around the sun. Karen was concerned that too many objectives are incorporated into the same lesson: planetary rotation and revolution, and how the seasons occur as a result of the earth being tipped on its axis. All of these are difficult and abstract concepts for fourth graders to grasp.

Karen began by using actual students to represent the sun and the earth. She placed them in the middle of the room and had the "sun" stand still while the

“earth” spun around in place and simultaneously traveled around the “sun.”

While they were doing this, she explained how different portions of the earth encounter day and night as they face either toward or away from the sun. Each pair of students was then handed a model set and told to use them to depict the motion of the earth around the sun. The moon was not included in the activity at all. Karen instructed them to “show how to make night and day.”

The students eagerly worked with each other to perform the task, but many seemed to be having trouble physically manipulating the models. Karen remarked on the difficulty of coordinating the movements: “You’ve got a lot of things going on at the same time, don’t you?” She moved around the room, asking students to demonstrate the movements to her. Most of the students seemed able to accurately recreate the movements, but Karen commented that many of them were unable to correctly match the terms “revolution” and “rotation” to the respective movements. While we were watching the tape, Cindy added that “the models are very, very difficult to work with.” Toward the end of the tape, Karen called a pair of students to the front of the room to demonstrate the earth’s movements for the rest of the class.

As we discussed the lesson after the viewing, Karen was rather hard on herself. She felt the students really hadn’t “gotten” the difference between revolution and rotation. Pat disagreed, saying that the students seemed to be doing well and could explain the movements correctly. Beth added that the kids appeared to enjoy the activity, and she felt it was helpful for them to use the manipulatives to learn the concepts of rotation and revolution. Beth also liked the

fact that Karen had made the lesson personally relevant to the student by having them locate Michigan on their globes and asking them whether it was night or day here as they showed her the movements.

We all felt that astronomy is a very abstract unit to teach elementary-age children. The week before the meeting, I had been outside with my telescope observing a lunar eclipse. Even as an astronomy buff, I found the concept of eclipses difficult to understand. You can't actually see all three bodies involved, you're standing on one, and for children to understand this is almost impossible. I shared this opinion, along with the fact that I had once attended a science inservice in which the instructor said that astronomy should not be taught until the high-school level. The concepts are just too abstract. I agreed with this somewhat. But, children do seem to have a natural curiosity about space that can counteract the difficulties inherent in understanding the content of the astronomy curriculum. Cindy agreed with this and felt the key was to keep the content simple and very introductory. She said that it is still difficult for her to accept the fact that the sun is not really going down, and instead it is the earth that is moving, or that the extreme distance of the stars (relative to the speed of light) makes it possible for us to see a faraway sun even when it no longer exists.

We also discussed a video some of us had seen which illustrates how difficult it can be to counteract scientific misconceptions once they are embedded in someone's mind. A researcher interviewed 22 Harvard graduates in caps and gowns and asked them to explain the cause of the seasons. Only one or two were able to accurately describe how the tilting of the earth on its axis causes the

different seasons in the northern and southern hemispheres, although they all confidently gave an explanation which in all but one or two cases was wrong in response to the interviewers' question. The researcher also asked students in a high-school science class the same question. Much to their teacher's anguish, even her brightest student was unable to give an accurate answer. After the teacher re-taught the concept, this girl still stuck to her belief that the earth travels around the sun in a strange, figure-eight type orbit, and this resulted in the seasonal differences throughout the year.

In the conceptual-change model, a teacher probes for students' preconceptions before beginning a unit of instruction. In order for students to abandon any misconceptions they have, the teacher must guide them through activities that will challenge the students' personal hypotheses and cause them to question their current understandings. Providing appropriate experiences for the students, especially hands-on experiences in which the students can use several senses to develop a feeling of disequilibrium, enables the student to develop more accurate understandings of the natural world and scientific processes. This group of teachers felt it would be very difficult, if not impossible, to provide those types of hands-on experiences in the area of astronomy.

After sharing these stories of how difficult it is to teach astronomy to any age person, let alone elementary students, I think that Karen felt better about her lesson. The group recognized Karen's lack of confidence and wanted to support her attempts as much as we could. When I interviewed Karen after spring vacation, she seemed to be far less hard on herself. In fact, I believe she felt

good that she was able to recognize the difficulty of the concepts she was teaching. She may not have felt as comfortable critiquing the curriculum the year before. Karen commented on the lesson's effectiveness:

That was one of the problems. We were trying to do too many objectives. We were trying to do both revolution and rotation of the earth in relationship to the sun all at the same time. I think the better students caught on because they could differentiate enough between revolution and rotation. But the poorer students needed one idea at a time, so they were just thinking one idea at a time. So it would've been more effective if I had divided the objectives.

Despite the difficulties Karen faced as she negotiated teaching this concept, she felt that the lesson was a step forward in her efforts to include more hands-on activities in her science instruction. She also thought that the lesson had forced her to become better prepared and to familiarize herself with the content behind the concepts she was trying to teach the students. This lesson did require direct instruction beforehand, so Karen had to feel knowledgeable and comfortable describing and modeling the earth's movements herself. She said:

I tried to put some models into the hands of the kids so they could see how the movement was going on. I did give them some direction for this concept because just to give them the models, I didn't think they could do it on their own. We did talk about it. I tried to show them using kids themselves as models. And we tried to transfer that to the models.

Karen had admitted to being very uncomfortable with teaching science at the beginning of the study to the point where she either used the textbook in the classroom, or took her students to the lab and let Donna lead an activity. She had set early goals for herself to deepen her scientific knowledge, which she was

trying to do by attending the Michigan Operation Physics workshops and taking the children through more hands-on activities herself.

Karen was just becoming comfortable with lessons that involved manipulatives instead of the textbook, but at the same time she was having her definition of constructivist science challenged by other members of the group. Cindy was quite vocal in her opinion that constructivism at its best entailed very little teacher direction, and that students should be allowed to engage in self-discovery as much as possible when they worked with materials. This was influencing Karen's thinking as she reflected on how much talking she had done in the lesson and expressed her rationale and justification for the directions and discussion she engaged in. She was moving beyond a preliminary definition that equated constructivism with hands-on activities and was beginning to see that a variety of instructional strategies could fit into the realm of constructivism, given the concept that a teacher was trying to help students understand.

Even though she wasn't entirely pleased with the results of the lesson in terms of learning achievement, Karen did agree with the study group's observation that the children seemed motivated and excited during the activity. She commented: "I think the children were real relaxed. I think they enjoyed it." Sharing her videotape with the rest of us also had actually been easier than Karen thought it would be. The group was supportive of her. This actually made her feel better than she had after she had watched the tape by herself, because

she felt she was her own worst critic.

I felt better about it with the group than by myself. Maybe because you guys were so nice about it. I didn't feel threatened like I thought I would be.

It was obvious that the supportive nature of the study group was an important element in Karen's participation. If an administrator or consultant had told her that she had to join a study group because her science teaching needed improvement, her attitude may have been far different. Karen felt that much of our group's cohesiveness was because participation was voluntary. There was no outside pressure put on her to perform since she had chosen to participate on her own. Karen commented on this:

I think too that since this was such a voluntary group. I think that if you tried to set these groups up and kind of forced teachers into them, I don't think you'd get as much cohesiveness as this group. Because this was all voluntary. Everybody volunteered their time. Everybody wanted to learn and was willing to put the time in. To make them go into a group, I don't think it would be as cohesive. I think they would resent being there.

I was pleased that Karen continued to work with the group all year long. It was encouraging to know that the group had met some of her needs. Hopefully she was becoming more comfortable in the role of classroom teacher as she learned that many of us share the same frustrations and feelings of ineffectiveness as we try to practice the art of teaching or desired changes in our practice.

Reflection and Analysis

I completed a data analysis matrix for the "post-video sharing" interviews, just as I did for the second round of interviews. Figure 5 is a condensed version of that matrix.

Themes of Teacher Reflection	Beth	Cindy	Karen	Pat
Negotiation of Constructivism in Videotaped Science Lesson	Teacher asked a lot of questions, built on students' prior knowledge, teacher tried to draw out student questions, used hands-on activity to simulate a real-world event and made connections to that event.	Engaged students in a "secretivist" Batteries and Bulbs lesson – students were given materials and little direction, left to figure out how to light the bulb on their own. Very hands-on, student-directed. Fit Cindy's definition of constructivism because students "gained their own knowledge." This lesson was discovery oriented with little teacher input or direction.	Students used themselves as models, as well as the little earth and sun spheres. She tried to make the lesson more "hands-on" than what she had generally done in the past, which was one of her main goals. Engaged in some accompanying direct instruction, which she felt was necessary for students to be able to manipulate the models accurately. Fit Karen's developing practice of constructivism as a hands-on activity, with some teacher direction justified in order for students to simulate the motions of the Earth and Moon.	Students did hands-on activities to explore the concept that different forms of matter have mass. Teacher asked guiding questions and encouraged students to talk and write about what they were seeing and discovering. Teacher also utilized the demonstration method with materials that would be too difficult for 2 nd graders to manipulate, but which served as added exposure to the concept she was teaching.

Figure 5 Data Analysis Matrix for Post-video Sharing Interviews

Figure 5 (cont'd).

Themes	Beth	Cindy	Karen	Pat
Teacher's perception of the lesson's effectiveness	Students' comments and written notes during and after the activity showed that most students understood the connection between rainfall and erosion. Teacher felt this was due to the hands-on activity, guiding questions she asked, and the connections to the real world she made through the newspaper photograph and article about a recent mudslide.	Students were frustrated because they had not had a lot of experience in this type of problem-solving, self-directed activity. About 20% lit the bulb the first day, the rest the second day. Students needed follow-up lessons and activities for them to have a complete understanding of the necessity of a circuit in current electricity, but this lesson was an effective introduction that also gave the students an opportunity to engage in challenging problem-solving.	Students enjoyed the active nature of the activity, but Karen was concerned that while students seemed to understand the motion of the Earth and Moon as a result of the lesson, many were still unclear of the differences between the terms "revolution" and "rotation." Some learners were confused by the two terms, which are so similar. Karen was beginning to become more confident in her ability to critique and improve lessons, as she suggested that dividing the lesson into two parts might address the confusion students were experiencing.	Students understood the concept that matter has to take up space and that it has mass. Lesson was designed to address some common misconceptions that young students have, such as that gases have no mass and do not take up space. Pat was concerned that the balloons on the meter stick activity did not work in the lab because this failure might have served to perpetuate this misconception. Pat kept working back in the room until she got the apparatus to perform correctly because she wanted to be sure to address the concept that all matter has mass, even if this mass is quite insignificant. While she wanted students to know that experiments don't always perform as expected, she also did not want this failure to perpetuate one of the principle misconceptions she was addressing.

Figure 5 (cont'd).

Themes	Beth	Cindy	Karen	Pat
Negotiation of Support Relationships with Other Group Members Through Videotape Sharing	Was an enlightening first experience because she became aware of positive and negative facets of her teaching through viewing the tape and listening to the group's feedback. Group members helped her focus on the content of her science teaching. Beth appreciated the "positive strokes" other teachers gave. Watching the videotape caused her to observe that much of the activity could have been designed by the students themselves. They were anxious to get to the materials, and the procedure could have accommodated some flexibility in design without compromising conceptual learning.	Felt confident that this was a good lesson before viewing the videotape and wished that more lessons were designed this way. Cindy did not feel confident reworking lessons herself because of her insufficient content knowledge. While this lesson was a positive experience for her and one which exemplified constructivist teaching, she felt the group members were generous in their praise as a result of our being too "nice" and too inexperienced in viewing and critiquing constructivist science teaching. Admitted she purposely focused on the students during filming to take the pressure off herself appearing on tape, but she gleaned insights from watching the children struggle with the batteries and bulbs.	Videotaping was a surprisingly comfortable experience. She had been very nervous, but in reality the group members' positive feedback helped build her confidence. The act of taping a lesson to share with colleagues forced her to experiment with new pedagogy and to become more familiar with the concepts she was teaching. Both her own taping experience as well as viewing and critiquing others' lessons helped her become more comfortable judging effective science teaching and the science curriculum itself.	Helped her "dissect" her lesson and analyze what worked and what didn't. Wanted to tape additional lessons in her own room so that she could hear student comments more clearly (lab acoustics were poor) and reflect on student questions and responses. Found sharing the videotape with her own students afterward a neat experience. Children were in awe watching and listening to themselves. Pat appreciated the positive comments and support from the other teachers.

Figure 5 (cont'd).

Themes	Beth	Cindy	Karen	Pat
Self-reflection on lesson	Students understood concept, but Beth felt this was an example of a lesson where she could have given the student groups more freedom to design their own experiment instead of giving them such precise directions with the materials.	Strengths – has done it before and knows that students will get frustrated, so she discussed this with the students beforehand. She prepared them for the number of attempts it would take them to get the bulb to light. Weaknesses – didn't feel she had the "expertise" or comfort level with electricity to "get through to the basic science concept after the experiment" – concept was very difficult for students to grasp.	Strengths – students were excited and relaxed, Karen built confidence in her ability to lead hands-on activities. Weaknesses – some students did not meet the objective; were confused about which term described which motion. Karen was beginning to be able to critique her teaching.	Strengths – students learned the objective and were active an on-task in the science lab. Pat was frustrated by the "technical difficulties" with the balloon portion of the lesson, but persevered until she got it to work. Pat felt she hurried around the room during reporting time too much to engage in enough discussion with each small group.

The study group's activities could be loosely categorized into two components. In the first set of meetings and activities, we focused on familiarizing ourselves with the theory of constructivist learning, particularly in the context of teaching elementary science. Although we did this within our own building and set our own agenda for what we discussed, this component of the study group was still quite similar to what teachers often experience in a traditional inservice or workshop format. In that setting, there is usually quite a bit of theory-dispensing but very little connection made with the participants' own practice. Although I see a few more professional development programs attempting to offer follow-up classroom support, this is still quite unusual. The 1998-1999 Ojibway County Intermediate School District schedule of professional development workshops listed approximately 40 programs, only one of which offered follow-up support in the participants' schools and classrooms (Integrated Thematic Teaching).

The second component of our study-group activities, and the part that really set this project apart from most professional development opportunities, was the videotaping of our lessons and subsequent sharing of those videotapes for analysis with a supportive group of peers. Everyone in the group agreed that the videotaping experience was a positive one. I was extremely pleased with this component of the study group's activities. The videotaping allowed us to personalize the process of familiarizing ourselves with constructivist science teaching, and it allowed us to share our teaching with our colleagues. Teachers rarely have an opportunity to observe each other's teaching or to receive

feedback from peers. In general, the only time our teaching is observed and critiqued is during a rare evaluation from the principal. Speaking for myself, administrative evaluation is always fraught with some anxiety and is a vastly different experience from voluntarily sharing your teaching with a group of colleagues.

Beth, Cindy, and Karen had all expressed some nervousness about the videotaping, but their comments afterward indicated that their fears diminished considerably. While I think there might have been some expectation among the group members that the rest of us would be looking for what the sharing teacher was doing “wrong,” given the use of the feedback form, the feedback instead tended to be quite positive and constructive. For this group of teachers, many of whom were feeling disheartened and overwhelmed in their efforts to improve their science teaching, the complimentary feedback served to bolster their efforts. All of the participants stressed that sharing made them feel better about their teaching.

Cindy felt we were probably “too nice” or that we weren’t yet experienced enough with this type of teaching to be able to be effective evaluators of its practice. This opinion warrants acknowledgement. We first worked to familiarize ourselves with the tenets of constructivist science teaching. We began to apply it to our own practice and at the same time began videotaping our lessons in an attempt to evaluate our efforts. Since most of us were relative novices in constructivism, this was an ambitious goal to set for ourselves, as Terry observed when he first came to help us.

