

CHEMISTRY TEACHERS' SENSE-MAKING OF COMMUNITY-BASED INQUIRY
LESSONS: A TEACHER INQUIRY PROJECT USING THE VIDEO ANALYSIS TOOL

by

YOUNGJIN SONG

(Under the Direction of J. Steve Oliver)

ABSTRACT

The purpose of this study was to investigate how chemistry teachers made sense of their students' learning and their own teaching practices when participating in a teacher inquiry project using the Video Analysis Tool (VAT) within the context of Community-Based Inquiry Lessons (CBIL). While empirical studies have reported what science teachers learned from the experiences of teacher inquiry, not enough attention has focused on *how* science teachers learn about their own students through inquiry. This research used a qualitative case study with multiple sources of data such as videos, classroom observations, in-depth interviews, and documents. Three research questions guided the study: (1) How do chemistry teachers make sense of students' learning of science?; (2) How do chemistry teachers make sense of their approaches to instructional tasks with regard to student learning?; and (3) How do chemistry teachers adapt and use teacher inquiry practices through VAT?

The findings demonstrate that the teacher inquiry project, joined with the VAT, provided the chemistry teachers with a window to experience their students' thinking and reasoning that is normally unobserved. Analysis shows that teachers were able to pinpoint specific student's misconceptions and to tailor their instruction accordingly. In addition, teachers made sense of

how their students cognitively engaged in the CBIL by examining the ways students applied, transferred, and expanded their experiences and knowledge. Besides the cognitive aspects, the teachers became more aware of how students' social interactions in the learning community were related to students' learning. The research findings also illustrate that these chemistry teachers came to think about new ways to implement the CBIL while participating in the teacher inquiry project. Examining students' interactions served as a catalyst for the teachers to revisit and expand their own science content knowledge. The teachers used their reflection using videos of their teaching to modify teaching practices and became better able to recognize their orientations to teaching and learning. The successes and challenges that teachers perceived in terms of using VAT are examined as a component of the results. Implications for teacher education programs with regard to potential outcomes from embracing teacher inquiry are also described.

INDEX WORDS: In-service science teaching, chemistry teaching, teacher inquiry, teacher research, science teacher education, teacher learning, knowledge for teaching, student learning, student inquiry, qualitative research, video technology

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DEDICATION

To my Mom, Kum-Ok Park, for your endless love and sacrifice,

To my Dad, Ky-Sun Song, for being my role model as a respectable educator,

and

To my husband, Sae Wung Kim, for your being with me in every step of this journey.

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CHAPTER I

INTRODUCTION

Emergence of the Study

Educational researchers have perceived teaching not as a simple activity driven by the application of prescriptive types of knowledge or skills, but rather as a problematic, challenging, complex, and uncertain practice that requires immediate responses to specific instructional situations (Ball, 1993; Hammer, 1997; Loughran, 2006; McDonald, 1992; Roserbery & Puttick, 1998; Schön, 1983). As a former in-service chemistry teacher, I remember how many times my lesson plans changed depending on the details of a given class period while ultimately teaching the same lesson to fifteen classes; I remember how many times my students brought up the questions that I had never thought about; I remember how many times they showed unexpected actions and thinking; and I even remember how they frequently did not make their science related thinking explicit. The curriculum, textbooks, national standards, and my knowledge of science often did not provide clear guidance in those situations; I found that the best solution was for me to be sensitive to my students in each of these given situations; I learned about teaching science literally every day, every moment.

This perspective that I developed is very much in keeping with many current descriptions of the nature of teaching that have been evolving within what is known as “the teacher research movement” (Cochran-Smith & Lytle, 1999a). In this movement teacher learning and professional practices are considered as:

a never-ending process of investigation and experimenting, reflecting and analyzing what one does in the classroom and school, formulating one's own personal professional theories and using these theories to guide future practice, and deciding what and how to teach based on one's best personal professional judgment. (Myers & Simplson, 1998, p.58)

The idea of teachers investigating their own teaching practices has become increasingly prominent within the teacher and teacher education communities locally, nationally, and internationally (Cochran-Smith & Lytle, 1999a). There is a growing consensus that effective teacher education programs immerse teachers into the inquiry of practice embedded in real classroom contexts (Ball & Cohen, 1999; NRC, 2007; Borko & Putnam, 1996). Consequently, a number of teacher education programs in various countries have used teacher inquiry as a component but with diverse purposes (Barnatt, Cochran-Smith, Fredman, Pine, & Baroz, 2007). Within the science education community, national science education reform documents largely require teachers to scrutinize their own practice, suggesting that “teachers of science approach their teaching in a spirit of inquiry—assessing, reflecting on, and learning from their own practice” (NRC, 1996, p. 42).

Previous researchers have addressed the idea of teachers investigating their own practices and these researchers have used a variety of labels for this activity including: action research, practitioner inquiry, teacher inquiry, self study, teacher narratives and so forth (Ball, 2000; Barnatt et al., 2007; Cochran-Smith & Lytle, 1999a; Roth, 2007). In the present study, I decided to use the term *teacher inquiry* embracing the notions of “a stance of inquiry” (Ball & Cohen, 1999), but earlier studies that applied the great variety of labels are relevant as background for

the present study. The specific definition of teacher inquiry used in this study is discussed in chapter II.

Efforts to make teacher inquiry the centerpiece of teacher education has been supported for several reasons. Researchers argue that teacher inquiry is one of the decisive features that differentiate teaching from technical work and aid it in becoming professional practice (Clarke & Erickson, 2003). In addition, teacher inquiry can serve as a powerful tool for teachers to learn how to teach and improve one's teaching (Cochran-Smith & Lytle, 1999a). In science education, researchers have advocated that teacher inquiry is necessary for science teachers because science teachers need to experience the kinds of inquiry that characterize science itself as in the case of student inquiry (McGoey & Ross, 1999).

Although inquiring into teaching practices can serve as a powerful way for teachers to learn how to teach and to improve one's teaching (Cochran-Smith & Lytle, 1993; 1999a), what could be missed in this kind of inquiry is that teachers overlook whether students learn or how their instruction affects students' learning (Hiebert, Morris, Berk, & Jansen, 2007). What is going on in the classroom in terms of students' learning is not all that teachers need to focus on, but, I believe, it should be at the core of the issues into which they need to inquire. Rodgers (2002) put forth a similar argument: "... student learning should guide teaching. Teachers' classroom practice must be seen as an integrated, focused response to student learning rather than as a checklist of teaching behaviors."

Recent curriculum reform in science education supports science teachers' ongoing focus on students' learning. Science education reform documents in the United States such as *Science for All Americans* (Rutherford & Ahlgren, 1990), *Benchmarks for Science Literacy* (American Association for the Advancement of Science [AAAS], 1993), and the *National Science*

Education Standards (National Research Council [NRC], 1996) envisioned that all students can learn science with understanding (Carpenter, Blanton, Cobb, Franke, Kaput & McClain, 2004; Shymansky, Yore & Anderson, 2004). A more recently released report *Taking Science to School: Learning and Teaching Science in Grade K-8* proposed learning goals that describe what it means for every student to achieve in the science classroom (NRC, 2007). In learning science, students should understand and use scientific knowledge, be able to reason scientifically, understand the nature of scientific knowledge, and participate in scientific enterprises. Helping students learn science in reform oriented ways imposes a demand on science teachers. That is, ensuring all students access to science with understanding requires science teachers continuously to inquire into their students' progress and difficulties within the context of learning during everyday classes.

However, in spite of the importance and value placed upon teachers' close attention to students' learning, research has demonstrated that teachers' main concerns while teaching are students' behavior, motivation, and participation in activities, a smooth implementation of activities, or even themselves as teachers rather than students' learning or changes in students' thinking (Fischler, 1999; Marton, 1994; McCutcheon, 1980; Morris, 2006). This tendency is more salient in the case of pre-service or beginning teachers (Davis, Petish, & Smithey, 2006). According to Prawat (1992), teachers naively conclude that "student interest and involvement constitutes both a necessary and sufficient condition for worthwhile learning" (p. 389). My own personalization of those circumstances led me to design this teacher inquiry project through which science teachers' attention could be turned more onto their students' learning of science.

Several empirical studies have reported what samples of science teachers have learned from the experiences of teacher inquiry (e.g., Boz & Boz, 2008; Cox-Petersen, 2001; Kang, 2007;

Yerrick, Ross, & Molebash, 2005). Yet, not enough attention has focused on *how* science teachers learn about teaching from practices through their own classroom inquiry. I found two studies that do shed light on this aspect of my concern. The work by Hammer (1997) illustrates how he, as a researcher and as a teacher, became more aware of his own students' learning and teaching of physics through scrutinized classroom inquiry. In the inquiry-oriented high school classroom, he approached students' learning science as a form of discovery. In the same way, he considered teaching science as discovery in that curriculum is not decided completely beforehand because it depends on what teachers perceive within the enacting of the lesson. That is, the uniqueness of *discovery teaching* is "a stance of inquiry wherein teacher discovery plays a central, essential role in shaping the substance and form of the course" (Hammer, 1997, p. 491). With this perspective, Hammer described the process of his discovery of students' thinking and how his own discovery shaped his curriculum.

Along a similar line, Rosebery and Puttick's (1998) study of one beginning elementary teacher (Liz) detailed how she constructed meaning while learning science as well as teaching science. The window for this study was created through a professional development project that required her to examine her own classroom. The researchers perceived science as an activity of making meaning historically and socially. Similarly, teaching science was regarded as a process of *sense-making* in which teachers draw upon intellectual resources to build linkages between students' ideas and the currently accepted ideas of science. This process occurred when Liz examined videotapes and transcripts of science lessons that she taught. The two studies, along with recognition of the dearth of research on the process of science teacher inquiry, also shaped the focus of this research. That is, embracing the notions of *sense-making* (Rosebery & Puttick,

1998), the current study focused more on the process of science teachers' sense-making of students' learning than on the outcomes or products resulting from classroom inquiry.

Meanwhile, the current study builds on the work of others who incorporate video for teachers' classroom inquiry activities (Borko, Jacobs, Eiteljorg, & Pittman, 2008; Roth & Chen, 2007; Rosebery & Puttick, 1998; Sherin & van Es, 2005). Recognizing the potential of modern video technology that provides enduring records of the classroom, Video Analysis Tool (VAT) was used as a main instrument in the teacher inquiry project.

Purpose and Research Questions

Overall, the main goal of this study was to investigate the way chemistry teachers made sense of their students' learning and their own teaching practices when they joined the teacher inquiry project by using the Video Analysis Tool (VAT). The specific instructional context of the project determined by participating teachers and researchers was the Community-Based Inquiry Lesson (CBIL) in which students worked as a scientific research community to solve a given problem. The detailed explanation of the CBIL is provided in Chapter III.

The purpose of this research was three fold. First of all, this study attempted to explore how the chemistry teachers made sense in terms of their *students' learning* given the opportunity to participate in the teacher inquiry project. Specially, the instructional context of teacher inquiry project made it difficult for the teachers to perceive what was going on in the classroom in terms of students' learning because students took a leading role during the entire class period. Therefore, this study sought to conduct research within a situation that challenged teachers' focus on either themselves or typical students' actions and activities in the science classroom. The study explored how the opportunities of analyzing and reflecting on video-captured

classroom activities facilitated teachers' understanding of students' learning in the CBIL. In addition, the current study provided insights into the way chemistry teachers adapted their instructional approaches in line with their increased sense of students' learning.

Second, this study sought to obtain a detailed picture of teacher inquiry by focusing on the *process* of teachers' sense-making while they were engaging in the teacher inquiry project. The empirical studies that do exist related to teacher inquiry most often focus on describing changes in teachers' abilities to analyze teaching practices (e.g., Anderson & Bird; Crockett, 2002; Sherin & van Es, 2002, 2005) or learning outcomes of teachers (e.g., Cox-Petersen, 2001). While these studies are helpful in understanding the impacts of professional development efforts which embrace the notion of classroom inquiry, they do not provide the detailed picture of what actually occurs when teachers closely examine their classrooms. The current study presented what the chemistry teachers learned from the teacher inquiry project concomitant with *how* their sense-making process occurred through the teacher inquiry project in the normal course of instruction.

Finally, this study aimed to gain a better understanding of the use of video recording and examination technology in teacher inquiry. Most of the professional development studies that included video reported the benefits of using video for teachers to investigate teaching practices (e.g., Borko et al., 2008; Sherin & van Es, 2005; Sherin & Han, 2004). The current study employed VAT as a tool for classroom data collection and analysis. By revealing the successes and challenges that the teachers encountered throughout the project, this study gave us insight into how video would be used in an effective way in supporting science teacher inquiry.

Specifically, three research questions guided the study:

Given the opportunity for inquiring into one's own classroom in which the CBIL was implemented:

- (1) How do chemistry teachers make sense of students' learning of science?
- (2) How do chemistry teachers make sense of their approaches to instructional task with regard to student learning?
- (3) How do chemistry teachers adapt and use teacher inquiry practices through VAT?

Rationale

Considering the complex arena of science teaching, close examination of students' actions and talk is thought to be one of the most effective ways for science teachers to both understand students and improve their teaching practices. Teachers' inquiry into their own classroom has been widely accepted in the teacher education community (Cochran-Smith & Lytle, 1999a, 1999b; Richardson, 1994; Zeichner & Noffke, 2001). However, in the handbook chapter about teacher inquiry from the *Handbook of Research on Science Education*, Roth (2007) pointed out that the notion of teacher inquiry is still at an early stage in the area of science education. In addition, reviewing 78 examples of studies about science teacher inquiry revealed that only 14% of studies focused on students' learning and thinking in relation to a particular topic while 71% dealt with teaching strategies. She also reported that among those 14% of studies, only 12% used video as a data to provide evidence of student learning and stated "this is a surprisingly low percentage, given the wide availability of this technology and its potential for

enabling teachers to examine their own practice” (Roth, 2007, p. 1231). In this circumstance, it is significant to conduct a study about science teacher inquiry with the focus of students’ learning as well as with the aid of video technology.

In relation to the focus of teacher inquiry, consider these two findings from education research. First, science teachers tend to pay more attention to “the most visible issues such as student behavior or teaching strategies” and “activities and teacher actions” (Schwille, Givvin, & Chen, 2007) than students’ learning in the classroom. Second, analysis of classroom practices typically fall short in that they exclude an examination of students. It is necessary to assist teachers to turn their focus into students’ learning while engaging in teacher inquiry. In addition, in the case of research on using video in teacher education, researchers warn of the possibility, that teachers could watch video much as they might watch television if not given guidelines or scaffolds (Brophy, 2004). This study is meaningful in that it challenges science teachers to focus on students’ learning when they examine video from their own classroom. This study was conceptualized using the belief that the opportunity to closely examine students’ learning will enhance their sense-making of students’ learning, and further, will enable teachers to support the kinds of student learning identified in the science reform documents. Science teachers can make instructional decisions based on students’ learning needs.

The current study was conducted in a normal setting compared with most of the teacher inquiry research reported by scholars was implemented in professional development programs (e.g., Rosebery & Puttick, 1998) or in degree-awarding programs (e.g., Briscoe & Wells, 2002; Kang, 2007). In this sense, this study shows what it really looks like to conduct classroom inquiry in the ordinary situation of science teaching. It also offers more clear pictures of science teacher inquiry by addressing the process and outcomes of learning resulting from the teacher

inquiry project. Consequently, this study suggests a practical guideline of how teacher educators appropriately support teacher inquiry activities based on the better understanding the nature of teacher inquiry.

By turning teachers' attention from the mundane aspects of their actions as teachers toward the more important issue of students' learning, the current study also satisfies the need to fill in the gap between research on teaching and research on learning. Researchers have pointed out that in the research on teaching literature, rarely has there been discussion of the relationship between teaching and learning or between instructional practice and research on learning (Graham, 2004; Hammer & Schifter, 2001). On the other hand, Kennedy's (1999) study of teachers' thinking about research on teaching showed that teachers regarded the studies that addressed the relationship between teaching and learning as the most relevant, persuasive and influential to them. She concluded:

The relationship between teaching and learning is the most central issue in teaching, and it is also the most perplexing and least understood. Teachers often feel that learning outcomes are unpredictable, mysterious and uncontrollable. It is not surprising to learn that teachers find studies most valuable when the studies give them a deeper understanding of this fundamental relationship. (Kennedy, 1999, p. 528)

In this regard, this study provides comprehensible and practically useful research findings for other science teachers. In addition, it contributes towards the limited volume of work currently available that builds practice-based links between research on teaching and research on learning in the science education literature.

Summary and Preview

In this chapter, I have provided the underlying assumptions of this study and how the current research on the teacher inquiry project has evolved with a synopsis of the literature informing it. I have also articulated the purpose, research questions, and rationale of this study.

In chapter II, I furnish pertinent literature drawn from three bodies of scholarship that provide perspectives to this study; they are: teaching as inquiry, teaching as learning, and teacher learning through inquiry as situated within a specific context. In chapter III, my epistemological framework and the research design are outlined. A description of the three chemistry teachers who participated in this study and their instructional context provides important details regarding the research design. Finally in that chapter, I provide a description of the process of data collection and data analysis within the methodological literature review. In chapter IV, the findings from the research study are presented in a manner that is organized around the three research questions. I present several themes with vivid and detailed excerpts from interviews with teachers and video records of the classroom in each section. In the closing chapter V, I briefly summarize the study and discuss major findings in line with scholarship. Finally, I draw implications for practice and research, and then end with a concluding remark.

CHAPTER II

THEORETICAL FRAMEWORK AND LITERATURE REVIEW

Chapter Overview

In this chapter, I provide an overview of the three main strands of literature used as frames to inform this study. The first line is drawn from the literature on teacher inquiry which takes the perspective that the act of teaching is a form of inquiry. This line of research is a key to the model in which the current study was bounded in that it provided insights about the structures and content of teacher inquiry. A second body of literature that considers teaching as a learning process across the professional life span informed the theoretical frame of this study. This perspective makes teacher inquiry the centerpiece of teacher education. Finally, the literature surrounding a situated perspective, which regards the value of placing the opportunity of teacher learning in a teachers' own classroom, provides a rationale for the use of classroom video in this study.

Teacher inquiry

This section begins with a brief definition of “teacher inquiry”—the concept I used in the current study—while distinguishing between diverse concepts such as teacher research, teacher inquiry, and reflection as they appear elsewhere in the literature. Then the importance of teacher inquiry is addressed. Finally, a structured way to promote effective teacher inquiry is described. This approach uses lenses and inquiry cycles as tools for teacher inquiry.

Teacher Inquiry

Teachers' inquiry into their own instructional practices has a long historical tradition. One of the first studies was conducted by Kurt Lewin, in the 1940s. This work was a study of how teachers attempted to understand their own teaching and its effects not by researchers, but by the teachers (Sowder, 2007). Since then, the idea of teachers investigating their own practices has become increasingly prominent within the teacher and teacher education communities at local, national, and international levels (Cochran-Smith & Lytle, 1993, 1999a; Barnatt, Cochran-Smith, Friedman, Pine & Baroz, 2007). This approach (i.e., teacher inquiry) to the study of teaching has been defined in a variety of ways and used as an umbrella term that is referred to as action research, practitioner inquiry, teacher inquiry, self study, teacher narratives, and reflective practice (Ball, 2000; Barnatt et al., 2007; Cochran-Smith & Lytle, 1993, 1999a; Roth, 2007). Although all these diverse approaches share a common focus of teachers examining issues of teaching practices, I will attempt to differentiate these perspectives.