Looking back at our work, I feel the members of this group would have been served better if this had been a multi-year project. We really were just beginning to get our feet wet when the official activities of the group ended. During this first year, we were developing the “clinical expertise” (McLaughlin & Marsh, 1979) necessary to reflect effectively on our own and others’ science teaching. The summer after our project ended, our principal was transferred to another building. In the fall, we attended a seminar together, and he asked me how the group was going. His assumption was that we would continue to meet even after the official data collection period had ended, whereas I had been fearful to continue after the UCRHIS date expired. In the final interviews, everyone but Cindy expressed a desire to keep meeting. Pat specifically wanted to continue videotaping more of her lessons. Beth felt we should have made a stronger commitment to meet more often during the course of the project. I agree with both of these thoughts.

Just as I think it’s naïve of those in charge of professional development to think that a one-shot workshop will have any powerful, long-lasting effect on educational practice, I think that it was naïve of me to assume that only one year of contextualized, personalized work would turn us all into master science teachers. Terry told us that he thought it could take several years to make constructivist science teaching a natural part of our practice. I’m not sure if this is true for every teacher, as we all come to the table with individual experiences and levels of expertise, but I do agree that one year certainly was not enough time. We either needed to meet more often, or meet for a longer period of time.

Doing both would probably have been the most beneficial, as Beth suggested in her final interview. Given that we were working entirely on our own time, it was difficult to accommodate our schedules and time demands to meet more often in this context, which is a problem others involved in study groups have faced (DiShino, 1987; Miller, 1990). As we came to realize, this type of work requires a genuine commitment of time.

In my original proposal, I had planned to ask the teachers to share videotapes three times throughout the year. I had not anticipated the anxiety that would accompany this activity. The teachers wanted to feel comfortable knowing what “good” constructivist science teaching looks like in others before they tried to apply it to their own practice and open themselves up for critique. As stated earlier, this was why the group decided during one of our early meetings that we should delay taping until we were more familiar with what we were trying to do, although Pat was eager to start taping from the get-go, and she also was the only member who did not express any nervousness about videotaping during the initial interview.

It is interesting to note that while the teachers were struggling to make their *teaching* more constructivist, they had difficulty applying this process to their *learning* as well. With the exception of Pat, the group members seemed to feel the need to display some degree of expertise in their science teaching before they were willing to expose it to the group’s evaluation. This involved a level of risk-taking that was uncomfortable for them. In constructivist science teaching, we ask children to engage in learning behavior which leaves them vulnerable:

exposing their prior knowledge and personal hypotheses; asking questions; designing their own experiments; making mistakes; forming conclusions, etc. The teachers themselves were hesitant to share their early “works in progress” on tape, even though they were willing to discuss their frustrations aloud. I think the realization that our own learning also needed to be constructivist was slow to sink in.

The experience with videotaping ourselves was beginning to be an effective tool. By the time we shared our tapes, we had formed a collegial, supportive group. During the sharing sessions, we were often our own worse critics, pointing out private concerns to the others. Although several of the group members had said that they were initially nervous about being videotaped, I never sensed any fear from the group members during the time they were sharing; nor did anyone express this during the meetings or subsequent interviews. The group members, especially Pat, Beth, and Karen, felt that the videotaping had been helpful to them, not only for constructive criticism but for affirmation of our successes. However, I also think that this group of teachers was supportive enough and close enough to have begun the videotaping much sooner and thus practice a more constructivist approach to professional development ourselves. Although we became closer as a result of working together in the study group, Cindy commented in the final interview that she felt the bonds between us had already been established beforehand. Some of the rapport-building that would have been necessary if this project had been initiated by an outsider was unnecessary in this group.

As stated earlier, I felt that those who presented the videotapes early on were careful to choose what they felt exhibited a positive example of constructivist science teaching. By the time Karen shared her videotape, however, the need for this security blanket was disappearing. Karen, who was the most tentative member of the group, chose to share a lesson she felt had problems. She wanted serious feedback on how this lesson could be reworked and improved. The group was beginning to move into a more comfortable phase, one in which the members were ready to acknowledge the difficulty of constructivist pedagogy. The teachers were ready to admit that this was hard work, work that we struggled with and which still troubled us. We had learned to understand that negotiating the new science curriculum brought many moments of frustration along with the moments of success.

If I had this project to do over again, I would expand the process from one year to two years, continuing where we left off into another year of videotaping and sharing. If I had this project to do over again free from the constraints of dissertation research requirements, I would not have placed an ending date on our activities at all. Rather, I would have taken up Beth's suggestion that the group meet on standing days (regardless of whether all members could attend each time), allow new members to join, and espouse a philosophy of never-ending, lifelong learning. Although we made quite a bit of progress, I think we were really on the verge of accomplishing something extraordinary and quite novel had we continued to meet into the next year. Through sharing our

teaching, a practice that tends to be kept private and unobserved among most teachers, we had established an unusual set of bonds among us.

These are the teachers I feel closest to. These are the teachers I turn to for advice. When I see these teachers in the hall, I can look past the superficialities because I know something about them and their practice that only the rest of us in the group knows. They helped me, and I helped them. We care about each other. These are simple but powerful truths. We built a strong foundation, but I have this lingering feeling that the rest of the house is still just a framework waiting to be filled in.

Final Interviews

The meeting in which Karen shared her videotape was our last. Over the course of the school year, we had met 11 times, not counting the inservices at the intermediate school district. The group members attended only those workshops that were related to own individual, grade-level responsibilities, although Donna Workman had gone to every session. The final interviews were conducted with each of the four teachers in May of 1997.

Beth's Experience

The study-group experience provided Beth with several benefits but not necessarily the ones she had predicted. Initially, she expected the group's work to be more content-oriented, much like a typical inservice workshop. The fact that it was more process-oriented in an attempt to improve our pedagogy was unexpected. However, she liked that just as well.

Beth also hadn't expected the study group to become such a cohesive source of support for her. This impacted her greatly, and she talked at length about this aspect of the group experience. Rather than being a burden, Beth actually wished that the group had been able to meet more often, such as once or twice a week. She also wanted the group to continue to meet during the following school year. She felt she had just started to really work on adapting her actual teaching and welcomed the continued feedback and support the study group could offer. Beth commented on the supportive nature of the peer group:

I think we needed to meet more often than we did. I don't know if we could've with the time restraints. But I don't think we met often enough. I think that as a support group we need to make this a standing once-or twice-a-week meeting, that you cleared your calendar for that. Because I don't think elementary teachers have enough support. We go in, we shut the door, we teach our curriculum. Every now and then a Comp. Ed. person comes in, but they don't really help us process the information.

Regarding the group as a support system in itself, she shared: I think it's necessary. It's not just important, it's necessary. And I think a mentorship is something that all teachers should have. At least we're facing some of the same issues and are able to say, "Well, what about if you tried this?" I could see that without a support system, teachers would become very textbook-oriented. Um, your heart may say you want to teach constructivistly, but without that encouragement and that place to blow off and get more ideas and be renewed, it could quickly become, "Open up your textbook, now let's do this."

Beth's comments point to the difficulty of negotiating the proposals of the science reform movement. Anderson and Smith (1987) have discussed the prevalence of didactic science instruction and the challenges teachers face as they try to practice conceptual-change teaching. Beth makes the point that without the supportive structure provided by her colleagues, it would be easy to slip into didactic instruction (which is much easier to navigate and organize). Even when faced with the knowledge that children may not be learning as well or as much as

they would with a conceptual-change format, teachers are so overwhelmed by the demands of their jobs, they must constantly struggle to avoid over-reliance on didactic methods.

In the larger sense, the science reform movement is typical of many other reforms over the past century that have arisen from external recommendations and have struggled to take hold in American schools (Tyack & Cuban, 1995). Teachers are being asked to make radical changes in their practice that often link to radical changes in their educational philosophies as well, and are largely unprepared to do this. Their personal weaknesses in scientific knowledge and conceptual-change pedagogy may prevent them from understanding how infrequently children are experiencing science instruction that leads to meaningful learning. Without being confronted with this problem, or without being able to understand the significance of the situation, teachers may not feel a great deal of pressure to change their practice. If we hope to counter the hold that didactic-centered instruction has on science education, then we must do whatever we can to help teachers negotiate the process of change. As Beth reveals, the collegial support of like-minded peers is vital to this process. Michael Fullan (1991) summarizes the research on collegiality and the change process:

At the teacher level the degree of change was strongly related to the extent to which teachers *interact* with each other and others providing technical help. Within the school, collegiality among teachers, as measured by the frequency of communication, mutual support, help, etc., was a strong indicator of implementation success. Virtually every research study on the topic has found this to be the case. And it does make sense; significant educational change consists of changes in

beliefs, teaching style, and materials, which can come about *only* through a process of personal development in a social context. (pp. 131-132)

Beth found that participation in the study group gave her an opportunity to reflect on her teaching, which she had not been taking the time to do. As elementary teachers, each lesson is quickly followed by a change of subject. This leaves little time to reflect on what was just taught. In fact, there is little immediate incentive to do so, since the same lesson will not be taught for another year. When Beth worked as a middle-school math consultant, she had to repeat the same model lessons during the course of a day. This provoked her to reflect on what had happened and attempt to make improvements for the next hour's class.

Beth found the study-group experience gave her the chance to process her teaching and also receive feedback from her peers. In her previous position, she had an opportunity to talk with the other mathematics teachers, and she found that the middle school teachers she worked with spent more time discussing their pedagogy together than the elementary teachers she has worked with do.

Beth felt that not only had her science teaching become more constructivist, but her teaching of other subjects had become more child-centered as well. She commented:

I'll be teaching for many, many years to come, and I can say that it will affect things. In some other subjects, it has affected. It's allowed me to be more constructivist in teaching -- researching historical facts and role playing some of those things, and more constructivist in reading. It also seems to be the latest approach in math.

Beth was extending her definition of constructivism so that it now consisted of a more general category of instructional activities that all included an active learning approach. Her definition was more flexible than Cindy's, and Beth seemed more confident in her ability to gradually adapt her instruction across the curriculum to a more constructivist approach.

As a result of the videotaping, Beth set some new goals for herself, which she planned to work on during the coming years. She was working to allow the children more time and freedom to design their own experiments and make mistakes. She also had found that while most students eagerly participated in the hands-on activities, they weren't always so enthusiastic when it came time to process and reflect on what they had learned. Beth wanted to find ways to motivate children to go beyond the activity, to talk and write about what they discovered. She commented on one of her attempts at letting kids design their own investigation:

I had one of those moments in which I allowed students to set up their own experiments. It went with the Hard as Ice unit, and they had to construct their own experiment. The question was: "Do ice and liquid water weigh the same?" And I let a group, a whole group, go right down the wrong road. [The group filled one cup with liquid and another with ice cubes. They ignored the air spaces between the cubes and assumed both cups held the same amount of water] And I held my tongue and asked them questions later on. "Well, how do you know you have the same amount of water?" "Do you have the same amount of water?" Through the questions, they realized their error. I think that's really important that they understand that scientists make a lot of mistakes, and then they try something else, and then they make more mistakes. I think we've really set kids up into a wrong understanding that scientists do this little recipe and they come out with a "Ta-da, here it is," and all easy answers. Real-life science is not that way. I think that, once again, we've pulled them out of the real-world context so many times.

Beth was hopeful that our students would become more comfortable with formulating questions and designing investigations as they progressed through the revised science curriculum. As the children gain more experience doing activities and move farther away from textbook instruction, she predicted that this process would become easier for them. However, she was also cognizant of the fact that this type of teaching is very difficult, and without support it would be hard for teachers to implement and sustain constructivist science teaching. She reminded me of Dan Lortie's (1975) writings when she commented:

Here's my opinion. I think that people fall back on the way they've been taught. And if they don't carefully process things and really think about what they're going to do here, and make a concerted effort to change, they will do exactly as they've done.

As I listened to Beth, I saw that she was making some connections between the ways in which both teachers and students have been asked to perform. While students have not been given the opportunity to ask open-ended questions and investigate those questions, teachers have not often been given the chance to design the curriculum. "Teacher-proof" curricula have been promoted by textbook companies and adopted by most school districts. Neither students nor teachers have been given the credit to engage in higher-level thinking. Beth shared her feelings:

Ideally, I think there has to be some kind of revolution in education, where teachers say, "Excuse me, you would not have the gall to walk into a surgery and tell the doctor how to do his job. How dare you tell me? I know best. I have the education. I know." In my graduate class that I'm taking, last night a term was thrown out -- "the deskilling of teachers." That from above we are handed these curriculums and told, "Teach this. You need to cover these areas, here are the questions, here's what you do, here's what you read, say this, here's the appropriate response." I'm sure you can click off in your mind how many different things we have.

Even our science program's that way. Yet we really, they're deskilling us. "Do this, don't think about it. I want to know that every fifth grade teacher's doing it the same way. We don't have enough trust in you to do your job."

While at the time I disagreed with Beth that the science curriculum had "come from above," since it was designed by teachers within our district, she did make some very good points. For the teachers who were not members of the district science curriculum committee and who were not involved in designing the curriculum, the materials were just as unfamiliar as if they had come from any outside source. Fullan (1991) remarks about teacher's participation on curriculum committees:

One of the great mistakes over the past 30 years has been the naïve assumption that involving *some* teachers on curriculum committees or in program development would facilitate implementation, because it would increase acceptance by *other* teachers.... As far as most teachers were concerned, when the change was produced by fellow teachers it was just as much *externally experienced* as if it had come from the university or the government. (p. 127)

In the case of the Ojibway district, I have already noted that the teachers who were members of the curriculum committee seemed to have had less trouble navigating the new curriculum because of the several years they spent working to understand the tenets of the science reform movement and the MEGOSE objectives, as well as their ownership of the curriculum development process. Most of the other teachers had a great deal of difficulty in negotiating the new program, which Beth seemed quite cognizant of and concerned with.

The curriculum was presented in a binder as a "recipe" for teachers to follow, even if the activities and units themselves were constructivist in nature. Many teachers wanted the opportunity to meet periodically throughout the first

year, walking through the curriculum and doing condensed versions of the same activities the students would be engaging in -- engaging in constructivist learning themselves.

Cindy's Experience

Cindy's responses during the final interview varied quite a bit from the rest of the group. While everyone else's opinion of the group's activities was generally positive, with minimal disappointments or suggestions for improvement, Cindy seemed discouraged by the lack of progress she felt she had made. She really didn't link this lack of progress to the group, but felt that she was constrained in her present teaching situation. The list of reasons she gave for not being able to make her teaching more constructivist was long. The demands of the MEAP created a high-pressure teaching context and cut down on the time available for unlimited student exploration. She did not have the background knowledge to ask kids the right questions. Today's urban children lacked the prior knowledge to be as successful as her former suburban students in their elementary science learning. She didn't have the ability to master the physical science material. Teaching a split-grade class was difficult. The new report card created constraints. At one point in the interview, she complained that the science lab/paraprofessional arrangement kept her from having complete carte blanche over the materials. Later, she said that having the science lab and not having to gather our own equipment was a big help, however.

It seemed that Cindy externalized her own lack of progress. Knowing that she is a dedicated teacher and that she was stressed about the effects her battle

with cancer was having on her teaching, I think she was feeling legitimately overwhelmed. Her attitude had changed significantly over the course of the year. In the initial interviews, she was the one who had stressed that we needed to set specific goals for ourselves so that our sessions would go beyond griping and produce real results. In the end, however, she was the one who was displeased with her perceived stagnation and complained excessively about external factors. While we all agreed that this type of teaching is difficult, Cindy was the only one who ended the year feeling it was actually impossible for her at this time. She said:

I try very hard, but there's just the reality of the split. And the way our equipment is disbursed to us, I don't have complete carte blanche. I wouldn't say it has anything to do with the group. I think it has to do with the school system. I cannot be as constructivist a teacher as I was when I first started.

I feel that Cindy was exhausted and that her illness was setting up a temporary but very real barrier to her efforts to improve. She was coping with coming to work, but to expect her to incorporate drastic changes in her teaching was beyond her current abilities. At times during the interview, she seemed negative to the point of almost being oppositional. I think she wanted to deny the effects the cancer was having on her body by denying any personal responsibility for her difficulties. While I can't begin to put myself in her shoes, in reality I think her illness had a far greater effect on her teaching than she was ready to admit. She was dealing with an illness whose eventual outcome was unknown, and that created a major obstacle in her life. At this point in her life, she may have been focusing on the obstacles over which she felt she had little or no direct control.

This had to be extremely frustrating for her, a feeling that carried over into her professional life and created an air of pessimism regarding her ability to adapt her teaching.

It is important to note that many teachers may have personal, professional, and contextual constraints that make constructivist science teaching as difficult as it was for Cindy. The concerns she raised had merit. I believe she would not have experienced as many of these perceived constraints had she not been experiencing serious health problems, but she stood as a voice for many teachers who may feel the reformers' vision is beyond them. She may also have developed a clearer, more realistic understanding of the constraints and obstacles learning to teach this way entails. The group of teachers who participated in this project were recruited based on a perceived openness and commitment to professional growth. There were teachers at Westdale whom I never would have approached at all due to my perception that they had no interest in changing their pedagogy. What hope do we have of teachers such as these practicing the type of science teaching envisioned by the reformers, entrenched as they are in traditional teaching and reluctant to invest the time and effort required to change? It was difficult enough for this group of teachers who was committed. Cindy's health concerns, which sapped her energy, caused her to raise some of the same issues other teachers likely were dealing with.

Cindy felt that the collegial relationships among the group members had already been formed before we began meeting. In fact, she felt that due to the formal nature of the group and the fact that we were engaged in a unique, novel

experience, there was even less collegiality among the participants than there was when we met in more relaxed settings, such as the faculty lounge at lunch time. I do believe that the research parameters afforded the group a degree of formality that would not have been there had the group not been part of a dissertation project, but I didn't personally sense any difference in the level of collegiality among the group members when we met in the study group setting and when we met in the hall, lounge, or copy room. However, my role as the researcher distinguished me from the rest of the group, and Cindy may have felt differently toward me when we met in the study group meetings. She and the other members may have shifted from viewing me as just another colleague in the lounge, to a formal researcher who was engaged in examining their practice. This was a perspective that I would not have had the opportunity to feel myself.

However, Cindy felt that the study group had offered her a source of support, as it helped her realize that this type of teaching is difficult for all of us.

She shared:

The benefits were, well, to find out that I don't feel as defeated personally because I realize that its difficult for everybody. So it gives me a little more encouragement to keep going 'cause I think this is still uncharted territory for most classroom teachers. Most of us have not even come to comfort zones with this, let alone proficiency.

Toward the end of the interview, Cindy seemed to recognize how pessimistic she was sounding. She said:

But you know, I won't be so negative because I can honestly say that when I came to this school four years ago that no one was doing any science experiments of any kind. So there is a great deal of change, and there has been a great deal of help, you know, with having the equipment in one location and having it set up for us. No, there has been. We are trying. We are trying.

Cindy admitted that she was very tired at the end of the day, and this made it hard for her to meet after school. She suggested that it would have been nice if we could have met over the summer time and brought some students in for “test classes” in a summer enrichment program. We could experiment with constructivist teaching with this group of children and videotape and discuss our work away from the demands of the regular school year. This was a creative and intriguing idea that has much potential for any teachers involved, as well as students, and is similar to the project coordinated by Smith and Neale (1991). The local ISD had hosted “Model Teaching Weeks” for several years to introduce teachers to the Integrated Thematic Instruction (ITI) model, and these workshops had proved to be enormously popular. Although it was not as personally intensive as Smith and Neale’s study, the ITI program also introduced teachers to the program during the summer, with students brought in for a week of “model” instruction using the ITI format, and follow-up support with a visiting ITI consultant back in the classroom during the next school year. Something similar done on a smaller scale would be a way of helping teachers focus on constructivist science teaching away from the harried demands of the busy school year.

Pat’s Experience

Pat felt the study group had helped keep her “accountable” as she tried to do more hands-on science activities with her class during the year. At second grade, heavy emphasis is placed on reading and math. Many of her primary colleagues put science on the back burner. Pat found that her grade-level

curriculum makes it hard to find time for science, but she has always tried to prioritize it. She said:

I really wanted to try to do more actual hands-on in the lab, and I ended up not really doing that so much as it's just too inconvenient to get over there. But I did try to do more investigations in science in the units I used. I think it kind of pushed me to do this. You know, it kept me going, and I've got to get this done because we're going to be meeting, and we need to talk about things and we're going to have to do your video, and so it kind of kept me motivated.

Pat's comments illustrate how the study group not only supported its members but also put some social and professional pressure on the participants to follow through with the agenda. All of the study group members struggled with extenuating factors that interfered with their commitment and ability to focus on adapting their science instruction. In Pat's mind, the external pressure placed on her as a result of her participation in the group had positive consequences, as it prodded her into placing more of a priority on her science teaching than she may otherwise have done. The pressure was not overwhelming, but just enough to have her feel an extra sense of accountability.

Pat believed that her teaching had become more constructivist over the course of the school year. She felt more comfortable in defining this type of teaching and was motivated to incorporate it more into her science instruction. She found second graders to be very enthusiastic "scientists," and she wanted to provide them with more opportunities to experiment:

I think they would say that they wish we could do it more often. They liked doing things, activities, "experiments," they call them. I think they would wish that we would do it more often. They're always real excited about it. Sometimes it's not a real formal, where, all right, we're going to do science. I've had a lot of discovery areas out, just have things sitting out for them to question and for them to try. And I usually had a science

activity at a center, which they always loved to do. They were kind of on their own to do that, and some of them came up with different things than others would, as far as results.

We used the book a couple of times as a reference tool, but other than that, I found that this particular group of kids was very interested in science. So they had lots of questions, and they did a lot of "What ifs?," if we did this, what would happen? So they were real good to work with.

Like Beth, Pat found the study group to be a good source of suggestions and support, although she was still disappointed that another lower-elementary person had not participated. She had found, however, that she had come to enjoy meeting with a different group of teachers than she normally worked with at the primary level: "I think it was great. I mean, I don't have as much chance to interact with everybody over there." To address her feelings of isolation at her grade level, she believed it would be helpful to go outside our building: "Like district-wide. It'd be nice to get the second-grade teachers together and talk about our science curriculum. I would really enjoy that." Even though she was outnumbered by upper-elementary members in the study group, Pat still found the meetings to be a beneficial source of support and camaraderie:

I think it was good to get together and talk about our experiences teaching science and our frustrations, and things that worked and things that didn't work. And it was nice to get encouraging comments or helpful hints about how our lessons went. I just think it's been kind of fun. I've enjoyed it. I mean it's hard for all of us to get together to talk about it, but I think it's a good idea. I wish we did it more often. And maybe not just for subject matter, like science, but grade levels, and you can share and get together more.

Like Beth, Pat wished that the study group would have had time to meet more often. She was especially interested in doing more videotaping. She had felt comfortable sharing her tape and thought the group would only get better and better at critiquing each other if we filmed ourselves more and continued to meet.

Pat felt that time was still the biggest obstacle facing her. She had come to realize that the study group could not provide her with any more time to organize her units and actually teach science with her class. Finding space for all her materials and equipment was also a problem. She described these difficulties:

The old time constraint. When there's no time for everything, it's very hard to get it all in. And with my younger ones, they're so enthusiastic, and you can only do it in little short bursts of time, and then anything you do, you kind of like to leave out, and there's a space problem. Gathering all the materials together to do everything is time-consuming. You know we don't have a book for this, we don't have a book for that, so I've got materials all over, for every subject. A box for science, a box for math. And that's what's frustrating, I think. I can plan all these wonderful things, but then the actual time. Or you get an activity all planned, and then the weather doesn't cooperate. But that's the way science goes, I guess!

Overall, Pat felt the study group experience had been a positive opportunity to find support from her peers. She said, "I think you get a lot of good ideas, and you're not the only one having the frustrations, and you can work things out."

Karen's Experience

Karen had started the school year feeling very unprepared and tentative in her role as a science teacher. From her remarks during the final interview, it seemed she had become more comfortable in this role as a result of participating in the study group, although she felt she still had a "long way to go." Karen had not found the half-day, district science inservices with the hired consultant to be helpful to her. While the consultant was there to promote constructivism, she spent time lecturing the audience of teachers. While Karen had left that

workshop feeling confused, she felt the study group had helped her become more familiar with the nature of constructivist science teaching. She explained:

I feel like I understand it a little better, but I admit I'm not all the way there yet. And I think when the lady, when we first went down to those big meetings, that lady was just trying to push constructivism, but she didn't use it. I guess I felt at the time it was like she just said we have to use constructivism and that's it. It was bad because she just talked about it, and if you don't know what it is, she could tell you about it all day, but unless you see it...and she didn't even show us a film or anything about somebody doing a short lesson that way.

Karen felt that she had accomplished what she had set out to do by agreeing to participate in the group. While she was nervous about joining and especially about having others watch her teaching on camera, her fears dissipated as the group continued to meet. She commented:

I was more at ease than I thought I would be. And in showing the video, I didn't want to do that, and it was better than I thought it would be. I learned, and I was hoping I'd learn a lot, and I feel like I did, about hands-on science. Although I still have a long way to go, but I learned a lot and I was hoping I would do that. I benefited from seeing other people teach science and learning more about the hands-on part, and I was glad I was in the group, too, because I got to go to some of the science seminars at the ISD that I never would've done by myself, on my own. But because you filled out the paperwork, I was able to attend. I liked that part, too.

Each of the group members began the project at a different level of proficiency and comfort in teaching science. By her own admission, Karen had not felt capable of leading students in hands-on activities on her own. She made progress in this over the course of the school year, but she was still defining constructivism rather narrowly as "hands-on" instruction. She was not yet asking the difficult questions of nuance and technique that the other teachers in the group were struggling with. While she still felt she had a "long way to go," the changes she had made and the risks she had taken were big steps for her.

Karen could see the benefits in students' responses to her teaching. They seemed to have a very positive attitude toward science when she used a hands-on, constructivist approach as opposed to the times when she used the Silver-Burdett textbook. Although some of the kids didn't seem to mind reading from the text, Karen felt it turned most of them off. It was important to her to continue to improve her teaching. She had several areas she identified as weaknesses, which she planned to work on in the future. One of these areas was her lack of scientific content knowledge:

I still need more background knowledge. Like I said, I went to the workshops at the ISD. I mean, he [Terry Farmer] really gives you a lot of background knowledge, so I wish I could keep going to those with all the different areas that I'm supposed to teach. Because I really feel like he does a good job of that. And that's what we need. Not somebody else coming in to lecture us.

Karen felt that as she expanded her background knowledge, she would also be able to improve her questioning skills. She agreed with me that "when you know more, you talk more," but she felt her scientific illiteracy hampered her ability to formulate questions and lead discussions. By deepening her own scientific understandings, she could "just let them do more constructivism, and I could do more cueing...like even asking the right questions. That's a real skill, too, that you just need lots of practice at."

Like the other members of the study group, time to do all of this was an obstacle for Karen. She found it difficult to find the time to prepare the lessons, to set up the activities, and to actually conduct hands-on lessons in an already overloaded school day. Even sacrificing the time to participate in the study group was tough. While she felt it would have been nice if we could have arranged for

substitutes and met during the day, she noted that this would require school district funding. That would take control out of our hands, which she was reluctant to do. She explained:

It was real relaxed and everything, but it still took a lot of time. And it would've been nice, just somehow, to put in the time in a different way, during the day or something. I feel that I learned enough to help outweigh the time input, but it still would've been nice to have it that way.... But like I told you before, I think it was good that it was voluntary, and if you did it during the day, then maybe it wouldn't be voluntary and that wouldn't be... it would be just as bad. Since it was voluntary and after school, going to ask these people for other help, you felt more like they would have the time to do it. Because they were volunteering time, too.

While Karen felt the study group had formed a supportive network for helping each other improve our science teaching, she didn't think the members had fostered more collegial relationships among each other on a deeper level than that. She explained:

We formed more of a science group, but it didn't seem to go much farther than that. So maybe you'd feel more comfortable going to one of these people and talking to them about science and asking them for science input, but I didn't get a lot closer to anybody else just in a... day to day, maybe a little bit because you're seeing them more, but not really a lot closer, just more, it was a science, like you feel you could go and ask them questions and maybe not just about science, but about other things, too.

Karen welcomed the opportunity to work more closely with her peers, however. Westdale's school improvement plan provided for grade-level planning time each month in which substitutes were brought in to excuse each group of teachers for a half-day of planning. She enjoyed this chance to talk and plan with Cindy and the other fourth-grade teacher: "I think that the planning half-days we've had have been just wonderful because you get ideas of who's doing what and what

you can do. In elementary, it's always hard to share, and we're all in our own little domain."

As Karen had been the most tentative and the least vocal throughout our meetings, I wondered if that had impacted her feelings of cohesiveness with the group. The other members, especially Beth and Pat, had really relished the opportunity to work together and found the study group to be a supportive environment in which to share their frustrations and successes. Perhaps Karen did not feel as vested in the group because she did not feel as comfortable speaking when we met.

Reflection and Further Analysis

Figure 6 displays a data matrix analysis of the final interview questions (see Appendix G) and the participants' responses, categorized according to one of the three major themes of negotiation previously presented: negotiation of constructivism and the new science curriculum; negotiation of support relationships with others, including the group members, Donna Workman, Terry Farmer, and the district administrators and science consultant; and negotiation of external and internal resources, obstacles, and constraints that influenced teachers' attempts to practice constructivist science teaching. These three themes arose during the final analysis and writing phase of the dissertation, as it became apparent that most of the significant experiences and processes the teachers engaged in fell into the realm of one of these themes.

Themes of Negotiation	Cindy's Views	Karen's Views	Beth's Views	Pat's Views
Negotiation of Constructivism and the New Science Curriculum	Her definition of constructivism had changed little since the beginning of the year: equated constructivist teaching with a discovery approach, and felt that this approach was best suited for science instruction. Valued didactic forms of instruction as well, especially in other subjects, but did not see how didactic teaching could fit within her definition of constructivism. She had not made as much progress in adapting her instruction to fit this discovery approach, due to the constraints she mentioned.	Students seemed to have a very positive attitude toward the more constructivist lessons she taught. She felt the students developed better conceptual understandings from the lessons in which they had hands-on experiences. Was beginning to understand that constructivism entailed much more than hands-on activities, but felt she had a long way to go before she would have the background knowledge and questioning skills she needed to reach a conceptual-change level of instruction.	She applied constructivist pedagogy to some other subjects as well as science, and felt that she was involved in a career-long process of adapting her instruction so that as many lessons as possible actively engaged her students. Viewed constructivism as a more general approach that could include a variety of activities promoting conceptual-change. During the study, Beth actively critiqued the curriculum content and sequence, as well as the nature of individual lessons, with the goal of increasing students' conceptual learning.	Spent more time this year facilitating active science investigations. Focused on changing her teacher talk from telling to questioning. Encouraged children to ask their own questions and led investigations to explore these questions. Thought she would make more progress increasing hands-on lessons than she did, but did do more than she had before. Students like doing activities and experiments and they loved to do the science centers, which created opportunities for free exploration and question forming. Pat's focus on activity-based and discovery-based science was guided by her intent to build background experiences and curiosity in her young students.

Figure 6 Data Analysis Matrix for Final Interviews

Figure 6 (cont'd).