The various approaches presented in the literature can be traced back to Schön's (1983) idea of reflection-in-action and its potential to improve practice (Richardson, 1994). Reflection-in-action, according to Schön, 1) implies conscious thinking and modification while on the job, and 2) demands rational and moral processes in making reasoned judgments about preferable ways to act (Hatton & Smith, 1995). An individual's ability to think about why they are doing "while they are doing it" is at the heart of the teaching profession. Schön's view includes the notion that reflection involves the reconstruction of experience. That is, within the uncertain and complex context of teaching, reflective teachers are able to frame and reframe the problems that they encounter, and consequently, change their actions.

Often times, the term reflection is used as one and the same as the term teacher research / inquiry, but Roth (2007) points out that unless teachers' reflection is intentional and systematic, reflection on one's own educational practice or being thoughtful about one's work could not be considered as teacher inquiry. Further, she distinguishes reflective practice from teacher inquiry in that it does not require any special research plan or design. Although I agree that teacher inquiry cannot be perfectly correlated with teacher reflection, it does not mean that teacher inquiry is one thing and reflection is another. Rather, reflection is an important part of teacher inquiry in that reflection can function as an important thinking device when teachers conduct inquiry activities. The current study can be situated in prior research on teacher reflection where the intentional and systematic elements exist. For instance, this study is aligned with research like that of Rodgers (2002) who described reflection as a structured process that helps teachers think about what they see within the classroom, how they describe and analyze it, and how to respond to it in terms of student learning.

In teacher research, teachers are invited to be "the principal investigator of the research" on teaching and learning; teachers "ground questions, structure analysis, and represent interpretation" (Ball, 2000, p. 365). That is, teachers function as "architects of study and generators of knowledge" (Cochran-Smith & Lytle, 1993, p. 2), who are in charge of the entire research procedures, with the goal of "changing practice as a result of study and changing practice to better understand it" (Zeichner & Noffke, 2001, p. 306). It is common that we could hear the voice of "first-person" (Ball, 2000) about teaching and learning in the writing of teacher research.

In contrast, teacher inquiry is characterized by teachers' careful investigation of their own educational practice. Both activities (teacher research and teacher inquiry) begin with the same

goal, yet teacher research is more definitive as the teacher is taking on the role of principal investigator. However, some teachers are not interested in conducting research but are rather interested in understanding more about their teaching, their students, or improving their instruction, so they undertake daily analysis of their teaching practices. Therefore, the focus of teacher inquiry is more on teachers' capabilities of "posing questions, interrogating one's own and others' practices and assumptions, and making classroom sites for inquiry—that is, learning how to teach and improving one's teaching by collecting and analyzing the "data" of daily life in schools" (Cochran-Smith & Lytle, 1999a, p. 17). Teacher inquiry shares some characteristics with teacher research such as their attention to collecting concrete evidence to inform decisions about teaching; however, there are important differences as well. Teacher inquiry does not include the development of research skills needed to conduct a range of research studies in the classroom. The assertion by Eleanor Duckworth addressed the distinction between teacher research and teacher inquiry:

I am not proposing that school teachers single-handedly become published researchers in the development of human learning. Rather, I am proposing that teaching, understood as engaging learners in phenomena and working to understand the sense they are making, might be the *sine qua non* of such research.

(1987, P. 168, as cited in van Zee, 2000)

Many scholars use the terms teacher inquiry, teacher research, and reflection without distinction, and sometimes, without precise definition. However, Cochran-Smith and Lytle (1999a) pointed out that the great variations and widespread application of "teacher research movement" generates danger of "anything and everything" (p. 17) being included under those labels. Along this line, some researchers (Richardson, 1994; Wong, 1995) tried to make an effort

to differentiate between teacher research and teaching with an inquiry stance. Hammer and Schifter (2001) also gave a warning regarding the situation of equating teacher inquiry with teacher research. Those authors distinguished teacher inquiry from teacher research in terms of the audience, the scope and purpose, and the manner in which teachers identify themselves. Ball and Cohen (1999) put forth a similar argument by emphasizing “a stance of inquiry” (p. 11) as the central role of teachers. They argued that it is not necessary for teachers to become researchers; rather, teachers need to ask and answer questions such as “What is working? What is not working? For whom are certain things working or not working?” (p. 10) when they investigate teaching practices.

In the current research being reported here, I use the term “teacher inquiry” for the purpose of this study, recognizing the differences among teacher inquiry, teacher research, and reflective practice. The chemistry teachers were asked to inquire into their own classroom in order to make sense of their students’ learning and teaching practices. I, as a researcher, supported their inquiry activities by applying systematic and rigorous processes designed to explore instructional practices with a specific focus. Since the teachers and researchers shared the responsibility of research within the scope of the activity of where chemistry teachers conducted their own inquiry, I used the term teacher inquiry instead of teacher research.

In addition, adapting the definition of teacher research provided by Cochran-Smith and Lytle (1993) and by Eisenhower National Clearinghouse (2000), I take the following as a working definition of teacher inquiry: *an ongoing process of systematic and intentional study in which teachers examine their own teaching and students’ learning for the purpose of improving classroom practice*. Systematic means ordered ways of inquiry process and intentional means the planned and deliberate nature of inquiry (Cochran-Smith & Lytle, 1993, p. 24).

Why Teacher Inquiry?

There is a growing consensus about the centrality of teacher inquiry as a factor related to effective teaching and student learning (Weinbaum et al., 2004). Why is teacher inquiry so important and necessary for science teachers? First of all, teacher inquiry is one of the crucial characteristics that differentiates teaching, not as technical work, but as a professional practice (Clarke & Erickson, 2003). Considering commitment for lifelong learning as one of the dimensions of professional practice, Clarke and Erickson (2003) argued that in order for teaching to be seen as a profession, what is needed is “the ability and willingness of its members to inquire into their own practice; into ways of improving and developing their practice consistent with the unique contexts in which they work and with an appreciation of current trends in education” (p. 3). Their emphasis on teacher inquiry as the cornerstone of the teaching profession is well expressed in the following sentence by Clarke and Erickson: “Without inquiry, practice becomes perfunctory and reutilized” (p. 5). In fact, this perspective which regards inquiry into practice as an essential element of the teaching profession has been given almost universal support within the teacher education community. For instance, the National Board for Professional Teaching Standards (NBPTS) in the United State defines accomplished teachers as those who are able to “critically examine their practice, seek to expand their repertoire, deepen their knowledge, sharpen their judgment and adapt their teaching to new findings, ideas, and theories” (NBPTS, 2002, p. 4).

Second, teacher inquiry plays an important role in enhancing teacher learning (Ball & Cohen, 1999; Cochran-Smith & Lytle, 1993, 1999a; Roth, 2007; Weinbaum et al., 2004). What teachers should know and be able to do cannot be delivered to the teachers as a predetermined set of tips of tricks. Rather, teachers learn about teaching and student learning in the context of

their practice. In addition, there are no monolithic strategies for effective teaching in that a particular classroom context needs a particular solution to a particular problem. The fact that one method that is working in class A does not guarantee that the same method will work in class B in the diversity and complexity of the teaching environment. Therefore, teachers need to pose questions and find solutions in each particular context. For these reasons, teachers have to learn “how to learn in and from practice” (Ball & Cohen, 1999, p. 10) and teacher inquiry is indispensable for such learning. The review of research findings by Roth (2007) in her handbook chapter about science teacher research demonstrates positive learning outcomes of teachers as a result of teachers investigating their own practices, including the development of abilities related to reasoning, monitoring their own classroom practice and reflection on teaching as well as the improvement of science teaching. Tabachnick and Zeichner (1999) referred to

a voluminous literature representing work in several countries has consistently reported that teachers who engage in action research generally become more aware of their own practices, of the gaps between their beliefs and their practices, and of what their pupils are thinking, feeling, and learning” (p. 310).

In the section below, I discuss the perspective which might be called teaching as learning across the life-span.

Third, especially in the science education community, researchers suggested that inquiry into teaching practice provides an opportunity for teachers to experience the kinds of inquiry that characterize science itself. McGoey and Ross (1999) argued that “in order for science teachers to demonstrate authentic inquiry, we must be engaged in authentic research ourselves. Researching our practice is a natural fit” (p. 118). The Video Case Studies in *Scientific Sense Making Project* are good examples of using teacher inquiry in order to help science teachers better understand an

inquiry approach to teaching and learning science (Rosebery & Puttick, 1998; Rosebery & Warren, 1998).

For the above three reasons, scholars assert that both pre-service and in-service education programs should include teacher inquiry experiences. For instance, Abell and Bryan (1997) challenge teacher educators to “coach prospective teachers to purposefully and systematically inquire into their own practice, encouraging them to make such inquiry a habit that will become increasingly valuable throughout their careers” (p. 136). In-service teacher professional development programs also contribute to a view of teaching as inquiry by requiring teachers to closely investigate their practice. The eight standards for effective professional development, identified by Hill (2004) through a critical review of literature on professional development between 1986 and 2001, gave evidence that effective professional development engages teachers in inquiry into classroom practice for the construction of meaning. Furthermore, the development of standards for science teaching and learning at state and national levels largely require teachers to scrutinize their own practice: “Teachers of science approach their teaching in a spirit of inquiry—assessing, reflecting on, and learning from their own practice” (NRC, 1996, p. 42).

Despite the widespread enthusiasm for teacher inquiry within the teacher education community, science teachers entered into this type of teacher inquiry movement relatively late when compared to other subject areas (Roth, 2007). In addition, teacher inquiry with specific subject matter has come into the spotlight only recently. Therefore, the current study contributes to the limited volume of work currently available in the research area of science teacher inquiry. The current study supports the growth of research related to science teacher inquiry.