Themes of Negotiation	Cindy's Views	Karen's Views	Beth's Views	Pat's Views
Negotiation of Support Relationships with Others: Group Members, Donna Workman, Terry Farmer, District Administrators and Science Consultant	Realizing that the other teachers also faced many obstacles helped her see that we were all in the same boat, and this helped her start seeing the positive assets we had as well. Learning that this type of teaching was difficult for all of us was actually beneficial to Cindy because she no longer felt isolated in her frustrations. Thought we'd all have more expertise to share; those with more experience could provide answers. Found that we all struggle with this type of teaching. Felt less defeated, more supported – this was difficult for everyone, we were in uncharted territory. Felt that the science lab had sparked a school-wide change from textbook-based instruction to hands-on instruction.	Watching the other teachers' videotapes, and attending the physics workshops helped her develop more content knowledge and take some risks with "hands-on" teaching. She feels the study group made an impact on her teaching by providing a supportive network in which she could try new pedagogy. More at ease with group work and videotaping than she predicted. Wanted to learn a lot about hands-on science and felt she did. Terry Farmer's ISD workshops really helped, wouldn't have participated in those if not for the group. Would've liked meeting during the day with substitutes providing release time, but then it might not have been "voluntary," which kept it nonthreatening.	We focused on our own teaching, reflecting, sharing. Felt that the group collegiality supported change in practice. Wanted to meet more often – "This was so important, make it a standing commitment." Wanted the group to continue meeting. Had unresolved issues of teaching control with Donna Workman.	Study group helped her feel accountable. Group pushed her to do this, kept her motivated. Liked the support and encouragement, interacting with others. Still wished for a lower-level elementary colleague to share and dialogue with.

Figure 6 (cont'd).

Themes of Negotiation	Cindy's Views	Karen's Views	Beth's Views	Pat's Views
Negotiation of External and Internal Resources, Obstacles, and Constraints that Influenced Teachers' Attempts to Practice Constructivist Science Teaching	Many constraints (personal illness, lack of time, students' background knowledge and experiences, etc.) limited her ability to be as constructivist a teacher as she would like. Study group could not help her overcome all those constraints. She admitted that science teaching in the school had come a long way in the four years she had been there, but felt that the increase in hands-on activities fell short of her perception of the depth of constructivist science teaching.	Still felt hampered by lack of time to plan, set up materials, and carry out experiments/lessons, as well as her own limited content knowledge and ability to pose appropriate, guiding questions. Found that this type of teaching was much more time-consuming than text-based instruction.	Students liked the science activities, but they had a harder time processing the information. Beth felt kids weren't used to this type of thinking but that she built a foundation for their future learning. Most of the kids really seemed to like science. She needed more time to plan and rework lessons and units she felt needed improvement. Felt that Donna Workman's authoritarian manner prevented students from taking risks and designing experiments in the lab.	Her biggest obstacle remained the labor-intensity of preparing for two manipulative-based curricula, but she managed to deal with this as best she could and make progress. She also struggled with finding enough classroom space to set-up science centers and leave out materials from science lessons, so that students could investigate individually on their own time.

In analyzing the experiences of the study group members as we spent the school year meeting together, I reflected back on the guiding research question for this study, which was: What role can a teacher study group play in helping elementary teachers understand and implement constructivist science teaching? The teachers in this study went through phases in their efforts to become more constructivist science teachers. Just as teachers have been shown to go through phases in their teaching careers, with successive levels carrying labels. "Survival" reflects the initial years when teachers are indoctrinated into the profession and are struggling to create a personal framework for handling their myriad responsibilities. "Stabilization" reflects the next few years that see teachers settling into the profession and fine-tuning their repertoires. "Mastery" level is achieved when teachers have reached a well-developed level of capability and are confident in their skills (Huberman, 1989; Feiman-Nemser, 1983). These teachers proceeded through a series of successive stages in changing their science teaching, but they began from different points. All of the members began with an initial curiosity about constructivist science teaching, but Beth was further along in her attempts to refine her current practice of constructivism. They had an open mind and were eager to learn more about the benefits of this type of teaching over more traditional pedagogy. In the initial interviews, they also expressed a need to have a better picture of what this type of teaching looks like in others so that they could work toward incorporating it into their own practice.

Anyone who has worked in schools during a curriculum renewal project invariably has heard some teachers bemoaning the change. A curriculum change throws an experienced teacher into a state of disequilibrium and temporarily returns that teacher to the point of “survival,” as he or she becomes acquainted with the new program and adapts his or her teaching. Such was the case with the Ojibway School District’s new science curriculum. Linking teachers’ negotiation of the new curriculum with another taxonomy, the Concerns-Based Adoption Model (Hord, Rutherford, Huling-Austin, & Hall, 1987) discussed earlier, it can be seen that many teachers were coping with “self” concerns (awareness, informational, and personal issues) and “task” concerns (management issues), especially at the beginning of the study. Concerns that centered on “impact” issues (consequences of the innovation, collaboration with others, and refocusing/refining of instruction), such as those that Beth focused on, arose more infrequently, or were intertwined with task concerns (for example, comments that the support of the study group helped members address management concerns). Few elementary teachers could be expected to have both the scientific content knowledge and the experience with constructivist pedagogy that Beth did, and would be less inclined to raise “impact” concerns as she did regarding assessment of students’ understanding and learning. However, even Karen benefited from hearing the concerns that other members of the group raised, and this helped her understand that she still “had a long way to go,” and that constructivism entailed more than just hands-on activities.

As the group discovered during our first few meetings, this process of change was more difficult than most of us at first expected. Only Cindy seemed to have brought a realistic picture to the group, based on her previous teaching experiences in a highly progressive school where constructivist teaching was emphasized. This reality set in with the rest of us by the time of the second interviews in November, 1996. At that time, the group dwelled on the obstacles it was facing as we worked to improve our science teaching. Lack of time to do such things as plan, rework lessons, set up materials, and reflect on our teaching were listed as major deterrents to changing our practice.

As the group members began videotaping and sharing their lessons, the obsession with obstacles seemed to be tempered by a new feeling of budding confidence within the group. As we shared our tapes and were offered both constructive criticism and support, we all came to realize that this process of changing our practice would be a long one, but it was one that we all cared about. With the exception of Cindy, the need to give excuses fell away as we realized we were all in the same boat. There was no longer a need to be on the defensive because no one was accusing us of being poor science teachers. We were making progress, slow to be sure, but progress nonetheless. By the time of the year-end interviews, Pat, Beth, and Karen had stopped dwelling on the time issue and were dealing with meatier issues that involved reflecting on their own practice. Cindy was still focusing on obstacles, which I believe was largely predetermined due to the uncertainties and realities imposed by her illness.

This was the promising phase at which the study group's efforts came to a halt because of the boundaries of this study and its time-line as a research project. Had we continued to meet we would have proceeded even further. During the course of the year, we struggled with developing definitions of constructivist science teaching that meshed with our own definitions of what constituted valuable teaching and learning. Only Beth's teaching consistently fit within the conceptual-change model because she was the only one who had the background knowledge to really understand children's misconceptions. Karen had moved from a didactic approach to an activity-oriented approach, and although she was beginning to ask questions about children's learning and how she could refine lessons, she still felt relatively uncomfortable with her science teaching. Pat and Cindy's descriptions of their teaching generally fell into the realm of discovery, although they each had moments when activity-oriented and conceptual-change teaching were practiced. Overall, Beth, Cindy, and Pat still faced some significant obstacles to overcome on their road to inquiry-based science teaching of the conceptual-change variety deemed to be most effective in building conceptual understanding in children (Anderson & Smith, 1987; Smith & Neale, 1991).

All reform movements require change on the part of teachers, as well as additional learning. However, few reformers have considered how difficult the "adventurous teaching" (Cohen, 1988) they advance would be for practitioners. Cohen elaborates on the naivete embodied in many of these efforts:

Reformers... have seen no great obstacles to improvement. They have argued that teachers simply had the wrong books, or used the wrong

methods, or worked in the wrong conditions, or had the wrong sort of education.... Once the institutions were changed, or curriculum pointed in the new direction, children and teachers could adventure off together. Everyone believed that such teaching would be very different, but hardly anyone thought it would be very difficult. (p. 23)

As evidenced by the experiences of this group of teachers, reforming practice is difficult. Practicing constructivist science teaching will take a career-long commitment on the part of teachers, a willingness to put in hard work and allocate precious time, and a continued expansion of their background knowledge and developing skills in constructivist teaching. This effort would be greatly supported by a more conducive and understanding district atmosphere, a context in which administrators and coordinators supported constructivist learning opportunities for teachers and recognized the resources that are needed to be allocated to this learning process. With no sustained support for teachers, it's too easy to fall back on old, comfortable habits of practice.

There were many components of this model of professional development that I believe were effective. Those most helpful were:

- working in our own context to personalize our professional development within a supportive network of peers
- bringing in Terry Farmer as a consultant
- attending the physics workshops to expand our knowledge base
- defining for ourselves what constructivist teaching is and what it looks like, compared to theorists' or teacher educators' conceptions of this
- videotaping our lessons and sharing these with the group
- identifying obstacles and working together to overcome them
- rejoicing in each other's successes

While none of the members made as much progress as she would have liked, no one faulted the study group as a vehicle for professional development. The members were in agreement at the end of the year that the study group had helped them improve their science teaching to varying degrees, depending on the individual. We also identified some improvements that possibly could have helped the study-group project be even more successful:

- Arrange for release-time substitutes so that all meetings didn't have to be held after school when teachers were tired.
- Meet more often.
- Meet during the summer when teachers have more time and energy, and include students in a "constructivist science teaching daycamp/week."
- Build on what teachers accomplished by continuing to meet the following year.

One of the major impressions this experience left me with was how important it is to overcome the isolation elementary teachers feel as they go about their business each day. This study group could have focused on any subject area: social studies, language arts, mathematics, etc. The fact that the impetus for this group's formation was a new, elementary-science curriculum was in some ways incidental. Teachers struggle with isolation and the demands of school reform efforts every day.

This study served to explore the possibilities of using a small study group as a means of reform, teacher empowerment, and support. We did have a goal: improving our science teaching through the incorporation of constructivist teaching practices. We made some progress in reaching that goal, and I believe

we laid the groundwork for continued progress. We also overcame some of the feelings of isolation that many of us feel as we work in our classrooms with children.

However, we also experienced many of the obstacles that teachers will face if they seek to practice the vision of the national science reform movement. We struggled all along with defining and practicing constructivism in our own learning as well as in our teaching. It is obvious that the reform vision demands drastic changes in the ways in which science has been taught by most elementary teachers. It should also be obvious that many teachers are unprepared for these changes. This study gives a detailed description of a small group of teachers struggling to make those changes together and the ways in which they negotiated their understandings and practice. As the reform movement continues, it is important to recognize that innovations are negotiated by teachers in schools and classrooms, that obstacles arise which impede teachers' efforts, and that the support of colleagues can help teachers respond to innovations in educative, proactive ways.

As a model of personalized professional development, this study has implications for teachers, those responsible for curriculum development, professional development coordinators, and science educators. Chapter Eight discusses the themes of negotiation that arose from this group's work and the implications these have for science teaching in a world where reality does not often support the ambitious vision of science education reform before us.

CHAPTER EIGHT

Conclusions, Implications, and Recommendations

Introduction

This study documented one model of professional development. It was designed to help teachers grapple with the recommendations of the science education reform movement on a personal, contextualized level. This study is unique in that the researcher was involved with this group of teachers as a colleague for several years before the study began, and this presented an opportunity for an intimate portrait of educators struggling to make sense of constructivist science teaching and their attempts to practice it. In analyzing the experiences the study group members brought to the study and the activities they engaged in throughout the school year, several implications and recommendations come to light. The findings have particular relevance for those involved in promoting constructivist teaching and reforms in science education.

Like many of their counterparts in other schools, the teachers in this group faced a difficult challenge as they negotiated paths of understanding and practicing constructivist science teaching. They felt they had many strokes against them. Most of the members of the study group had weak science backgrounds, which they felt hampered their ability to teach scientific concepts effectively and improve their lessons. There was very little time during the course of a busy day to devote to the improvement of their science teaching, and the district had not devoted much in the way of fiscal or human resources to support them in their efforts. The participants were frustrated with the lack of

commitment the district seemed to give to science, which they felt was evidenced in several ways: teachers were forced to share one set of materials in an effort to conserve substitute costs, teachers had only been allowed to attend one of the three inservices, and the “science” consultant was really the “math” consultant, trying to do two jobs at once.

Along the way, no one in a position of power in the district had asked the teachers if they needed additional support as they implemented the new science curriculum. Nor had any of the teachers communicated their frustrations to anyone in a position to commit district personnel and financial resources to professional development. The sharing of their complaints and frustrations had been limited to “lounge talk,” which probably would not have resulted in any positive change had I not been looking for a dissertation topic at the same time.

The troubles that faced the Ojibway administrators and teachers as they struggled to make sense of the movement in science education toward constructivist pedagogy (and design a curriculum that represented this pedagogy) were not unique. The Michigan Statewide Systemic Initiative research has revealed these same challenges among educators in the nine school districts studied. Spillane, Thompson, Lubienski, Jito, and Reimann (1995) comment:

Most local educators have had few opportunities and little time to learn about these recent theories on teaching mathematics and science education. Moreover, given that what we learn is shaped by our prior knowledge and beliefs, we should not be surprised to find that many local educators have constructed understandings of key reform themes that differ significantly from the ideas promoted by state and national reformers...unless local educators are given opportunities to learn about these new reform ideas – that is, occasions when they can test out

understandings of these recent reform ideas and talk with others about change their conceptions of key reform ideas. (pp. 78-79)

In order for teachers to become familiar with the tenets of the current science reform movement, they must or need to have opportunities to meet with people who are knowledgeable about them. They need to be exposed to literature and professional development activities that can help them understand what constructivist learning and teaching is, and why it is being promoted by science education reformers. They need to understand that most methods of science teaching currently being practiced are not helping children understand scientific concepts or processes. In other words, they need to develop an understanding of the pitfalls of didactic and activity-oriented science in terms of children's learning and why conceptual-change teaching offers more hope. Unfortunately, the ability to meet this need is mediated by a realistic examination of teachers' backgrounds and proclivities, current formats of professional development, the organization of schools, and the difficulty inherent in the process of understanding and negotiating constructivist teaching.

Teachers need to become more critically aware of their current beliefs and instructional practices, and they must reflect on how these current beliefs and practices compare with those espoused by the reform recommendations. The teachers in this study group all began with different definitions of what constructivist science teaching is, with some common ground among them, and they practiced science teaching that ranged from didactic to conceptual change-based orientations. Through the activities of the study group, they were able to clarify their own beliefs and practice, and come to a better understanding

of what changes they needed to make. They ended the year having negotiated personal definitions of what “good” science teaching meant to them and with personal goals for their own continuing growth.

The teachers faced internal and external challenges in trying to bring about many of the changes they felt they needed to make, which caused each of them to make choices and decisions that affected the individual paths they laid for themselves. In this regard, they were similar to other teachers at other times and places who have also engaged in mutual adaptation of an innovation and/or created an enacted curriculum that varied from the original intentions of reformers (Fullan & Hargreaves, 1992; O’Neil, 2000; Sikes, 1992; Snyder, Bolin, & Zumwalt, 1992). This process of negotiation was undertaken alone and within the support structure of the study group, and was alternately facilitated and hampered by other key people who played support roles in science teaching, such as Donna Workman, Terry Farmer, Carol Tate, and the district administrators.

In this chapter, I will focus on the changes in these teachers’ conceptions of constructivist science teaching over the course of the year and how they came to personal understandings of what it meant for their own practices. I will then analyze the resources and challenges that influenced the study participants’ efforts to change their teaching so that it aligned more closely with their own understandings. The ways in which the teachers negotiated support from each other and with other people who could play key support roles in their efforts will also be discussed. From this group of teachers’ experiences, implications for a

wider audience will be presented. These implications focus on the difficulties and contradictions inherent in transforming one's practice toward a constructivist approach, and the kinds of choices teachers make as they negotiate their understandings and practice of the recommendations of the science reform agenda.

The Research Questions

Once again, my dissertation was guided by the following research question: **What role can a teacher study group play in helping elementary teachers understand and mediate constructivist science teaching?**

Subsidiary questions branching from this guiding question were:

- What previous experiences, knowledge, opinions, and misconceptions regarding science and science teaching do teachers bring to the discussion of constructivist science teaching?
- Within a peer study group, what types of activities can help teachers bridge the gap between constructivist theory and practice, resulting in a feeling of preparedness and comfort in teaching science?
- How can the support and constructive criticism of a peer study group help elementary teachers refine their practice of constructivist science teaching?
- What tensions and struggles do teachers experience as they work together to mediate constructivist science teaching?
- What tensions and struggles do teachers experience as they seek to become constructivist learners themselves?

When analyzing the data collected during the study in light of the research questions above, the significant pieces of data tended to fall into one of three themes of negotiation: negotiation of constructivism and the new science curriculum; negotiation of support relationships with others (study group

members, Donna Workman, Terry Farmer, district administrators and the science consultant); and negotiation of external and internal resources, obstacles, and constraints that influenced teachers' attempts to practice constructivist science teaching. Figure 7 on the following pages presents a summary analysis of the group's experiences, struggles, and successes.

Each of the three major themes was drawn from evidence related to the research questions. Teachers' experiences and comments related to science and science teaching fell predominantly into the negotiation of constructivism and the new science curriculum category. The struggles and tensions faced by teachers as they attempted to change their teaching practice fell predominantly into the negotiation of external and internal resources, obstacles, and constraints category. Finally, the support and constructive criticism experienced by the group members is predominantly described in the negotiation of support relationships category. Following the chart, each of the three themes of negotiation is discussed in further detail, along with implications of these findings.

Themes of Negotiation	Evidence and Analysis
Negotiation of Constructivism and the New Science Curriculum	Group members' definitions of constructivism and personal teaching goals for their own practice shared some common features (more hands-on opportunities, asking better guiding questions, focusing on student talk and discussion, assuming a facilitator role and avoiding an authoritarian role, etc.) but also varied according to personal experiences, teaching philosophy, and knowledge base. Teachers negotiated their own teaching goals based on their current understanding and comfort level with science and constructivism. The teachers deliberated the nature of constructivist science teaching throughout the year and never came to a complete consensus of understanding or agreement of opinion regarding its "exemplary" practice. Exposure to constructivist models of teaching (through videos, workshops, Terry Farmer's visits to the study group's meetings) served to spark discussion and reflection on personal practice and led to experimentation in practice.
Negotiation of External and Internal Resources, Obstacles and Constraints that Influenced Teachers' Attempts to Practice Constructivist Science Teaching	- While the study group members' efforts to change their practice was facilitated by the science lab (as far as facilitation of science materials), a supportive principal, the collaboration with each other, and the new curriculum, the study group members' ability to change their practice was hampered by the limited amount of time available to them for professional development, planning, and reflecting on lessons and units. Other conditions affected teachers' ambitions negatively, but to a lesser degree: district financial constraints (necessitating limited sets of science materials and taking turns attending half-day science inservices, instead of all three), and the quality and sequencing of some of the science lessons in the new curriculum. While teachers often perceived value in the models they were exposed to, their ability to incorporate much of what they encountered was hampered by lack of time, energy, and/or commitment. - Teachers' science content background knowledge affected their ability to feel comfortable with the unit they were teaching, to ask appropriate, guiding questions of students, answer student questions, and design additional activities when assessment or intuition told them students weren't understanding a concept.

Figure 7 Themes Emerging From Teacher Participants' Negotiation of Constructivist Science Teaching

Figure 7 (cont'd).

Themes of Negotiation	Evidence and Analysis
Negotiation of Support Relationships with Others: Group Members, Donna Workman, Terry Farmer, District Administrators and Consultants	• The study group served as a positive source of collegial support for its members and was a place for teachers to share frustrations, discuss possible solutions, and open up their practice for self-reflection and peer critique. Some members were influenced by the accountability aspect of participation in the group. Knowing that they were going to be sharing and discussing their practice encouraged them to work harder at improving their science teaching. • Study group members appeared reluctant to share negative criticism with peers, which led one member to believe that participants weren't given completely reliable feedback. • While Donna Workman and the science lab she staffed alleviated much of the lesson set-up/clean-up burden for teachers, her authoritarian nature created personality conflicts with some teachers and presented an obstacle to students' self-direction, risk-taking, and experimentation. • Terry Farmer was a valuable source of expertise in science content and instructional methodology, but the group found that some of his suggestions were impractical for the classroom and that he sometimes became too busy to provide the individual, follow-up help he had promised. • District administrators, such as the elementary science consultant and the assistant superintendent, presented conflicting messages regarding the goals for science teaching in the district. Although a constructivist methodology was officially advocated in the creation of the new district materials, the professional development and ongoing support provided and the MEAP-preparation materials were shallow and much more didactic in nature. The Westdale principal was a supportive, interested administrator who entrusted the group members with "free reign" in our work.

While each of the findings listed within each theme fits primarily into the category listed, there is some overlap among some points. For example, in Beth's relationship with Donna Workman, the science lab paraprofessional, there are elements that fit under the "relationships with others" category as well as the "resources and obstacles" category. I have tried to categorize the findings as clearly as possible, but I have still found that in a situation such as this, in which teacher's opinions, successes, and struggles were influenced by the curriculum, the support people around them, and by obstacles beyond their immediate control, some overlap of categorization was inevitable.

Negotiation of Constructivism and the New Science Curriculum

The teachers in this study group, including myself, began and ended the project with personalized definitions of constructivism. Although there were strong common threads that wove through these definitions, there also were differences in what each teacher expressed. In keeping with the interpretivist paradigm that all knowledge is mediated through individual human experiences and perceptions, it is natural that there would be some differences among us about what constituted constructivist pedagogy and "good" science teaching.

There was also some discrepancy in the goals the members had for what "good" science teaching should hope to accomplish. Did we want children to enjoy science more? Do more hands-on activities? Develop problem-solving skills and the ability to make independent decisions and conclusions? Learn important scientific concepts? Make real-world connections from what they learned in class? Become better at asking questions, taking risks, and

expressing their ideas? Did we want all of these things at different times depending on the particular lesson, or did we hope constructivism would weave all these wonderful aims together into one package?

The teachers in this group made comments throughout the year that suggest they wanted all of these things for their students, but they were at different stages in their ability to make these things happen. Their definitions of constructivism and their practice of inquiry-based science seemed to fall along the continuum of teaching behaviors described earlier (Anderson & Smith, 1987; Smith & Neale, 1991). Karen began the study with a basic definition of constructivism that equated with activity-based, hands-on instruction, although her practice at that point was didactic. Her goals were to get away from the science textbook (which she said turned off many students) and to become more comfortable leading hands-on activities herself. She wanted her students to enjoy science more and could see that they liked hands-on activities. Karen also knew she had a weak science-content background herself, which had caused her to fall back on the textbook and the help of Donna Workman in the first place. She wanted to expand her own scientific knowledge base, but it was not until later in the study that she began talking about how large a role a teacher's knowledge base played in the constructivist teaching practices of designing and evaluating lessons (both for initial teaching and coaching when students are struggling), pre-assessing student understandings, asking guiding questions, and knowing the larger concepts children needed to understand.

The reform agenda is an ambitious one, especially for elementary teachers. Karen may be typical of many elementary teachers who took the minimum number of science courses required: one or two in high school and college. Her early definition of constructivist teaching equated with hands-on, “fun,” high-interest activities and aligned with popular science materials and workshops such as Activities Integrating Math and Science (AIMS) that many elementary teachers are familiar with. Through her participation in the study group, Karen understood many of the complexities inherent in the practice of constructivism and could see that she was “a long way” from having the content knowledge and comfort level with constructivist pedagogy to be able to be a great science teacher, but she was pleased with the progress she had made. She had moved beyond her reliance on didactic pedagogy and was now feeling more comfortable incorporating hands-on activities into her science teaching. Her instruction now combined these two styles, but she was beginning to acknowledge that simply plugging in hands-on activities was insufficient. In the final interview, she discussed how her limited content knowledge still impacted her ability to “ask the right questions” and had come to the realization that she needed to continue expanding her knowledge base in order to progress toward conceptual-change teaching.

Cindy began and ended the study with a view of constructivism that aligned with discovery-oriented teaching. She also admitted that her own preferred learning style (verbal-linguistic) was at odds with this approach. In what is perhaps telling of this preference for language-related learning, she

seemed to focus on the root word “construct” and opined that constructivist learning is learning that is “totally hands-on, constructed out of their heads.” Cindy critiqued the science curriculum as not including enough discovery-oriented lessons and acknowledged that these types of lessons are difficult to create, especially in certain topics (such as the Solar System unit). Interestingly, although Cindy felt that science instruction ultimately should be discovery-oriented, she did not apply this principle to her own learning. She began the study hoping that the other teachers would have solutions to offer and that educators would have solved the problems she first encountered in her progressive, constructivist science teaching experiences of the late 1960s.

Whether her illness incapacitated her to the point where she was unable to devote the energy and time necessary to rework some of the lessons she was unhappy with is a matter of speculation. Had she not been ill, Cindy may have been able to engage herself in “discoveries” of her own, redesigning lessons and experimenting more in her practice. Instead, she videotaped a lesson she was already comfortable with, after previous tinkering, and now seemed to feel she lacked the content knowledge and time to engage in further personal discoveries in her science teaching. She was encouraged by the progress the school had made in the four years she had been there, and although she acknowledged there was still much room for growth, at the time of the study she appeared immobilized in her ability to take action on what she felt needed to be improved.

Beth was an unusually strong elementary science teacher. She began the study already engaged in conceptual-change teaching. She probed students’

understandings, strived to connect hands-on activities with solid conceptual understandings, worked to help students design their own experiments, and assessed students' learning. Throughout the year, she was engaged in the "career-long" reflection, experimentation, and curriculum development work she expressed would be an ongoing part of her journey as a teacher. Like the others, she found her efforts to "speed up" her progress hampered by insufficient time for these activities. Although she knew she would be continually refining her science teaching for the duration of her career, she still battled with guilty feelings when she was teaching a unit she felt needed to be improved. As we were fifth-grade colleagues and classroom neighbors, we had many after-school conversations about our day-to-day teaching. She seemed to have time to reflect on what was successful and what went wrong, but finding time to take action on these reflections and actually rework/rewrite lesson plans for the next year was difficult.

Pat had also been working on improving her science teaching for many years, although her focus was somewhat different than Beth's. As a fifth-grade teacher, Beth was predominantly concerned with her students' learning achievement and their development of conceptual understandings (a goal influenced in part by the fifth-grade science MEAP test). Pat, as a second-grade teacher, was more interested in developing eager, curious, questioning, active, science learners. She strove to create an interactive classroom, circumnavigated by science centers and learning stations. Pat concentrated her energies on the nature of classroom dialogue, seeking to engage students' in more conversation

and conjecture, and doing less lecturing and more open-ended questioning herself.

Pat's lower level of concern with learning achievement aligned with Terry Farmer's opinion that elementary-level science instruction should focus on building background knowledge and hands-on experiences for children. Conceptual understandings and scientific vocabulary would come more easily later when students could reflect back on the "intuitive understandings" they had developed through manipulation of materials and ideas at an early age. Pat was more interested in providing experiences that would contribute to the later learning of key concepts and avoiding experiences that would lead to early misconceptions (and thus interfere with students' future learning). While Pat certainly did not ignore opportunities for learning achievement, her negotiation of constructivism led her to focus on building excitement and experiences, and was probably more appropriate for the young students she taught.

Designing the Ojibway curriculum was a learning opportunity in itself for the teachers who were involved in the developmental process. Those who were responsible for creating the new science curriculum seemed to have a clearer vision of what the new science reform movement entailed. The process of curriculum development also served as a form of professional development as the committee members met together over the course of several years, attending workshops, working with Terry Farmer, familiarizing themselves with the MEGOSE standards, examining science materials, and becoming acquainted with the learning cycle model (Loucks-Horsely, et. al, 1990) presented in Chapter

One as the predominant outline used in designing district science units. This was obviously a beneficial experience. While it may be realistically impossible for all of the teachers in a large school district to be equally involved in a district-level curriculum design process, for the teachers on the Ojibway committee, this process was a form of professional development in itself. But the teachers on this committee had an interest in science. Many elementary teachers don't, or they lack the expertise or comfort level to seek involvement in designing science curriculum. Some teachers are not interested in the process of designing curriculum in any subject (Adelman & Walking-Eagle, 1997) due to a lack of time or other priorities. Therefore, it is unrealistic to expect that all teachers will or should be involved in district-level curriculum renewal, even if participation in such activities serves as a valuable learning experience.

The act of designing curriculum is a constructivist activity in itself, as is the adaptation of curriculum by teachers during the implementation phase of curriculum renewal. Regardless of the expertise teachers may or may not have in teaching science, they do make choices with the curriculum materials they have at their disposal. They also design lessons and modify materials in light of their professional beliefs and pedagogical styles. It is naïve to deny that they do this or focus on how much the "fidelity" of innovations is kept intact as reforms and curriculum materials move into classrooms.

Constructivist teaching involves a close knitting of content and process for teachers. During the year the study group members spent working together, there were many instances where teachers made choices regarding the lessons

in the new curriculum binders or made plans to modify the lessons when they were next taught. Beth and I made a conscious decision to leave the Landforms unit lessons in the prescribed sequence, even though we thought students had some difficulty with this order. Cindy had modified the Batteries and Bulbs lesson to include a discussion of the struggles that scientists go through so that students would understand that learning is not always quick and easy. She did this based on her previous experience with the frustrations children felt as they struggled to find a way to light the bulbs.

The teachers in this study group identified their own professional development needs. When it became clear that most of the participants needed to expand their knowledge base in the physical sciences, several of the participants made arrangements to attend the Michigan Operation Physics workshops. When we realized we needed further clarification of the theory of constructivist science teaching and how this might be incorporated into our own curriculum, we brought in Terry Farmer to help us.

Loucks-Horsely, Carlson, Brink, Horwitz, Marsh, Pratt, Roy, and Worth (1989) advocate for further research into teacher-led professional development:

We recommend the funding of research that focuses specifically on alternative patterns of decision making for the improvement and maintenance of good science teaching. This research should pay special attention to current efforts in site-based decision making to examine how science is taught and the priority it is given. (p. 78)

This approach, which recognizes the negotiation that takes place between teachers and science teaching, may be difficult for people whose orientation to reform is based on a fidelity approach (Snyder, Bolin, & Zumwalt, 1992). Given

elementary teachers' history with science instruction, this deserves additional discussion. How can teachers who have little knowledge of the big ideas in science and in the practice of conceptual-change pedagogy really do service to the lofty goals of the science reformers' vision?

Loucks-Horsely, et. al. discuss the fears that some science educators have about teachers gaining too much decision-making authority:

How and what decisions are made about curriculum and instruction are critical to the future of science education. Some science educators fear that when teachers have decision making authority, science may be lost from elementary schools, curriculum development efforts may result in collections of teachers' favorite (but tired) units, and central office support roles and responsibilities will be eliminated entirely. Such concerns raise a need for careful examination of the influence of new decision making structures on science teaching, and the contexts and conditions under which science teaching is improved and thrives. (p. 78)

I believe these fears are overstated. Teachers will negotiate the curriculum whether reformers like it or not. When there is a dichotomy of opinion regarding whether they should be allowed to or not, it overlooks the impact that teachers play in the classroom. Teachers' power may not be acknowledged in some circles, but there is no question that it exists. I believe that it should exist. The powerful knowledge that experienced teachers bring can improve instruction (Feiman-Nemser & Floden, 1986; Snyder, Bolin, & Zumwalt, 1992), just as was seen on the part of this group of teachers. We made important decisions regarding our course of science instruction, based on reflective reasoning and substantive discussion with the other group members. I would recommend that other schools find ways to help teachers do the same. We know many elementary teachers need help in teaching science. We also know that they will

enact the curriculum as they see fit when the classroom door closes. Therefore, in the interest of promoting excellent science instruction, we need to find ways of making this negotiation more explicit and enable teachers to dialogue with each other as a part of this negotiation.