Teacher Inquiry and Lenses

When teachers conduct inquiry into their own practices, to which aspect of classroom practices should teachers pay attention? This is a major focusing question for the current research study. Sherin and her colleagues (Sherin, 2004; Sherin & Han, 2004; Sherin & van Es, 2002) argue that noticing and interpreting classroom interchanges are important skills for teaching in that they enable teachers to adapt their own teaching in the midst of instruction. Using a “learning to notice framework”, they propose that a teachers’ ability to notice the activities within the classroom consists of three skills of “(a) identifying what is important in a teaching situation; (b) using what one knows about the context to reason about a situation; and (c) making connections between specific events and broader principles of teaching and learning” (van Es & Sherin, 2008, p. 2).

However, research reports that teachers often do not have these skills and do not know how to think about their own practice. For instance, Stein, Simith, Henningsen and Silver (2000) reported that when teachers were first required to examine their own practice, they showed lack of a coherent focus and experienced reflection, thus frustrating efforts to bring meaning to the numerous actions and interactions of classroom activity. Moreover, researchers warned that there existed a very likely possibility that when teachers investigated teaching practices by using video, they could watch video much as they might watch television (Brophy, 2004). Given the difficulties of teachers making a “call-out” (Frederiksen, 1992; as cited in van Es & Sherin, 2008), “check points” (Leinhardt, Putnam, Stein, & Baxter, 1991), or “points of impact” (Recesso et al., in press) in teacher inquiry, it was suggested that teaching practice must be investigated with a specific objective that teachers would pay attention to. (Borko, Jacobs, Eiteljorg, & Pittman, 2008; Recesso et al., in press; Roth & Chen, 2007; Stein et al., 2000).

Three research projects illustrate the way in which specific focuses were being used when teachers participated in inquiry related activities. Stein et al. (2000) designed the *Mathematical Task Framework* in order for teachers to learn to critically examine and reflect on their practices. Originally, the *Mathematical Task Framework* was developed as part of the *Quantitative Understanding: Amplifying Student Achievement and Reasoning (QUASAR) Project*, which was a national project aimed at improving mathematics instruction for low-performing middle students. The framework guided the analysis of cases as well as a teacher's own practice in which the focus was placed on how teaching tasks unfolded during classroom instruction and how these tasks provided learning opportunities to students. The researchers found several advantages of the *Mathematical Tasks Framework* when teachers inquired into episodes of classroom practice through the lens of this framework. The framework provided (a) direction for teacher inquiry by turning teachers' attention from themselves as teachers to what students are actually doing and thinking about during classroom lessons, (b) explicit criteria for teacher reflection and discussion, and (c) a way of connecting an individual teacher's practice to a larger set of ideas about teaching and learning (p. 37-38).

The *Videocases for Science Teaching Analysis Project, (ViSTA)* and the *Science Teachers Learning from Lesson Analysis Project (STeLLA)* are two ongoing studies of pre-service (ViSTA) and in-service (STeLLA) science teacher learning (Roth & Chen, 2007). Based on a review of literature about teacher knowledge for effective science teaching, the researchers developed a conceptual framework of two projects. In the framework, two essential areas of science teaching are presented as "lenses" for helping pre- and in- service science teachers see and analyze science teaching and learning: the "student thinking lens" and the "science content storyline lens". Pre-service and in-service science teachers in the projects learn about the two lenses and

practice analyzing and using the various teaching strategies through analysis of videotaped lesson segments, videotaped student interviews, students work, student assessments, and lesson plans. Although the effects of two projects on teacher and student learning are at the preliminary stage, the researchers argued that, by challenging teachers' "typical focus on the activities and teacher actions in science lessons" (p. 8), the lenses provided teachers with the opportunities to look more closely at two aspects of science teaching that are often not visible to teachers.

The *Supporting the Transition from Arithmetic to Algebraic Reasoning (STARR) Project* is a professional development program aimed at helping a group of middle school mathematics teachers to expand their professional knowledge within the supportive peer communities (Borko et al., 2008). Based on the Problem-Solving Cycle (PSC) which consists of three workshops around a mathematical task, teachers collaboratively developed a lesson plan, implemented the lesson, and examined their classroom practices through the lenses of "teacher's role" and "student thinking". In addition to the use of specific lenses, the PSC model is based on a structure through which the facilitator takes a lead role in determining the analytic focus of the workshop. The researchers considered careful planning and highly specific guidance as supports for this teacher inquiry activity as crucial elements which make the PSC model successful.

These three research projects suggest that teachers need an obvious focus, guideline, or scaffold in order to inquire into their own teaching practice effectively. With this in mind, the study being reported here also used a specific lens. Furthermore, the three empirical studies described above, all included an effort to examine what students learn and think about specific subject matter as a lens through which teachers look at their teaching practice. The current study utilized the lens of student learning as well. That is, chemistry teachers examined their teaching

practices with the focus of student learning science in the context of the Community-Based Inquiry Lesson.

Why Create a Students Learning Lens?

Why should teachers pay attention to student learning? This rhetorical question is best answered with a self-evident proposition; student learning is a fundamental purpose of schooling. Teaching is a process of helping student learning in which teachers must create or adapt strategies to meet the requirements of the curriculum as it relates to the specific needs and abilities of their students at particular moments (Clark & Peterson, 1986). That is, teachers need to observe what the students are doing and respond in ways that serve those students efforts to learn (Rodgers, 2002). Dewey pointed out the importance of teachers being “alive” to students’ meaning:

The teacher must be alive to all forms of bodily expression of mental condition—to puzzlement, boredom, mastery, the dawn of an idea, feigned attention, tendency to show off, to dominate discussion because of egotism, etc.—as well as sensitive to the meaning of all expression in words. He must be aware not only of *their* meaning, but of their meaning as indicative of the state of mind of the pupil, his degree of observation and comprehension. (1933, p. 275, italics in original)

This perspective suggests that teachers need to understand the learning processes occurring in the students’ mind and how their teaching practices affect those processes (Graham, 2004).

However, researchers have demonstrated the fact that teachers’ main concerns while teaching are students’ behavior, motivation, and participation in activities, a smooth implementation of activities, or even themselves as teachers rather than students’ learning or

changes in students' thinking (Fischler, 1999; Marton, 1994; McCutcheon, 1980; Morris, 2006). According to Prawat (1992), teachers naively conclude that "student interest and involvement constitutes both a necessary and sufficient condition for worthwhile learning" (p. 389). Rodgers (2002) put forth a similar argument that we cannot assume simply "covering the material, moving students through activities, having fun, being on task, and getting work done" as student learning. Considering this circumstance, it has been suggested that there is clear needs to provide teachers with opportunities to deeply inquire into their students' learning (Hiebert, Morris, Berk, & Jansen, 2007, Rodgers, 2002, Sowder, 2007).

In science education, understanding how students learn science has been a matter of grave concern for researchers. Usually, the process of students' learning science was understood by science educators in the absence of science teachers. Science teachers were considered to make sense of their own students' learning through a perspective dominated by the role of a teacher in students' learning. Science teachers' understanding of students' learning has been received attention in the literature with a growing interest in what teachers need to know about subject matter content in order to teach it to students. Shulman (1986, 1987) and his colleagues (Wilson, Shulman, & Richert, 1987) launched this line of inquiry by proposing the concept of pedagogical content knowledge (PCK). Elaborating on Shulman's work, Magnusson, Krajcik, and Borko (1999) defined five components of PCK for science teaching, among which knowledge about students' understanding of science refers to knowledge teachers have about student science learning, including knowledge about students' way of thinking, students' common learning difficulties, students' alternative conceptions, and students' change of understanding within a particular topic area.

The research in this area reported teachers' knowledge of students' science ideas such as alternative conceptions, which has been measured by survey methods or interviews outside of the teaching context (e.g., Pine, Messer, & St. John, 2001). Within the context of teaching, researchers demonstrated the extent to which science teachers, especially expert and novice teachers, realized the difficulties students would encounter in learning specific science concept (e.g., Geddis, Onslow, Beynon, & Oesch, 1993) and how teachers' knowledge of students increased over time (e.g., Pinnegar, 1989). These studies have focused on teachers' understanding of science learners, but do not illustrate the ongoing process of teachers examining their students' learning, that is, these studies did not show teachers' decision about "where the learners are in their learning, where they need to go and how best to get there" (Assessment Reform Group, 2002). There is still much to be learned about how teachers utilize this type of knowledge in terms of student learning during the normal course of instruction (Park & Oliver, 2008; Roth, 2007).

Teacher inquiry with the focus on student learning science encourages teachers to make instructional decisions based on evidence of each student's learning rather than on their perceptions and expectations (Hiebert et al., 2007). Revealing evidence of student learning is facilitated by knowing one's students, knowing what ideas they bring to the classroom, and appreciating why individual students might differ in their thinking. In order to know what counts as evidence of student learning, teachers must be prepared to see, hear, and read the variety of responses from individual students. Information collected through inquiry provides teachers with knowledge of students' understanding that leads to informed decisions about teaching and learning activities in order to meet diverse students' needs and learning approaches (Black & Wiliam, 1998; NRC, 1996).

Hammer and Schifter (2001) demonstrated the viability of the kind of inquiry described above in which teachers conducted inquiries into their students' understanding and learning. In *Teachers' Intellectual Resources Project*, a group of physics teachers met biweekly during the school year and talked about students and teaching. They collected, presented, and discussed "snippets", which are small samplings of the information the teachers were talking about in regard to their students, such as samples of students' written work, brief narrative accounts of classroom events, audio or video recordings, and transcripts of interactions with students. Teacher inquiry through the window of snippets revealed the breadth of teachers' attention and awareness reflecting the range of intellectual resources that teachers have available for interpreting students' learning. The researchers also found that the focus of teacher inquiry was tied to the particular circumstances as teaching unfolded. Participants reported that inquiry processes were helpful in that collecting and discussing snippets required them to attend to students' thinking and actions with ideas for how they may respond.