As discussed in the first chapter, the Ojibway science curriculum units were developed based on a four-step model of constructivism (Loucks-Horsely, et. al., 1990):

- Accept an invitation to learn;
- Explore, discover, and create;
- Propose explanations and solutions, and;
- Take action on what they learned. (p. 59)

Throughout the year, the teachers in this study group negotiated their own definitions of constructivism and found that the new curriculum did not always align with the teaching model guiding its development. Each grade level's four science units had been designed by a separate group of teachers, and as stated earlier, very little time had been provided in the process of examination of the vertical articulation new curriculum. Each grade-level group of teachers had negotiated their own goals and agendas from the beginning. Each grade-level group and even each individual teacher interpreted MEGOSE, constructivism, the four-step learning model, the national reform agenda, and Terry Farmer's suggestions somewhat differently.

In designing their grade-level units, each group of teachers also negotiated how each of these influences should be interpreted for their age-level

students. Even the commercially-created and university-produced materials that were purchased to augment certain units were created by individuals who interpreted and negotiated their own understandings of the science reformers' recommendations. To assume that only policy-level science educators and reformers know best how to design curriculum and create learning models fails to acknowledge the interpretation and negotiations educators at all levels go through in the process of deciding what and how to teach, and the powerful, clinical expertise teachers bring to the table.

Most teachers, given an initial awareness that there is a better way of teaching, will be open to learning and will want to be the best teachers they can be. Shiffer (1978), in discussing a case study of change in elementary settings, stated:

Change usually began when teachers experienced disequilibrium after being exposed to alternatives to their present methods, which they suspected might be much more effective in meeting their goals. Some teachers tried out one or more of these methods on a small scale. Their initial experiments created further disequilibrium; they found that aspects of the innovation were in conflict with some old patterns of action, or with existing regularities in the school. They discussed these problems with colleagues, and found that new issues emerged from these discussions. Ideals were viewed in the context of the realities of teaching and of the school culture. There was much conflict, anxiety, and doubt. In time, behavioral and organizational patterns became modified to fit the innovation, and the innovation was modified to fit the realities inherent in the particular setting. During this process, teachers realized they lacked clarity about the innovation and set out to gain new knowledge and skills. (p. 8)

This was the same process the study group went through – a Constructivist process of being presented with a “discrepant event,” engaging in learning experiences that addressed this event, and coming to new

understandings as a result (Tobin, Briscoe, & Holman, 1990). Engaging teachers in conceptual-change experiences has the same potential for their learning as it does for children. The study group members found that some of their initial ideas about constructivism and exemplary science teaching were both challenged and supported during the course of the year. Through experimentation in their practice, reflection on their teaching, and discussion with other teachers, they came to new understandings about how they might work to improve their own science teaching.

The teacher study group operated on a constructivist set of assumptions, although we did not explicitly discuss this at the time. We were involved in a long-term effort to improve our science teaching, which centered on adapting our practice through heuristic activities. We assumed that we were able to identify our own learning needs and distinguish effective practice from ineffective as we reflected on our own and the other group members' teaching. Many of the difficulties and obstacles expressed by the participants stemmed from ways in which the organizational structure of the school, district, and even the curriculum were counterproductive to our work. Smith and Neale (1991) claim that teachers need to make a personal shift in orientation through personal experience in order to internalize and appreciate the conceptual-change model:

Some teachers with whom we worked appeared to shift their orientations only *after* trying the strategies in their own classrooms, and noticing how children responded and worked. This was not a sudden, all or nothing shift, but one which appeared to be a major reorganization of their frameworks to teaching science. Previous orientations, especially in the form of usual teaching routines, intruded on attempts to teach in a new ways. (p. 241)

Some of the difficulties the Ojibway teachers had in teaching the new science curriculum were due to the lack of professional development support during implementation of the revised program. This is typical of many reforms that have failed to take hold in schools through the years: much effort goes into planning and designing the innovation, but little time goes into implementation (Fullan, 1991; Hargreaves & Fink, 2000; Snyder, Bolin, & Zumwalt, 1992).

Therefore the time and energy put into the development phase comes to naught when practitioners are not enabled in practice. As Hargreaves and Fink (2000) explain:

Deep, sustainable, and scaled-up reform is not achieved by mandate, by shock-and-copy strategies, or by other quick fixes. Those who believe otherwise must ask themselves why simpler, short-term strategies have failed persistently until now. (p. 33)

Given the agenda of the national reformers is so ambitious, and that the task of creating excellent constructivist science teachers out of busy, elementary generalists appears to be a great challenge, it is beneficial to examine the resources and constraints that facilitate or impede this effort. If we understand how teachers make sense of constructivism and their attempts to change their practice, we may be able to identify areas where the limited resources of science educators and reformers can be focused. The resources and constraints identified by this small group of teachers working in context provide a glimpse into the everyday thoughts and struggles of teachers.

Negotiation of External and Internal Resources, Obstacles, and Constraints that Influenced Teachers' Attempts to Practice Constructivist Science Teaching

The National Science Education Standards (1996) acknowledges that elementary teachers are and should be expected to be generalists. Yet, if we reflect back on what the Standards expect all elementary teachers to be able to know and do, it is easy to become pessimistic:

- Understand the nature of scientific inquiry, its central role in science, and how to use the skills and processes of scientific inquiry.
- Understand the fundamental facts and concepts in major science disciplines.
- Be able to make conceptual connections within and across science disciplines, as well as to mathematics, technology, and other school subjects.
- Use scientific understanding and ability when dealing with personal and societal issues. (p. 59)

These are areas of specific expertise that most elementary teachers simply have not cultivated. Not only are we a long way from *all* elementary teachers being adept in these areas, this study and others (Cox & Carpenter, 1989; Smith & Neale, 1991) have shown that we may be overly optimistic to assume that more than a small minority of teachers are.

Therefore, it is appropriate to ask ourselves how realistic it is to expect that all elementary teachers can ever develop all the requisite skills and scientific knowledge they need to live up to the science standards. Will teachers ever have the time and opportunity to develop the conceptual understandings of a scientist or a science major? Will they ever place the same teaching priorities on science as they do on more “comfortable” subjects such as reading? Will there

be wide-scale acceptance of the learning potential of constructivist pedagogy? Or, do we need to modify our goal that all elementary teachers will become adept at conceptual-change teaching and instead focus on helping teachers continue to move along a pedagogical continuum, acknowledging the value of their learning and teaching along the way? Is there a point at which a teacher should stop feeling guilty and say, "I may not be perfect, but this is as good as I can do for now, and it will have to be good enough."?

As difficult as the challenge of living up to the Standards is, I strongly believe that any progress toward reaching this level of teaching is worth the effort. The genome-mappers of the future, along with those who can appreciate their efforts, are sitting in our classrooms right now. One of the first astronauts to travel to Mars may be sitting at a kindergarten learning center at this moment. So may the engineer who will help design the spaceship and the layperson who will have had the scientific experiences to understand the complexities of their work and marvel at our ability to make such dreams a reality. I cannot believe that these adults of the future will fulfill their potential for human accomplishment and understanding as a result of sitting in quiet little rows reading a stale textbook or listening to a teacher lecture with a limited science background. Therefore, it behooves us to identify and analyze the resources and constraints that impact teachers and influence their ability to become the best science teachers they can be.

The learning potential for teachers and students as teachers engage in Constructivist pedagogy vastly outweighs what is possible with didactic methods.

Just as they hoped to do with their students, the group of teachers participating in this study group engaged in constructivist learning aimed at conceptual change. They identified their prior understandings, engaged in activities designed to deepen their knowledge and expand their understandings, they experimented with constructivist pedagogy and reflected on their experiences, they engaged in substantive conversations with their learning peers, and they identified what they had learned to do and what they still wanted to learn. The teachers also put a great deal of thought into identifying the external and internal resources and obstacles that constrained their efforts.

One constraint that affected the efforts of several study group members related to perceived insufficient content knowledge. During the course of the study, Cindy and Karen discussed the deficiencies in their scientific content knowledge and the ways in which they felt their limited knowledge base adversely affected their ability to facilitate instruction, ask guiding questions, critique lessons, and identify student misconceptions. Pat disclosed that she had made a concerted effort over the years to make up for her limited formal science instruction by attending relevant workshops, inservices, and conferences. In discussing imposed change and the experienced teacher, Sikes (1992) points out that focusing on the "deficiencies" that teachers possess related to various reform efforts agendas is demoralizing to teachers and lays too much blame at their door:

Behind these factors and motivating all changes lies the assumption (which may or may not be justifiable) that all is not well and that students are not receiving the best education because teachers and their teaching is inappropriate or inadequate. The interpretation commonly placed on

this is that teachers are lacking in knowledge, skills, competences, and even sometimes, personal qualities.
(p. 37)

Although many people consider it demeaning to speak of teachers' deficiencies, in the case of elementary teachers and science, there is some truth to the matter. Teachers cannot be blamed for the major they chose or the personal proclivities that led them to favor one subject over another. Nor can elementary teachers, the vast majority of whom are women, be blamed for the gender discrimination and societal mores they experienced as students that impacted their perceived abilities to understand scientific and mathematical concepts. What is important in light of our need to improve science education and help teachers enrich their ability to participate in addressing this need is to help teachers understand why these deficiencies exist and what they can do to address them, but in a way that acknowledges women's ways of knowing (Belenky, Clinchy, Goldberg, & Tarule, 1986; Erdman, 1990) and negotiating curriculum.

The teachers in our study group frequently discussed the anxiety and pessimism they felt as they thought about how much they needed to learn and do during our year together and beyond. But they also mentioned the supportive strength they found in knowing that they were not alone in their needs and struggles, and that we were all challenged as we worked together. Erdman (1990) also has documented the strong sense of collegiality she has observed among women teachers in graduate classes in curriculum she has taught and their need to develop a sense of community as they discuss their work.

Karen began the study as the weakest science teacher in the group, and she ended the study in the same position. However, she had a better understanding of the nuances of constructivism, she was getting away from the textbook, beginning to lead hands-on activities, had attended the physics workshops, felt her understanding of scientific concepts was improving, had gained confidence from the supportive group members, and she had a sense of where she needed to go to keep improving. Should Karen feel comfortable with what she's accomplished, or should we continue to critique her for her inability to create a rich atmosphere of inquiry in her classroom? Should we be comfortable with the slow but steady progress she is making, given her starting point?

Karen may never be the science teacher Beth could hope to be. She hadn't majored in science as Beth had, and she was nearing the end of her career. She didn't have a love for science as Beth did. On the other hand, Beth may never be the reading teacher that Karen was. She didn't have Karen's background as a librarian and her wealth of experiences encouraging children to love books. Like the book, *A Good Enough Parent* (Bettelheim & Freedgood, 1988), is there also a point at which we can forgive elementary generalists for not having the background knowledge, time, or energy to become the expert science teachers described in the Standards and devote our efforts to doing as much as we can to help them become "good enough science teachers," doing the best they can with the resources they have and can realistically obtain? Karen brought other assets, such as her expertise in content reading and in helping

students conduct library research that a science-major teacher with a strong content background may not bring to collegial, professional development.

The abilities of the study group members to effectively respond to the new curriculum also were influenced by their personal experiences as science learners and teachers, and their attitudes about science. In a graduate course I teach at another college, "Teaching Science K-8," I begin the semester by asking the teachers in the class to write a science autobiography, detailing a lifetime of science experiences in and out of the classroom. It is always interesting to read how teachers' current attitudes and comfort levels with science were shaped by their own experiences as children, and a great many common threads run through their papers.

Invariably, teachers who were science majors or who love teaching science had memorable science experiences as children. Frequently, they describe one wonderful science teacher whose enthusiasm rubbed off, and often these teachers recall rich, detailed memories of times spent exploring nature with their families, on camping trips, or at a family cottage. Likewise, the teachers who have a more negative attitude toward science or who profess discomfort with the subject express common experiences. They often don't remember "doing" any science as elementary-age children, or remember reading textbook chapters unenthusiastically at various grade levels. Quite often they give a hideous description of some poor, ineffective, secondary science teacher who turned them off or intimidated them. These early experiences affected teachers'

proclivity to continue taking science classes, and they continue to negatively impact the way they view teaching science today.

The participants in the study group expressed similar experiences. Cindy and Karen both felt uncomfortable with science concepts and perceived themselves as having a weak science background. Pat also said that she felt rather inept in her own high-school science classes and stated that girls generally tried to get a boy for a lab partner “because they knew what they were doing.” However, it was obvious as Pat said this with a bit of sarcasm in her voice that she no longer believed that. She had overcome her early fears and consciously went out of her way to enroll in science workshops and classes that she felt would build her background knowledge.

Beth, on the other hand, recalled a wonderful, junior-high science teacher who sparked her interest in science, and she went on to major in biology in college. My experiences were similar. I went to junior and senior high schools known nationally for their science programs and had excellent high-school science teachers who wrote their own lab-based curricula. Our junior high had a planetarium, all of my classes were held in well-supplied labs, and the teachers incorporated many hands-on investigations and inquiry projects.

Given that most elementary teachers do not have strong science backgrounds, the challenges facing Karen and Cindy are likely being faced by many other elementary teachers as well. In fact, a federally-funded Goals 2000 grant that I am involved in, which is under the direction of the Saginaw Intermediate School District, is just getting underway. Between March, 2000 and

June, 2001, exemplary science educators from across the state will be working together to clarify the Michigan science benchmarks so that every K-12 science teacher, no matter how limited their science content knowledge, will be able to understand the science concepts children need to learn. Activities will be developed to help teachers understand each benchmark, and the team will develop a professional development plan to work with Michigan teachers. The impetus for this project is the very realization that elementary teachers often do not understand the very concepts they are supposed to be teaching.

While it is unrealistic to expect all elementary teachers to earn an additional college major in science or even to enroll in a number of science courses, there are other professional development opportunities, such as participation in the Michigan Operation Physics classes that can help address some of the scientific subject-matter needs of teachers, such as those expressed by Cindy, Karen, and Pat. In the final interview, Karen stated that her attendance at the physics workshop was one of the most beneficial aspects of participating in the study group. The state's network of Math and Science Centers all provide professional development opportunities for teachers in math and science teaching, both in content and research-based, "best practice" pedagogy of these subjects. The Michigan Science Teachers Association publishes a journal and newsletters, sponsors an informative website, and holds an excellent annual conference for teachers. Pat was a member of the association and attended the conference annually, finding it to be a supportive and educative source of help.

The Association also publicizes high-quality summer workshops and institutes for teachers, with locations inside and outside of Michigan.

While these are only two sources of continued professional development, they demonstrate that opportunities do exist for teachers who are willing and able to make the effort to become involved in changing their practice and expanding their knowledge base. Just as conceptual-change teaching can include forms of didactic instruction, off-site professional development opportunities can play a role in teachers' growth. They will not be effective as stand-alone efforts, but they can add the element of outside expertise to teachers' learning.

Some of the biggest factors influencing the teacher participants' ability to change their practice were the conditions of their work, most significantly the limited amount of time they had available to plan lessons, expand their background knowledge base, and reflect on their work. The teachers felt that many of these particular obstacles were beyond their control or influence, which at the time caused a great deal of frustration. The teachers had no control over the financial status of the district or how funds were spent. They had no control over the decision to eliminate or cut back physical education, art, music, and library time, and thereby the planning time they had when the children were in these special classes.

The participants in this study were frustrated that they just didn't seem to have the time or the energy to devote to making significant changes, and that they made less progress than they had wanted during the course of the year.

This is significant because this particular group of teachers' working conditions are similar to those of many elementary teachers. Our daily schedule, responsibilities, hours of work, etc. were quite typical. In fact, we enjoyed benefits that most elementary teachers do not: the science lab and the science paraprofessional relieved a large share of the burden of buying, setting up, and cleaning up materials. Our principal was widely regarded as the best in the district for his great organizational skills, personality, and supportive relationships with teachers. If this particular group of teachers had a difficult time overcoming the constraints of their work conditions, then I think it is fairly safe to assume that other elementary teachers might face similar obstacles.

Teaching young children can be mentally and physically exhausting, and there is certainly little time during the course of a day to do any planning or reflecting. At the end of a harried day, most teachers are too tired from the overstimulation of their constant interactions with children to have much energy left for professional development (Erdman, 1990). Several of the teachers in this study wished that we either could have had substitutes to relieve us so that we could have held our meetings during the day, or that we could have done a significant amount of our work during the summer with students brought in for a summer enrichment week in science. Teachers' comments illustrate how full their plate already was and that they had little time or energy to add any more responsibilities to it.

I believe that this study demonstrates the importance of organizational support in science reform efforts. The teachers involved believed that

constructivist science teaching was a more promising means of instruction for their students. They believed that the new curriculum was better than the Silver-Burdett textbook series they had been using, but they were upset at the district's failure to make teacher planning and professional development a priority. Unless we recognize how difficult constructivist science teaching is and work to facilitate positive changes in teachers' conditions of work, any significant change in practice will be very slow in coming, if not nearly impossible.

Negotiation of Support Relationships with Others: Group Members, Donna Workman, Terry Farmer, District Administrators and the Science Consultant

The teacher participants in the study group were undertaking a long and difficult change process. Throughout the year of the project, the study group served as a source of social and professional support. Karen and Pat also expressed their feeling that participation in the group placed some positive, professional pressure on them to devote time and energy to their efforts. The teachers felt they had peers they could turn to, but also peers they were accountable to.

The isolation that the study group teachers felt in their classrooms is a natural effect caused by the four walls that separate us from our colleagues and the highly-structured school day that disallows much contact with our peers. While some schools are using creative scheduling or team teaching to provide more collaborative time among staff, most teachers are still spending the majority of their day as the only adult in the classroom. All of the teachers in this study came to appreciate the study group as a means of breaking through this

isolation. The group members provided a means of support, feedback, and affirmation that none of us could provide for ourselves, but which the group members all felt was necessary.

Because we spend so much time isolated from our peers as well as administrators, we have a difficult time knowing what our colleagues are doing and experiencing. This is why it is so vital that teachers learn to communicate with each other and with administrators, sharing their frustrations and successes. None of us realized how difficult our task would be when we joined together to improve our science teaching. We knew that there would be some obstacles, but the hopefulness that came through in the initial interviews showed that we all felt we'd be able to make substantial progress during the year in adopting and refining constructivist science teaching. When we began to realize the extent of the task, we were able to bolster each other and provide the camaraderie that kept us from becoming too discouraged and disheartened. As Cindy said, knowing that she wasn't the only one struggling with the difficulties of pedagogical change kept her from feeling too much personal guilt over her perceived inadequacies and lack of progress.

For several years before I began this study, I had toyed with the idea of starting a "book club" among my fellow teachers in which we would meet in a relaxed setting after school, reading and discussing a professional book or article. I had never gotten around to starting it because I was afraid no one would want to participate due to lack of interest or time. This experience taught me that I should have given it a try. The members of this group enjoyed the

collegiality we developed, with Beth stating that she felt this experience was “not just important; it’s necessary.” I came to find that the other members of the group were feeling the same isolation, the same demands of time, and the same sense of frustration. Knowing that I wasn’t alone lifted some of the burden I was feeling off my shoulders.

Mentor-mentee relationships are becoming more prevalent, especially for probationary teachers. Michigan law now requires that new teachers be assigned a mentor teacher on staff to guide them through their probationary years. While I believe that these relationships have much potential to help teachers during the “survival” years, I found this experience with a study group had many benefits that a one-on-one relationship does not. First, the inclusion of several peers in the reflection process increases the variety of feedback that a teacher receives on his or her teaching. Often, the members of our group noticed different things when we observed each other’s lessons. This offered each sharing teacher a richer response than would have been possible if just one person had observed her teaching. In instances where two or more of us noticed the same things in a teacher’s lesson, we were able to give the teacher a greater sense of confidence and trust in our responses.

Secondly, the involvement of a larger group of teachers lays the groundwork for the possibility of larger-scale reform. A larger group involves more teachers in a given building, which creates greater potential for effecting organizational change and eventually interesting more teachers in participating. Third, I believe that a professional growth effort that involves several people is

less threatening than a one-on-one effort. In a mentor-mentee relationship, one person is always on the “hot seat,” which could be a cause of anxiety. In our study group, we all experienced our turn sharing our videotapes, which took the critical eye off any one person.

Finally, as this study demonstrated, a group of peers can become a supportive forum for sharing, uplifting each other, and overcoming isolation. Several of the group members expressed their opinion that the study group would have been beneficial for this reason alone, notwithstanding our goal of improving our science teaching.

While my role as a participant-observer doing research in the same building in which I taught may have been rather unique, collaborative efforts between teachers and scholars is not unusual. Other buildings around the country, such as Professional Development Schools (PDSs), also have access to professors and graduate students through partnerships with local universities. Teachers in these schools have the opportunity to work hand-in-hand with scholars as they attempt to restructure their schools and improve learning experiences for children. However, the number of schools that have programs such as this in place are still outnumbered by schools that do not. Some schools, such as those in rural and urban areas, may have little hope of ever attracting sustained, on-site support from colleges and universities. I believe that this study can serve as one model for teachers working where there is a need for sustained professional development in science instruction, whether or not the staff has access to “expert” support on a regular basis supplied directly by a

university. Such expertise may be available and reflected in others' roles and responsibilities, such as Terry Farmer, or teacher-leaders connected more closely with current scholarship.

Just as the teachers in this study identified our own needs, gave up our own time to meet together, and sought out our own help to expand our subject-matter knowledge, so can other teachers. Teachers need to empower themselves to identify the obstacles that are holding them back and ask for school-level and district-level support to overcome these obstacles. In cases where support is lacking, it may simply be due to ignorance. I don't believe the Assistant Superintendent of Ojibway Public Schools was purposely depriving teachers of the help they needed to become more constructivist science teachers. I think she just had very naïve notions about the substantive task at hand and the amount of support required to help teachers make the transition from a textbook-based program to a program promoting minds-on and hands-on, conceptual learning.

Experiences such as the ones the study group went through are vital if teachers are going to become adept at reflecting on and critiquing their practice. Cindy felt that the group's feedback was biased positively due to the nature of the women involved and the fact that we were inexperienced in practicing and critiquing constructivist pedagogy ourselves. Although I think she was being too hard on herself and underestimated her own capabilities, her point brings up an important issue. If teachers are inexperienced with critiquing their peers' practice, and I agree that most are, and if their daily isolation prevents them from

easily engaging in this type of opportunity, then how can they ever become adept at honestly critiquing their own practice or other's? For teachers to effectively make radical changes in their teaching, as called for in the science reform standards, they must be able to honestly reflect on their current work and pinpoint those areas that need to be changed. The study group served as an effective means of doing this, although we would have needed to continue meeting to really refine our abilities.

There is some contradiction in the literature regarding teachers' preference for either isolation or collegiality. While Grimmer and Crehan (1992) discuss the culture of isolation that dominates most schools, Erdman (1990) concluded that the women teachers she worked with were hungry for collegiality and the bonds of support and communication it brought. The teachers in this study all reflected back positively on the supportive nature of the study group, but in the beginning most were nervous about sharing their teaching via videotape. There is a certain amount of risk involved in sharing your teaching with peers in the same school, as one wonders at first whether gossip about teachers' practice may result. Erdman's work with students in graduate classes is different in that these teachers were sharing with other women with whom they did not work, and thus there was less risk of "gossip" about their teaching getting back to their peers at school.

Many researchers have written about the positive potential and effects of incorporating collaboration among teachers (Anderson, 1999; Fullan, 1993; Little, 1990; Tyack & Cuban, 1995) in the negotiation of innovations in schools, but the

majority of teachers' time is still spent in classrooms where they work as the only adult. The teachers in this study found that it took some time to feel comfortable sharing with each other, but not an amount that I would consider beyond the potential of most other schools and teachers. It is worth the effort to develop such collaboration, as the teachers in this study pointed to the support and collegiality they developed as a key factor in their ability to sustain their negotiation of constructivist science teaching.

Our study group was working autonomously from the administration in Westdale School. This was partly due to the fact that this was a dissertation study with issues of confidentiality attached. In order to protect the confidentiality of the participants, we could not involve administrators in the process. However, this also meant that we could not share our specific concerns and obstacles with the principal or the assistant superintendent to protect the participants from any possible repercussions. For their first experience of this sort, the group members seemed to enjoy the freedom to privately engage in a personal improvement effort without outside direction or authority. However, this also meant that we were limited in the support we expected or sought from administrators in the district.

While the need to preserve confidentiality resulted in the study group working in relative isolation from the rest of the staff and the organizational structure of the school and district, I would recommend that anyone initiating this kind of teacher-led, professional development work in tandem with those who are able to modify the organizational structure to facilitate good science teaching.

McLaughlin and Marsh (1979), commenting on the Rand Change Agent study, found that “grass roots,” professional-development activities were often only a little more successful than “top-down” efforts that involved little or no teaching input:

Projects that were conceived and planned at the school level with only cursory review by central office staff often evidenced high initial teacher commitment. But, in the absence of explicit support from district managers, that commitment waned over the course of project implementation. Project teachers often found it difficult to sustain initial enthusiasm and motivation when there was little indication that district officials also cared. In the long run, grass-roots projects generally disappeared as completely as top-down projects. Though teacher-initiated project practices and methods could be found in isolated pockets of the district, without district support, even successful projects withered away because of factors such as staff turnover, indifference, or lack of information on the part of building principals. (p. 74)

By providing a supportive environment for good science teaching and being responsive to teacher needs and concerns, administrators can provide the vital resources that will enable improvements to occur. Several support structures were already in place at Westdale Elementary School. These were factors that contributed both positively and (inadvertently) negatively to the study group’s work.

Donna Workman was a source of time-saving support for hands-on science, but her authoritarian nature created a barrier to constructivist learning. Her need for rules, strict procedures, and step-by-step experimentation, along with her desire to be the adult in charge in the science lab, created an atmosphere that hampered student discovery and risk-taking. Her approach was at odds with some teachers’ instructional philosophies. As a result, some

teachers (such as Beth) felt uncomfortable in a setting that was supposed to be a source of teacher support.

Creating conducive environments for science teaching reform will require creative measures. Many principals are already overburdened dealing with issues of student discipline, building management, state and district-mandated paperwork, etc. Instructional feedback for teachers is generally limited to summative observation/evaluation reports conducted twice a year for probationary teachers and less frequently for tenured teachers. Most elementary principals were once elementary teachers themselves and generally cannot be expected to have any deeper familiarity with meaningful science instruction than the teachers on their staff.

Although the Westdale Elementary School principal was supportive of the teachers' efforts, his support took the form of enabling teacher-directed professional development efforts, as opposed to providing significant suggestions and feedback himself. Although he was an extremely energetic and effective manager, as well as friendly and supportive, he had become a principal in his twenties after just a few years as a physical education teacher. His one fault was his limited ability to constructively critique the content of teachers' lessons in a substantive way (which likely contributed to Westdale's traditional teaching) or suggest pedagogical changes. He respected his teaching staff and could be counted on to provide requested support services whenever possible (the science lab; the half-day, grade-level planning days, money for materials, etc.).

He was an ideal administrator for this type of teacher-led project, but he rarely took a leadership role in directing instructional changes himself.

There is much potential in creating opportunities for teachers to become instructional leaders in their own buildings. By virtue of my dual role as teacher/doctoral student, I was able to initiate the study group endeavor at Westdale. I was viewed as an “insider” who could be trusted and respected. However, I was still responsible for teaching my own class full-time. This severely limited the amount of time I was able to devote to helping the other teachers. I think that we need to make instructional leadership and teachers’ professional development a priority. One recommendation is to support the advanced learning of individual teachers and allow these teachers release time and/or sabbatical time to work outside of their classroom helping their peers.

Feiler, Heritage, and Gallimore (2000) have spent the past four years studying the efforts of UCLA's laboratory school (Seeds University Elementary School) experimentation with in-house, teacher-leaders. Teacher-leaders have facilitated three separate professional development teams that work in the areas of literacy, mathematics, and technology. The teacher-leaders receive one day of release time per week to engage in activities such as meeting with the principal to discuss progress and new goals, visiting classrooms and modeling lessons, coaching teachers, and enhancing their own knowledge of subject matter and effective practices by attending conferences, reading, or consulting with outside experts. The teacher-leader roles are not permanent; teachers can cycle in and out. As a result of this study, the researchers make

recommendations for differentiated staffing that includes teachers on staff assuming the leadership for professional development:

- Select the leader roles that meet the greatest need.
- Choose teachers who have credible expertise and leadership skills.
- Clarify the leader role early on.
- Have teacher-leaders spend a majority of their time in classrooms or working directly with other teachers.
- Focus on student learning.
- Ensure that the principal supports the leader. (pp. 67-68)

Efforts such as this appear to have the potential for addressing several needs. They involve teachers directly in leading school-level professional development. They give teachers an opportunity to receive assistance in the classroom and encourage teachers to reflect on their practice. And they stand to help teachers negotiate the contextual difficulties that reforms have encountered as they transition into schools.

Of course, the project at Seeds School represented a reform in and of itself, and one that the teachers at a laboratory school might be expected to accept more readily than those at another school. University laboratory schools are often on the “front line” of experimentation, and their teachers may be more used to critical study of practice and change efforts. Other schools may find that involving teachers in coaching, classroom observation, and discussions with the principal present a threat to the privacy of their practice and an unwelcome intrusion. However, without changes like this that begin to confront the culture of

schools as “cellular organizations” (Grimmett & Crehan, 1992), it will be difficult to achieve the widespread collegiality necessary to support positive change.

Grimmett and Crehan elaborate:

When teachers are reticent to provide feedback to one another and prefer to act as “gatekeepers” to their isolated “kingdoms” rather than as professional colleagues, the prospects for positive educational change are reduced. (p. 62)

Educational settings as places of adult work are unique in that so few teachers spend much time with other adults during the course of their day. In a setting where no other adult really knows for sure what one does in one’s classroom, there is little pressure to change. Teachers have little direct knowledge of what their colleagues are doing and can only second-guess what goes on behind others’ closed doors. Tenure makes it difficult to remove a teacher for poor student learning achievement. Teachers generally enjoy solid job security whether they teach poorly or well, and merit pay for a job done well is very rare. So the cultural and structural traditions of schools operate against collegiality and substantive mutual collaboration. Few teachers have had opportunities to engage in a form of professional development akin to the study group, but if we hope to enact a paradigm shift away from isolation and toward collaboration, we need to plant seeds of other teachers working to demonstrate the power and support possible through collegiality.

Final Thoughts

The study group was a form of professional development designed to bridge the gap between vision and practice, providing a conduit for the science reform vision to reach the classroom. Many aspects of the project were either

successful or were beginning to show potential for success. Other aspects needed to be improved upon. My inexperience as a researcher as well as a professional developer resulted in my feeling that there were several things I would do differently if I could do the project over again. In addition, the participants had several suggestions in the final interviews for making this type of professional development more successful.

In keeping with a qualitative research perspective, I stress that while this form of professional development was appropriate for this group, each individual situation calls for specific activities that the involved teachers feel will benefit them most in their own context. We are all individuals, and we bring our own individual concerns to such experiences. One of the major assumptions associated with this study is the very notion that professional development should be personalized and designed to address the contextualized needs of individual schools and teachers. Curriculum development and renewal should be intertwined with professional development. Teachers are and should be intricately involved in both processes, whether this takes place in a meeting room with other curriculum committee members or back in the classroom when teachers design, adapt, and select lessons to teach.