In spite of the importance and value of teachers' close attention to students' learning, the NRC's (2007) report points out that "careful analysis of teachers' understanding of students' learning is rare in the science education research literature" (p. 301). Based on the result of a national observation study of a representative sample of classrooms (Banilower, Smith, Pasley, & Weiss, 2006), Banilower, Heck, and Weiss (2007) concluded that, "Where lessons tended to fall short was in the quality of teacher questioning to monitor student understanding, and in the lack of "sense-making" to develop conceptual understanding" (p. 376). Moreover, the standards-based vision for science teaching requires that teachers inquire into their students' progress and difficulties with learning during everyday class as well as inquire into their teaching to identify conditions that promote student learning and to understand why certain practices are effective

(NRC, 1996). Therefore, the current study turned science teachers' attention to their students' learning by asking how science teachers made sense of what they saw and heard as the substance of student learning in the inquiry lesson.

Teacher Inquiry Cycle

In addition to the lenses, tools for teacher inquiry that provide a map of inquiry processes make teachers' ongoing investigation more effective and productive (Weinbaum et al., 2004, p. 47; Barnatt et al., 2007). In this regard, the "inquiry process" or "inquiry cycle" is terminology frequently used in the literature on teacher inquiry.

The *Science Teachers Learning from Lesson Analysis Project (STeLLA)* previously discussed is a year-long professional development program and research study for 4th, 5th, and 6th science teachers (Chen, Schwille, & Wickler, 2007). One of the goals of this program is to increase science teachers' ability to analyze videocases as well as their own lessons for improving their teaching practices. To achieve this goal, the researchers developed the "cycle of analysis". The cycle of analysis consists of four steps: "1) ask a question / make an observation / make a judgment, 2) turn your question, observation, or judgment into a claim, 3) provide specific evidence to support or develop the claim, and 4) consider alternative explanations and/or teaching strategies" (p. 13). The researchers did not provide a theoretical background underlying this cycle, but reported that the process of the cycle encouraged teachers to think deeply about what they noticed in the classroom.

On the other hand, Rodgers (2002) described a framework for reflection on teaching called the "reflective cycle" and consisting of four phases. The first phase is "presence in experience" where pre-service teachers are "learning to see" where students are. The second

phase is “description of experience” in which teachers are “learning to describe” what really happens in terms of their students’ learning. Next, in the “analysis of experience” phase, teachers are “learning to think critically and create theory”. The final phase was “experimentation” when teachers are “learning to take intelligent action”. As pre-service teachers went through this reflective cycle, they became more sensitive to and responsible for student learning. The reflective cycle informs a process of inquiry into practice.

Hiebert et al. (2007) also proposed a framework in order to help pre-service teachers to learn how to analyze their own teaching for understanding of student learning. They argued that “analysis of teaching” is one of the characteristics that comprise teaching expertise. Further, they argued that there are two kinds of competence that contribute to this expertise. One is referred to in terms of particular kinds of subject matter competence and while the other is called analytic competence. The analytic competence is captured as four consecutive skills that teachers use while analyzing their teaching practices. That is, through the analysis of teaching, teachers need to 1) specify the learning goals, 2) conduct empirical observations of teaching and learning, 3) construct hypotheses about the effects of teaching on students’ learning, and 4) use analyses to propose improvements in teaching. Although the framework is not based on direct empirical data, this framework suggested a kind of pathway that teachers follow in their “disciplined inquiry into teaching” (p. 56).

In contrast to these three inquiry cycles that focus more on individual teachers’ inquiry, McLaughlin and Zarrow (2001) reported how the “cycle of inquiry” was used in a school-based learning community. The *Bay Area School Reform Collaborative (BASRC)* is a 5-year reform effort with the aim of changing school culture in ways that support evidence-based decision making. The schools participating in BASRC were required to utilize the “cycle of inquiry” in

order to pose, investigate, and respond to questions about policies and practices. This cycle has six steps: “1) propose a broad problem statement, 2) refine problem statement and focused effort, 3) identify measurable goals 4) build concrete action plan 5) take action 6) analyze results from data” (p. 80). Looking at activities and consequences associated with the cycle of inquiry, the authors identified that different patterns of inquiry evolved at the school and classroom levels. That is, inquiry and generated knowledge through inquiry was “path-dependent” (p. 96) depending on the types of questions, evidence, and so forth. Their finding supports that process of inquiry could influence the end products of inquiry.

These four inquiry cycles—no matter what the name is nor the number of steps —suggest that these cycles function as effective representations for guiding investigation of teaching. Lewison (2003) summarized that teachers, in a type of inquiry cycle, usually “question common practice, approach problems from new perspectives, consider research and evidence to propose new solutions, implement these solutions, and evaluate the results, starting the cycle anew” (p. 3).

Building from these existing studies, the current study enacted a “teacher inquiry cycle” to support teachers in investigating their practices with the lens of student learning. The specific use of teacher inquiry cycle is illustrated in the methods section.

Teaching as Learning

Efforts to make inquiry into teaching practices the centerpiece of teacher education have emerged from the body of literature that regards teaching as a learning process across the professional life span. Positive learning outcomes of teacher inquiry have been discussed in the previous section. In the following section, I address the notion of teacher learning in more depth, along with providing an additional perspective on teacher inquiry and teacher learning.

Teacher Learning, Learning from Practice, & Teacher Inquiry

The concept and language of “learning to teach” (Feiman-Nemser, 1983) began to spread out widely since its introduction in the early 1980s. Several factors including the growing concern for cognition and context in social science as well as with the emergence of qualitative studies of the classroom (Carter, 1990) were related to the interest in the conception of learning to teach. Attention to how teachers learn to teach has continued to the present, and much has been written about “learning to teach” or “teacher learning” (see, e.g., Borko & Putnam, 1996; Carter 1990; Wideen, Mayer-Smith, & Moon, 1998). Cochran-Smith and Lytle (1999b) referred to teacher learning as “one of the most important concerns of the educational establishment” (p. 249).

In addition, teacher learning is regarded as an essential constituent of a qualified teacher. For instance, the National Center for Education Statistics (1999) asserts that

In order to meet the changing demands of their jobs, high-quality teachers must be capable and willing to continuously learn and relearn their trade.... Continued learning, ..., is key to building educators’ capacity for effective teaching, particularly in a profession where the demands are changing and expanding. (p. 21)

Learning to teach is a constructive and active procedure in which the teacher interprets events based on existing knowledge, beliefs, and dispositions as well as personal experience (Borko & Putnam, 1996). It is also considered as a process of teacher change (Borko, 2004; Borko & Putnam, 1996; Hashweh, 2003; Richardson, 1990; Van Eekelen, Vermunt, & Boshuizen, 2006). This process occurs over the career of a teaching professional rather than at a certain point of time. It is clear that the knowledge, skills, and attitudes needed for optimal

teaching are not something that can be fully developed in pre-service education programs. Rather, teachers gain new knowledge and understandings of their student, schools, curriculum, and instructional methods as a result of their work as professional practitioners as well as by maturation resulting from the experiences of their professional development.

Along with the growing consensus of this point of view, there is a growing consensus that teachers need to learn “how to learn in and from practice” (Ball & Cohen, 1999, p. 10). Teaching practices include “a variety of instructional activities to promote student learning” (Hammerness et al., 2005, p. 387). Ball and Cohen (1999) consider teacher learning in and from practice as 1) learning to investigate classroom moments to increase knowledge, 2) learning to use knowledge from practice to improve teaching practice, and 3) learning to operate in response to situations and students. They argued that without practice, teacher learning would be analogous to a person who attempts to “learn to swim on a sidewalk” (p. 12).

However, research shows that teachers do not necessarily learn simply through “encountering” practice, even though this experience is potentially meaningful for their learning (Van Eekelen et al., 2006). Therefore, in order for teaching practice to be a learning experience, the investigation of teaching practice is indispensable because teachers can learn more about teaching, learners and learning, subject matter and curriculum, and schools and schooling when they scrutinize these facets of being a teacher. In a word, teacher inquiry is a necessary condition for teachers’ learning from teaching:

By “learning from teaching,” we mean that inquiry ought to be regarded as an integral part of the activity of teaching and as a critical basis for decisions about practice.... that classroom and schools ought to be treated as research sites and sources of knowledge. (Cochran-Smith & Lytle, 1993, p. 63)

Ball and Cohen (1999) put forth a similar argument stating that pedagogy of teacher education should be “pedagogy of investigation” (p. 13). They insisted that both teachers and teacher educators have to “cultivate the capacities to investigate teaching and learning, develop new claims on the basis of such investigation, and defend them with evidence and argument” (p. 16) in order for teachers’ professional learning to have impact on practice.

As mentioned before, this line of research originated in the 1980s, but matured in the 1990s in response to issues both methodological and technological, particularly the increasing availability of video capture technologies. For instance, Sherin and Han (2004) investigated what in-service teachers learned from analyzing and exploring their own or other teachers’ videotapes. They found changes in multiple dimensions of the teachers response to the video. For instance, they found that both *what the teachers discussed* as well as *how they discussed it (emphasis added)* changed. The nature of the teachers’ discussion changed over time from simply identifying statements of what the student said to examining the meaning of students’ comments and strategies. Furthermore, the teachers in the study became increasingly focused on examining students thinking rather than their own teaching or pedagogy.

As time passed, the context of the teaching experience came to have increased significance. Thus, the perspective which regarded teaching as an act of learning through inquiry into practice became closely connected with the situated perspective of learning. This is the topic that will next be examined.