I think it is time that we take seriously teachers' abilities to guide their own professional development. If classroom science instruction is ever going to reach the levels of excellence advocated in the national reform standards, then teachers are going to have to be intricately involved in the process of familiarizing themselves with the Standards. Working together with their peers and seeking

assistance when necessary from knowledgeable experts, teachers can improve their science teaching. As they negotiate this effort, they stand to learn a great deal about their own needs, as well as their students'. I posit that contextualized, teacher-centered, professional development, with assistance from those familiar with research-based best practices, offers a chance of substantively improving instruction.

Change is difficult. It seems to be especially difficult in classrooms. Reforms have come and gone, and change often occurs in painfully slow increments (Tyack & Cuban, 1995). This type of cyclical change leaves many teachers feeling that it's fruitless to put much time and energy into adopting the latest recommended teaching practices. Experience has taught them that what's "in" today may be "out" tomorrow. Better stick to the middle ground – don't be too radical in either direction, and you'll be safe when the next change comes about. Teachers tend to joke about this, but this developed cynicism is a real impediment to the fulfillment of major reform visions such as the ones espoused by the NCTM and the AAAS. Any suggestions for school improvement that originate outside the classroom are regarded with varying degrees of suspicion.

The Ojibway science curriculum renewal was an exception to this. None of the teachers I spoke with questioned the value of the pedagogy of the standards and the new curriculum. They either knew from experience or sensed that science teaching based on inquiry was better than science teaching based on the textbook or passive learning models. While they did not question the value of this type of teaching, many teachers questioned their ability to actually

be able to do it themselves. I believe there is hope for reform, given a commitment on the part of teachers to develop the skills and knowledge they need to be constructivist science teachers, and the understanding of policymakers and school districts that teachers need opportunities for conceptual-change learning themselves.

There are other creative ways of addressing the dilemma, some of which have been tried by the study group members since we stopped meeting. Pat now team-teaches with her two second-grade colleagues. She teaches science three times a day, and the others have assumed the math and social studies responsibilities. She has found ways of negotiating several of the obstacles that hampered her before: she collaborates with other primary teachers, she is keeping herself “accountable” to teaching science by ensuring that it is formally scheduled into the rotation of subjects each day, and she has created more time for “hands-on” science by eliminating two other subjects from her planning and set-up responsibilities. She also has alleviated the need, for as long as the collaboration continues, for the other teachers to become excellent science teachers.

Members of this group would tell other teachers that they felt empowered as a result of the study-group experience. While they were used to having things done “to them and for them” by the district, through the study group they learned to do “for themselves.” We’ve all heard the old adage, “The squeaky wheel gets the grease.” This was a perfect example of this. The teachers in this group helped bring attention to the fact that there was a serious lack of district support

for the new science curriculum, and as a result, more financial resources were devoted to personnel and professional development following this study. Every elementary building now has a science paraprofessional, whereas prior to the study only Westdale and one other building did. Elementary special subjects have been restored, and teachers also receive an additional 45-minute planning time each week made possible through the hiring of “floating” substitutes in each building. Carol Tate left her position for a principalship in another district, and I was promoted to the position of K-8 Science and Math Coordinator. This position has given me the opportunity to have teachers’ concerns heard and addressed, and to spend a lot of time working with teachers and the building science paraprofessionals. The district is a more conducive environment for constructivist science teaching than it previously was, although there is still room for much growth.

I think that all of us as teachers need to find ways within our own contexts to voice our concerns and act on these. We need to go beyond hopeless, day-to-day coping and make recommendations for changes in resource allocation, professional development, and planning time. Without changes in the support structure of schools, I fear that many teachers will find that the vision of the science reform movement remains a dream.

In order to make science teaching reform a reality, we must support teachers on-site in their efforts to improve their practice. This requires giving them the time they need to work. This also requires the creation of support services, such as science labs and science paraprofessionals, which would give

teachers more time for teaching and demand less of their time for preparation and set-up. Teachers must have the time and opportunity to meet together as the study group did, working through the process of personalized instructional change. We should not be surprised that teachers are having a difficult time “doing more with less.” Although some highly dedicated teachers sacrifice much of their personal time to their profession, which often pays off in high-quality teaching, it is not fair to expect all teachers can or will do this just because some do.

The study group began its activities with a big agenda and big goals. These were adapted as we began to realize the size of the task we were working on. We had a loose set of guidelines directing our activities, which emanated from the dissertation proposal, but we made several adjustments to our plans as the school year progressed.

We trusted each other to offer a confidential, supportive forum for sharing ourselves and our teaching. This was a risky venture, given that most of us, with the exception of Pat, had never videotaped our teaching or had our teaching critically observed by our peers. Because we had worked together for several years and established bonds of trust, the participants in this group entered into a bond of mutual learning. There was no distrust of outsiders. We were all equals with an equal voice in our meetings. Although we were at different levels with regard to our comfort and expertise in constructivist science teaching, we all had frustrations and struggles to overcome. This is the type of atmosphere that is conducive to real, sustained professional growth.

Any professional development effort that is truly responsive to participants' needs must be flexible and adaptive. As teachers identify their needs along the way, different activities must be planned to address those needs. This requires that the participants periodically step back and evaluate their goals, the progress they have made, as well as the obstacles that are creating hindrances. New short-term goals must be set to allow the participants to redirect their actions in ways that will help them progress. While it is natural to enter any professional development effort with a certain level of expectation and preconceived ideas of what activities will prove to be the most beneficial, it is likely that these ideas will change as time goes on and one's experiences are reflected on. This is a constructivist, conceptual change-based approach. When it becomes internalized for teachers, and their orientations to teaching science adapt as well, there can be hope for change in classrooms. We may come to realize that there isn't one set of needs that teachers have, such as are expressed in the Standards, nor one best way of teaching. We may come to realize that good teaching entails any number of approaches, and that this is best negotiated by a committed teacher in the context of a particular school with a given group of students.

I leave this project with mixed feelings. On the one hand, I feel very good knowing that the study group members feel they made progress in their efforts and that they established bonds of support that remain today. I am also pleased that more support measures were put into place that have helped to create a more conducive atmosphere for science teaching. However, I am also left

feeling that this project needed to continue. Just as we realized we had caught on to something that was working, it was over.

In my new position, I have had the opportunity to provide some release days for the study group members to continue to meet for the purposes of continuing our work and creating a cadre of expert science teachers who can branch out to support our district colleagues in their struggles. But I have also expanded my observation of many other teachers' science teaching, both in the Ojibway School District and in the graduate class I teach. I sometimes feel discouraged by the needs that so many elementary teachers have, and I am continuing to try to find ways to help teachers become better science teachers and "science lovers." The fact that I am still here after the completion of the study and am able to continue to learn and offer support is a testament to the power of teacher-directed, professional development and teacher empowerment.

APPENDICES

APPENDIX A

Expectations and Consent Form for Teacher Participants

In keeping with established protocol and federal regulations regarding research involving human subjects, this form is provided to inform you of your rights as a participant in the research study **Bridging the Gap Between Vision and Practice: The Role of a Teacher Study Group in Mediating Constructivist Science Teaching in an Elementary School**. This study is being conducted by Ellen L. Schiller as part of the dissertation requirement for the Doctor of Philosophy degree from Michigan State University. This form details the expectations involved as a participant in this study, as well as your rights as a human subject. Signing this consent form indicates your willingness to participate within the listed parameters.

1. Before signing this form, I will be provided with the "Research Design" portion of the researcher's dissertation proposal. In order to familiarize myself with the methods used, I will have read this portion before signing my consent.
2. I agree to be interviewed regarding the dissertation topic five times during the period between June, 1996 and April, 1997. Each of these interviews will be scheduled at my convenience. The interviews will be audiotaped and transcribed, but I have the right to refuse such recording, or ask that the recorder be stopped at any time. I also have the right to refuse to answer any or all questions. All information obtained will be kept confidential.
3. I agree to participate in an initial two-day group session in August, 1996 for the purposes of introducing the group to constructivist science teaching and for building group dynamics. This session will be audiotaped and transcribed, but I have the right to refuse such recording, or ask that the recorder be stopped at any time.
4. During the school year, between the months of September and April, I agree to engage in 12-18 study group meetings with the other members of the group. These meetings will be held at a time mutually convenient to all participants and will be limited to a maximum length of 1-1/2 hours. These meetings will be audiotaped and transcribed, but I have the right to refuse such recording, or ask that the recorder be stopped at any time.
5. I agree to videotape my own teaching of personally selected science lessons during the school year, with the goal of selecting three lessons to share with the study group: one from the physical science unit, one from the earth and space unit, and one from the life science unit. I have the right to view these videos before they are shared with the rest of the study group, as well as the right to not

have them shared at all. In addition, I have the right to refuse or stop videotaping at any time.

6. I will be asked, but not required, to keep a journal detailing my reflections, observation, and questions regarding my participation in the study. I have the right to keep this journal, or any portions of it, confidential to myself.

7. I understand that in order to protect the confidentiality of the participants, I will not discuss group meetings outside of the group itself. I will not discuss the comments made by other group members, nor will I discuss the videotapes of other members' teaching outside of the group.

8. In order to protect the confidentiality of the participants, the researcher will assign pseudonyms known only to her to all names of participants, schools, districts, cities, etc. to prevent identifying the individual participants in the written report of the dissertation. In addition, the gender, age, grade level, etc. of participants may be changed to further prevent identification of participants in the written report.

9. I understand that I have the right to withdraw from participation in this study at any time, with no penalty whatsoever involved.

I have read the above statements and agree to participate in the study. I have been given a signed copy of this agreement for my records.

signature of teacher participant

date

signature of researcher

date

APPENDIX B

Parent Consent Form

Student Assent Form

During the 1996-1997 school year, Mrs. Ellen Schiller will be conducting a research study at our school entitled: **The Role of a Teacher Study Group in Negotiating Constructivist Science Teaching in an Elementary School**. This research is being carried out as part of Mrs. Schiller's doctoral degree requirement from Michigan State University. Your child's teacher is participating in the study group with Mrs. Schiller and several other teachers. The group is working to improve science teaching at our school for your children.

As part of the research, the group plans to videotape some of the science lessons in your child's classroom during the school year. Teachers will observe these videotapes in an effort to help each other teach better. These videotapes will not be shared beyond the members of the study group. We are asking your permission to allow your child to be videotaped with the rest of the class during these sessions. If you choose not to give your consent, your child will not be shown on camera during the lessons. If your child is accidentally videotaped, that part of the videotape will be erased.

In addition, your child will not be penalized in any way for not participating in the study. You also have the right to withdraw your consent at any time during the school year.

If you have any questions about this study at any time, you may contact Mrs. Ellen Schiller at school or at home at (616) 847-0757. Thank you.

Please sign below to give your consent for videotaping.

signature of parent or guardian

date

As a minor, your child is asked to sign his or her assent to be videotaped below.

signature of child participant

date

APPENDIX C

Interview Protocol for Initial Interview

1. Today I'd like to ask you some questions about your science background and your experience teaching science in the elementary school. To start off, could you please describe your educational background in science, including college courses, workshops, and any other inservice training you've had?
2. Did you like science when you were in elementary or secondary school? Did you take very much science in high school? Why or why not? Do you remember things you did, anything you particularly liked or disliked?
3. How would you describe your teaching of science before this year, before the new curriculum was implemented? For instance, how many hours per day or week did you devote to science? What kind of a priority was science compared to math and reading? Did you use the textbook predominantly? What kinds of lessons and activities did you do before this year?
4. Can you think of any particularly successful or unsuccessful lessons you used to do and what the children's reactions were that made you think this kind of lesson or activity went really well and this kind didn't?
5. How would you describe your comfort level in teaching scientific concepts?
6. What was your initial reaction when you first saw the new science curriculum this year? How did you feel when you first looked at the materials and what was your reaction to the way in which the science curriculum was first introduced at the mass meeting?

7. Which of the three half day inservice sessions with [the hired science consultant] did you attend? What did you learn? What questions did you have after it was over? Was this inservice helpful to you?
8. Do you feel like you've been given enough inservice opportunities to help you with your science teaching? What kind of inservice or other professional development activities do you think would help you teach science better?
9. Have you heard the term constructivist learning or constructivism applied to science, reading, math, writing, or any other subject? If so, how would describe this kind of teaching? What is you opinion of the worth of this kind of teaching as opposed to other methods such as lectures, demonstrations, etc.?
10. Thinking about the adoption of the new science curriculum for this year, how would you now describe your science teaching -- thinking about some of the same questions we talked about before (how much time do you devote, what priority is science compared to other subjects, what kinds of activities do you do, etc.). What do you do differently or how is your teaching different from what it was before?
11. After working with the new curriculum for the past year, what is your opinion of the new materials, objectives, topics, and units for your grade level? How would you change or adapt them? How knowledgeable do you feel regarding the content of the units that you've been assigned to teach?

12. What have been the biggest obstacles for you in implementing the new science curriculum? What would make your job easier? How could the district help you do the best job you can in teaching science?
13. What are your initial feelings about joining a study group with other teachers in your building whose goals are to learn more about constructivist science teaching and to support each other in teaching science this way? How do you think this might be able to help you?
14. What suggestions do you have for this type of group? What suggestions do you have for making it operate effectively?
15. I have one last question for you. What are your feelings about the videotaping? Are you nervous about that or not?

APPENDIX D

Interview Protocol for Second Interview

1. Has your definition or opinion of constructivist science teaching changed over the past two months? If so, how?
2. What obstacles do you find yourself facing now in your science teaching?
3. Has your science teaching changed as a result of participating in the study group? If so, how? If not, can you pinpoint why not?
4. What comments and opinions of the study group's activities do you have so far?
5. What has been helpful to you? Not helpful to you?
6. What suggestions do you have for future meetings that you think would help you improve your science teaching?
7. Do you have any specific requests for help from either Terry Farmer or myself for your next unit?

APPENDIX E

Interview Protocol for Post-Video Interview

1. Can you give a brief summary of the lesson you shared and what the main learning objective was?
2. How did you try to incorporate what you have learned about constructivism?
3. What was your opinion of the lesson's effectiveness in terms of the students achieving the main learning objective?
4. How would you describe your teaching – did you accomplish what you set out to do? What were your strengths and weaknesses?
5. How did you feel as you watched the video by yourself and with the group?
6. Was the group's feedback helpful?
7. How has or how will the videotaping experience influence your science teaching overall, if at all?

APPENDIX F

Video Presentation Feedback Form for Group Members

1. Please jot down instances in the video that struck you, either positively or negatively, as you are watching.
2. What aspects of the member's teaching did you pick up that will influence your own teaching positively? Negatively?

APPENDIX G

Final Interview Protocol

1. Compare your initial predictions and feelings about participating in the study group with the actual experience. How was the actual experience similar to and different from what you expected? What were the benefits? What would you like to have done to improve the experience? Were you pleasantly surprised or let down by any portions of the study group experience?
2. How has your definition of constructivism changed over the past year, if at all?
3. Has your science teaching become more constructivist over the course of the study group?
4. Put yourself in the shoes of one of your students. What do you think they would say about your science teaching? What do you think their attitude is toward science as a result of your teaching?
5. In viewing the videotapes, I thought it was interesting that the two people who claimed to feel less comfortable teaching science chose to focus the camera on the kids and asked a lot of questions, while the three of us who claimed to feel more comfortable teaching science focused on ourselves and did more talking. What do you think about this? What do you think this says about constructivism and teachers' subject matter content knowledge?
6. One aspect of this experience that is interesting to look at is the formation of a study group in itself. Elementary teachers tend to associate themselves with

their students, while secondary teachers tend to associate themselves with department colleagues. What was your opinion of this experience as an opportunity to form more collegial relationships with your peers?

7. What obstacles still face you in your efforts to improve your science teaching?

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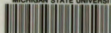
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