Teacher Learning is situated

As previously described, there is a growing consensus regarding the value of placing the opportunities for teacher learning in everyday teaching practice. This position is increasingly

grounded in a newer perspective about the nature of cognition and learning, especially, that knowledge, cognition, and learning are situated in particular physical and social contexts (Borko, 2004; Borko & Putnam, 1996; Freidus, Feldman, Sgouros, & Wiles-Kettenmann, 2005; Leinhardt, 1988; Putnam & Borko, 2000; Shuell, 1996). In this section, I describe a situated perspective and its' implication for teacher learning. This perspective accounts for the use of classroom video in this study. Some additional examples of using video in teacher education are illustrated. Finally, to conclude the literature review, the research literature related to the use of video analysis technologies including the Video Analysis Tool (VAT) (which is used in this study) is introduced.

Situated Perspective & Teacher Learning

Traditional research on cognition and learning sought to identify “context-free principled knowledge” (Leinhardt, 1988, p. 148) and “general law of learning” (Shuell, 1996, p. 746) that are applicable and accessible to a variety of situations. This view of knowing and learning began to be challenged by cognitive scientists and educational researchers during the 1980s (Shuell, 1996). Newer ways of understanding cognition and learning processes put forward the idea that knowledge cannot be thought of as independent from contexts and that learning is situated within specific contexts and is thus shaped by those contexts (Borko, 2004; Borko & Putnam, 1996; Freidus et al., 2005; Leinhardt, 1988; Putnam & Borko, 2000; Shuell, 1996). Brown, Collins, and Duguid (1989) noted that “The activity in which knowledge is developed and deployed ... is not separable from or ancillary to learning and cognition. Nor is it neutral. Rather, it is an integral part of what is learned” (p. 32; as cited in Shuell, 1996). This situated perspective also posits that people learn the most in personally relevant and meaningful contexts.

The situated perspective on knowing and learning has important implications for teacher learning, that is, teachers' own classrooms are powerful contexts for their learning (Putnam & Borko, 2000). Teachers constantly construct their knowledge about teaching within the context of teaching. According to Leinhardt (1988), "the situated knowledge of teaching has developed in a specific context, and within that context, is extremely powerful. ... Situated knowledge connects teaching events with particular environmental features such as classrooms, time of year, individual people, physical surroundings, specific pages of text, and more abstracted subject matter knowledge" (p. 147.). That is, construction of teacher knowledge is intertwined with teachers' ongoing practice, and consequently, teacher learning occurs within a specific context of teaching. In this sense, a situated perspective supports the idea that teachers should learn how to learn from the day-to-day work of teaching.

However, this perspective does not mean that all learning experiences for teachers should take place in actual classrooms. Ball and Cohen (1999) explain that "learning in practice" does not necessarily mean that teachers need always to be in the classroom in "real time". It can also happen away from real classroom, as long as the work being done is centered in authentic classroom materials:

Being "centered in practice" does not necessarily imply situations in school classroom in real time. Although the bustle of immediacy lends authenticity, it also interferes with opportunities to learn. Being situated in a classroom restricts opportunities to the sort of teaching underway in that particular class. Further, being so situated confines learning to the rush of minute-to-minute practice. Better opportunities can be created by using strategic documentation of practice. Copies of student work, videotapes of classroom lessons, curriculum materials,

and teachers' notes all would be candidates. Using such things could locate the curriculum of teacher education "in practice" for they could focus professional leaning in materials taken from real classrooms that present salient problems of practice. (1999, p. 14)

Leinhardt (1988) put forth a similar argument that situated knowledge is embedded in the artifacts of a context.

Along this line, situated perspective provides the study being reported here with a rationale of using classroom video as a tool for professional learning. Video captures the everyday experience of teachers and students. This allows teachers' inquiry to be anchored in specific classroom events with which they are already familiar. Specially, video from the teachers' own classroom situates their investigations of teaching and learning in situations which provide a highly motivating context. Thus, inquiry into teaching practice by watching video from one's own classroom has the "potential to be a powerful catalyst for change and improvement" for teachers (Borko et al., 2008, p. 419). Video provides a text for teacher learning. Examining this text opens a door to learning about teaching using particular students in a particular setting, at a particular time, and for a particular instructional purpose.

Use of Classroom Video in Teacher Education

Using video for capturing or analyzing teachers' practice is not a new trend in teacher education. After the first video tape recorder (VTR) captured live images in 1951, teacher educators quickly became aware of the potential of video for professional development programs of in-service teachers as well as for preparation of pre-service teachers (Brophy, 2004). Video has historically been used for teacher learning in microteaching, interaction analysis, modeling

expert teaching, video-cases, and hypermedia programs as well as in field recordings (Sherin, 2004).

In the 21st century, the potential of modern video and computer technologies offer great possibilities for teachers to inquire into their practices that are embedded in real classroom contexts, and researchers show a growing interest in investigating this potential (Abell & Cennamo, 2004; Borko et al., 2008; Le Fevre, 2004; Seago, 2004; Sherin & van Es, 2005; van Es & Sherin, 2002, 2008)

For instance, the Video Analysis Support Tool (VAST) (Sherin & van Es, 2002, 2005; van Es & Sherin, 2002) was designed to foster the teachers' ability to observe and interpret classroom interactions by using guided reflections on their own teaching. Twelve individuals in an alternative certification program of secondary mathematics or science education participated in this study. Among them, six pre-service teachers joined the three VAST sessions. Using VAST, pre-service teachers could upload digitized video from their own classrooms. They were expected to analyze three classroom aspects of their video such as student thinking, discourse, and the teacher's role, and also were asked four levels of questions within each of these areas. Prior to and following participants in the VAST sessions, they were asked to write narrative essays. Twenty four written essays were analyzed based on the framework, *Trajectory of Development in Learning to Notice*, developed by the researchers. The researchers determined that pre-service teachers who had VAST sessions organized their essays around significant classroom events, provided specific evidences, and appeared to be more interpretive in their analysis. That is, VAST provided pre-service teachers with the opportunity to learn to notice what is happening in their classroom by commenting on video.

In the field of science education, Minchew, Bryan, Deaton, Recesso, and Hay (2004) developed a novel and interactive form of digital video replay, the *Video Case Tool* (VCT), in order to examine how the use of VCT promoted reflection in a science teacher professional development course. The study focused on the reflection of 12 middle and high school teachers in a summer professional development course on modeling-based inquiry. VCT allowed the participants to record their interactions with students, view digitized video, and choose specific moments using preset coding tools. During the professional development course, participants went through four phases: introduction, apprenticeship, reflection on practice, and integration and dissemination. The participants were required to record their own working with students during the second phase which were analyzed in the third phase. Besides digital video footage including three episodes of teaching, written documents such as written reflections on their own video cases, teacher surveys, two observations and interviews, and handouts were used as data sources. Qualitative analysis as well as the *Video Case Evaluation Rubric* was used for data analysis. The researchers reported that the use of VCT allowed the teachers to rethink their teaching and the use of inquiry as a means of student learning even though the level and range of reflection differed among the teachers. This research demonstrated the way in which participants used their own teaching as cases by using video recording.

In a related vein, Yerrick, Ross, and Molebash (2005) investigated the use of digital video editing as the main venue for fostering reflection. Pre-service elementary teachers in a science methods course participated in this study. The context of this study was unique in that the methods course was situated in public schools in which pre-service teachers could connect educational theory to actual practice. Using state-of-the-art desktop video editing software and hardware, participants first created a 5-minute iMovie from their interviews with students. They

also taught a one hour lesson in the same class of students where they had conducted the interviews, and this teaching was recorded on video. Next, they transferred their data to computers and edited it in order to represent their reflection and learning. Autobiographies, weekly written journals, responses, lesson plans, curriculum critiques, and personal video-recorded reflections were also collected for analysis. The researchers suggested that there were shifts among pre-service teachers in (1) reflections regarding children's thinking, (2) planning and instruction informed by reflection, and (3) notions of teaching expertise and requisite knowledge by reflecting during digital video editing. That is, pre-service teachers reported that their focus changed from exploration about their own teaching to children's understanding of science concepts. By means of digital video editing, they also stated that they were able to examine the instruction as well as their planning process of instruction. Their interview comments revealed that pre-service teachers came to perceive themselves as a facilitator of inquiry activities instead of a disseminator of knowledge.

These three studies suggested that using classroom video can function as an effective tool for both in-service and pre-service teacher learning. Many researchers have explained why watching video of classroom instruction is useful in teacher education, but Sherin (2004) has succinctly summarized it by noting three affordances of video and considering how these features support teacher learning. First, the immutable characteristic of video provides teachers enduring records of instruction, so they can refer to the video instead of memory as evidence of their teaching; choose specific events for deeper reflection; and examine their classroom more closely multiple times. Second, due to the feature of video that allows collecting, editing, and reorganizing of classroom events—especially the ability of digitized video— teachers can change chronological order in the classroom and access the video around a particular topic. This

also promotes “multiple paths of inquiry” (Sherin, 2004, p. 13). Third, video affords a different set of practices that differs from teaching. That is, teachers can be released from dual tasks of teaching and learning to teach (Wang & Hartley, 2003). Therefore, teachers have additional chances to reflect on students’ learning rather than to act on, think of alternate pedagogical strategies, and to engage in fine-grained analysis of classroom practice while also maintaining a effective instructional session.

Video Analysis Tool (VAT)

In this study, I used the *Video Analysis Tool* (VAT) that was developed by the Learning and Performance Support Laboratory (LPSL) at the University of Georgia.

VAT is a web-based software program that is used to systematically capture, identify, and analyze educational practice as well as to store and organize it (Recesso et al., in press; See <http://vat2.uga.edu/Login.do>). Using VAT, educational researchers and practitioners—pre-service or in-service teachers—can record teachers’ practice in the classroom via a video capture device. These data are uploaded in a digitized format to VAT subsequent to the recording, or, in the case of a remote location, a special Internet Protocol (IP) camera is often used that records directly to the VAT server. Then, researchers and teachers can analyze the video using pre-developed instruments called lenses. During the analysis process, they segment the video into smaller and more manageable units called clips, which are then analyzed from the perspective of the lens. The VAT system also allows users to share their clips once they have analyzed them, to compare their own analysis to another one in a side-by-side view called “View Multiple Clips.”

In the current study, in-service science teachers had an opportunity to inquire into their own practices, reflect on them, and construct professional knowledge about student learning, in

turn, to think about change of their classroom practice. This opportunity was supported using VAT technology to scaffold their work.

Summary and Preview

In this chapter, I have furnished pertinent literature from three lines of scholarship. The first strand explored the concept of teacher inquiry including various approaches to the idea of teachers investigating their own practices. This review clarified the term and definition of teaching inquiry. I have also discussed the issues surrounding focus, structure, process of teacher inquiry, which were necessary for designing the teacher inquiry project in this study. The second line was drawn from the literature on teacher learning in relation to teachers' practice. The third body of literature dealt with a situated perspective, which offered a foundation for using video in the current study. In the following chapter, I discuss how the teacher inquiry project was designed and preceded in detail.

CHAPTER III

METHODOLOGY

Chapter Overview

This study investigated the ways chemistry teachers inquired into their own classrooms when the Community-Based Inquiry Lesson (CBIL) was implemented. The researchers and participating teachers used the Video Analysis Tool (VAT) for the systematic teacher inquiry process. In this chapter, I describe the epistemological framework guiding this study. Then, I present an overview of the research design and thorough description of research participants and of research context including delineation of the high school in which the study was conducted, of the instructional context of each teacher, and of the CBIL. Finally, I illustrate the types of data sources from which I gathered and then how I collected and analyzed those data. Within this context I also provide a methodological literature review.

Epistemological Framework and Application to Research

Epistemology is “a way of understanding and explaining how we know what we know” (Crotty, 1998, p. 3). It deals with “the nature of knowledge, its possibility, scope, and general basis” (Hamlyn, 1995, p. 242). Being conscious of my epistemological stance is an indispensable state while conducting research because it shapes “the meaning of research questions, the purposiveness of research methodologies, and the interpretability of research findings” (Crotty, 1998, p. 17).

Drawn on the work of Michael Crotty (1998), there are three epistemological stances: objectivism, constructionism, and subjectivism. Considering how I make assumptions about the making of meaning, I placed myself within the standpoint of constructionism. I do not believe that meaning is either *imposed* on the existence of objects *solely by* someone's subjective awareness (which is subjectivist epistemology) nor that meaning *independently exists* in objects apart from any consciousness so that it is *discovered* (which is objectivist epistemology). Instead, I take the position that meaning, and therefore all knowledge, is *constructed by an interaction* between human consciousness and the world within a social context. However, this is not to mean that a world of material objects would not be absolutely "real". Personally, I believe that, regardless of human beings' consciousness, there exists the objective material world pregnant with potential meanings but which may be meaningless in itself. Yet, the meaning of the world and the objects in that world can be attributed to the construction of human consciousness, so miscellaneous interpretations by different people can be formed of the same object. This stance goes with Crotty's (1998) view that "Constructionism is at once realist and relativist" (p. 63) and that "Objectivity and subjectivity need to be brought together and held together indissolubly" (p. 44). His example of a tree has encapsulated constructionist epistemology well:

What the 'commonsense' view commends to us is that the tree standing before us is a tree. It has all the meaning we ascribe to a tree. It would be a tree, with that same meaning, whether anyone knew of its existence or not. We need to remind ourselves here that it is human beings who have constructed it as a tree, given it the name, and attributed to it the associations we make with trees. It may help if we recall the extent to which those associations differ even within the same

overall culture. ‘Tree’ is likely to bear quite different connotations in a logging town, an artists’ settlement and a treeless slum. (p. 43)

From this constructionist stance, I believe that all research is a human construction. That is, the procedure and output of research are an interaction between the researchers and the outside world. Inasmuch as “Subject and object emerge as partners in the generation of meaning” (Crotty, 1998, p. 9) in the view of constructionism, researchers and participants can be partners in the co-construction of meaning. In this particular study, each participating teacher constructed her own meaning about her students as well as her teaching practice in her classroom through the process of inquiry. That is, the teachers were engaging with a classroom reality and making sense of it. However, with different experiences to engage with, the emerging interpretations each teacher constructed were not the same. In addition, I, as a researcher, also constructed meanings about the process and outcome of teacher inquiry. My interpretations were a co-constructive process in a sense that they were based on the constructed meanings that the individual teacher made of her own experiences. Taken all together, my whole research process as well as the process in which the teachers made sense of their classroom was a meaning-making procedure informed by a constructionist epistemological stance.

Overview of the Research Design

I employed a qualitative case study approach (Erickson, 1986) in this study. The goals of this research were to describe the processes and outcomes of chemistry teachers’ inquiry into teaching practice focused on students’ learning in the context of the Community-Based Inquiry Lessons (CBIL). That is, the study itself was an inquiry about science teachers’ teaching experiences as well as about the meanings they made through interpretation with regard to

student learning of science in the classroom. A qualitative study was well suited to the purpose of this research in that it allowed me to answer to the “questions about people’s experiences” and “inquiry into the meanings people make of their experiences” (Patton, 2002, p. 33). With a wealth of detailed data, I was able to investigate teachers’ sense-making in great depth.

On the other hand, the congruence between the case study as a research design and the purpose of this study was demonstrated by Patton’s (2002) remarks. Patton stated that the purpose of a case study is “to gather comprehensive, systematic, and in-depth information about each case of interest” (p. 447). He also wrote that a case study illustrates “the value of detailed, descriptive data in deepening our understanding of individual variation” (p. 16). These statements accurately describe this research of three chemistry teachers. Each teacher, as a case, was a rich exemplar for holistic, context sensitive, and in-depth study of their sense-making of students’ learning science and instructional practice. Indeed, in-depth case studies of classrooms play an important role in developing an “understanding of patterns of practice in classrooms” (Spillane & Zeuli, 1999, p. 20). Mayer (1999) asserted this stance by stating that “Much of what the country currently knows about the instructional process comes from in-depth studies done in only a handful of classrooms” (p. 30). Therefore, a case study was well suited to exploring science teachers’ ongoing inquiry into their teaching practices in terms of students’ learning.

Participants of the Study

Participant Selection Procedures

I collaborated with three high school chemistry teachers in this study. I used a “purposeful sampling” approach in selecting participants (Patton, 2002). In contrast to random probability sampling used in quantitative study, purposeful sampling provides “*information-rich*

cases” (p. 231) for qualitative study. I believe that I was able to learn a great deal about the issues of teacher inquiry and their sense-making from my participating teachers who yielded insights and in-depth understanding as information-rich cases.

Purposeful sampling is also called “criterion-based selection” in that qualitative researchers set up a list of attributes and characteristics the participants have to possess (LeCompte & Preissle, 1993). In this particular study, my primary criterion was that the participants should have a willingness to join the teacher inquiry project. In addition, I thought it would be fruitful for me to select participants who were teaching chemistry at the high school level considering my teaching background as a high school chemistry teacher. I believed that it would allow me to better interpret classroom situations and teachers’ sense-making of it.

With those criteria in mind, I asked professors in the teacher education programs about a feasible research site and potential participants. Those professors were able to help me successfully identify the site for the research which is to be described in a subsequent section. That is, I began to use a “snowball / chain sampling” approach (Patton, 2002), sometimes called “a network selection” (LeCompte & Preissle, 1993), among several strategies for purposefully selecting information-rich cases. In this approach, the researchers initiate the process of selection by asking key informants.

Making video within the classroom was a big concern at the beginning stage of this research, but I was able to focus on one particular district since a doctoral committee member already had permission for the use of video in the schools of that county. Then, another committee member recommended River Sound High School (RSHS; pseudonym) located in that district based on his research experiences there, so we contacted one chemistry teacher at RSHS. This teacher invited us to the science teacher faculty meeting which was held every other week

after school. There, one committee member and I presented the outline of the teacher inquiry project, introduced VAT, and provided a questionnaire (see Appendix A) for teachers who had an interest in participating in the research. As a result, eight teachers in different science disciplines volunteered for the project. Among them, I selected two teachers who were teaching chemistry during the 2007 academic year. These two teachers referred me to other chemistry teachers who were implementing the CBIL together with them, so from that referral I was able to obtain the third participant.

Introduction of Participants

My three participating teachers were Dorothy, Lisa, and Cindy (all were given pseudonyms for confidentiality). Among them, Cindy was a beginning teacher who just started her teaching career when I conducted this research. Two of them, Dorothy and Lisa were experienced teachers who each had more than fifteen years of teaching experience. These two teachers were National Board certified four years ago and were previously experienced as research participants with one of the committee members. In addition, they were co- science department heads at the time of this study. All three teachers worked at the same school, RSHS, in northeast Georgia. I provide background information of the three participants in Table 1.

Describing each participant again in terms of her demographic information, educational background, and teaching and working experiences is unnecessary reiteration. Instead, I believe it is more pertinent to hear their stories about learning and teaching science before the study began in order to get a glimpse of who they are as science teachers. I believe that personal experiences of teachers needs to be considered in order to create a better understanding of themselves as teachers as well as individuals.

Table 1

Background Information of Participants

	Dorothy	Lisa	Cindy
Ethnicity/ Age/ Gender	Caucasian / 43 / Female	Caucasian / 42 / Female	Caucasian / 29 / Female
Education	Physical Science (B.S.) Secondary Science Education (M.Ed.)	Chemistry (B.S. / minor in Biology) Secondary Education (B.Ed.) Broad Field Science (M.S.) Curriculum and Instruction (Specialist)	Forensic Science (B.S.) Industrial Chemistry (M.S.)
Current teaching subject	Honors chemistry	Advanced placement chemistry Gifted chemistry	Honors chemistry Advanced placement chemistry Gifted chemistry
Teaching experience	23 years / 14 years at RSHS (6 additional years in Georgia / 2 years in rural schools in Alabama / 1 year teaching assistant at the university in Alabama)	17 years / 7 years at RSHS (5 years in Florida / 1 year in a inner city school in Virginia / 1 year home bound instructor / 1 year part time chemistry teacher in Governor's School in Virginia / 2 years international field study science instructor in Governor's School in Virginia (1999-2001)	First year at RSHS
Other work experience			Analytical chemist (2003-2006)

Literature in teacher education reports that lifetime experiences influence both teachers' beliefs about teaching and learning (Pajares, 1992) as well as their professional knowledge construction (Bryan, 2003; Bryan & Abell, 1999). In this regard, I will introduce three participants by providing their own narratives. The stories that follow address how participating teachers became science teachers and what experiences they had in relation to learning and teaching science. The narratives reveal each teacher's view of science teaching.

I constructed the following stories in the light of Polkinghorne's (1995) notion of *narrative analysis* in which researchers synthesize and organize the data elements into a coherent account. Acknowledging that it is important to hear participants' voices (Kramp, 2004), I decided to use my participants' own words as they were. That is, all the words in the stories came directly from the teachers' voices through the interviews even though they did not tell the stories in the same order. On some occasions, I added some words for readability and coherence because spoken language is different from written language. In that case, I bracketed my words. All italicized words except the bracketed ones came directly from my participants.

Dorothy's story. My mother's a high school English teacher and she's retired now. My dad's a History college professor. [However], I never intended to be a teacher although I taught piano lessons all through high school and college. I loved it, but just never thought about it.

In high school, I felt like science was a lot of times [a subject in which] you just read the book and answered the questions. I didn't really see the joy in science in high school. [Thus], I was not turned on to science at all. To me, it [science] was just rote memorization and just using the book, reading [it], and answering questions; you're just not getting that much out of it. It [science] would be fun to try to solve the problems, but like I said, in high school it wasn't... We

didn't do very many labs; it wasn't very applicable to life; there was no relationship... [Thus], I was turned off [from] the science.

I didn't get turned on to science until I had some really good teachers in college and in graduate school. When I was in college, I was real close to a couple of my chemistry professors. One of them really wanted me to major in chemistry. I loved organic labs where you had to figure things out. One of the neatest classes I ever took was a Fluvial Geomorphology class in graduate school when I was working on my Master's. What we had to do [as] our class project was [study the] building [of] a new Wal-Mart. And they were worried that it was gonna flood the stream and flood a trailer park that was a mile and a half downstream. So, we had to walk that mile and a half, make all kinds of measurements and we had to predict whether it would be flooded. It was so exciting to me because of an application [of my science knowledge], and I felt we were really doing something important. There was later a lawsuit on it and it ended up, it [the rainwater runoff] did flood the trailer park. My professor knew what was going on around [the city] and it was just exciting. It was just a really fun project. I've always thought that was meaningful to me and it felt good when we did those calculations. It was a really neat experience. That was a real big application and that was very important to me.

In college, I majored in science, and I was pre-med. I really wanted to work with people and work with solving problems, trying to figure out what diseases people have and how to make their lives better. I wanted to be a doctor. [However], I didn't think I was accepted to medical school. But then, I was accepted to medical school. And by then, I was already teaching science and I loved it. So, I accidentally got a job teaching and it was so much fun and I loved it and enjoyed it and I've never had any regrets. I started teaching when I was 21 and that's the way it went.

I taught six years at [the name of the high school], which is also in [the same] county. I taught three years in Alabama. I taught two years in two rural schools in Northern Alabama. I was a graduate teaching assistant in [the name of the university] for a year. [Then], I've been around 14 years [at RSHS]. I learned the most science when I started teaching it and had to figure out things for myself.

Lisa's story. I think I always liked it [science]. I think I was always good at it [science]. I think the reason why I think I'm fairly good at teaching is that while I was always good at science and I was always confident about it. I never had just banged [my] head against the wall [because of] frustrated feeling. I always got A's. But I think I had to be deliberate about it. I wasn't brilliant. It wasn't like, "Oh yeah, don't you get that?" I had to study; I had to work at it. I remember when I was in high school how I set up problems. So, it didn't come so naturally to me, I guess. [But], like I said, it [learning science] wasn't [difficult] until I got to [the name of university] and I was taking organic chemistry and analytic chemistry at the same time. That was a little bit difficult. I would really have to work and I would go and hang out at the teacher's office. I was very diligent.

[In addition to science], I always loved school, going through. I actually went to community college for a couple of years before I transferred to a four year [the name of university]. So, I really spent a lot of time trying to think about what I wanted to do. [Thus], I did a lot of those personality [and] aptitude tests, and teaching was really kind of high up there. And, I really liked science. When people think about science, they think about the medical profession and stuff like that. But I'm not really a quick decision maker; I labor over things. I thought that would be a little dangerous for patients. [When] I did some undergraduate research, I really loved it. We'd have these eight hour reactions; it was very cool. But I realized quickly that what I

loved the most about the research was telling everybody about what I was doing. I like to talk and I'm a people person. I love to help people. [Thus], I really deliberately chose [teaching]; I didn't just fall into it. It just was the best fit for everything that I enjoyed and [for] my personality. So that's why [I decided to become a science teacher].

I've taught since 1990. I taught for five years of school in Florida. I taught gifted and AP mostly chemistry, a little bit of environmental science, and biology but not much. And then, I moved to Virginia and I taught at an inner city school, [which consisted of] 99% minority [for] one year. It was a very different population, but I really enjoyed it, actually. Then, about two years later, I was a home bound instructor [for] one student who went to a governor's school for the gifted, [but] was at home [because of] a stomach disorder. When I would go in and meet with the teachers [in the governor's school], they liked me so much that they asked if I would be interested in teaching because they needed a part time chemistry teacher. So, I worked for them a year or two.

And then, I coordinated some science field study courses in Costa Rica and Peru. It was way cool. It was a fourteen day trip. We stayed on the Amazon for a week and we went to Machu Pichu for the other week and we made it all. It's kind of interesting in that it's kind of like what I do with this community based inquiry learning in a way. The community based learning is all centered [on] around something that is real life, a real issue. When we went to Costa Rica, the whole theme for the course was biodiversity. So we even took over a lot of computers, CBL [computer based learning] equipment, [and] a lot of the water testing equipment. And we would go to different water ways and we would test the dissolved oxygen and whatnot. The kids had to read Sylvia Earl and lots of environment type essays and novels beforehand. We would have book discussions while we were there. It was very cool. We stayed at a sea turtle preserve for

four days [with] no electricity and we learned all about sea turtles. I related it to chemistry because the whole wave length of light... We kind of had our own little sea turtle symposium. Then, I ended up going to the international sea turtle symposium. That was great fun.

Then I moved here and worked at [RSHS] and I've been working here since 2001, again back to kind of my old teaching site which is AP and gifted. I thought this [teaching science] is obviously my passion and my profession.

Cindy's story. My father is a chemistry professor, so not only was science always a huge part of my life growing up, but education was too. I loved being in school, and I loved education. [However], I really didn't have too many positive experiences with science in school until I got to college. Through middle school and high school, my science teachers were not... I really have no positive experiences with any of my science classes, maybe with the exception of my seventh grade science teacher. She was really great. She was really an awesome, awesome teacher. But, every other teacher I had just didn't make it [science] interesting or didn't make it fun. That's why I want to try and make science as interesting and fun as possible because I don't want kids sitting through like what I was sitting through that class [saying], "Oh my goodness, this is so painful." I honestly think if it wasn't for the fact that I had the influence of science from my father, I probably would not have gone into science.

In college, I had some great professors especially in the forensic science program. Two of the main professors in the program had these very interesting labs and always very enthusiastic. That was really positive [experiences with learning science]. [For instance], [in] some of the classes I took, [we] were tracing evidence and we had to analyze hairs and fibers and create a whole portfolio. It was interesting to take samples from home, come in and look at them under the microscope and draw pictures of them and [take a] sample of our own hair and

everything. That was really interesting. In forensic biochemistry lab, like the DNA lab, they would create a kind of crime scene for us and we had to analyze [it]. They had clothing with blood stains on that we had to analyze, the real blood, and [we had to] do different things with that. I always thought that was really cool because of the applications of it; having the fact that you could see there was a real world type scenario. Especially, the crime scene was kind of a story you were dealing with. I always liked things that are more like a story, scenario versus basically just like a recipe, just [saying], "Here, this is the lab." I don't like those types of labs as much. [Thus], that was two of my favorite classes that I took. [Finally], I got a Bachelor's Degree in Forensic Science and my master's degree was in Industrial Chemistry. That was the degree program at the school, but really my research was environmental chemistry.

[Then, I worked] three years before I started teaching. I started off as an analytical chemist, just working with instrumentation, analyzing samples, using GC mass spec [gas chromatography mass spectrometry], HPLC [high performance liquid chromatography] and different instrumentation. I worked on taking instruments apart and fixing them if they had problems and all that. And then I moved up into doing quality control and reports, and basically sitting at a desk in front of a computer all day. I didn't like that either. Both jobs were pretty monotonous; pretty much the same thing day-in and day-out. You always knew what to expect, which definitely cannot be said for teaching; it's anything but monotonous.

I thought I would try working in industry for a few years, but I realized that wasn't really my calling and thought I would try teaching since I'd enjoyed it so much. As a graduate student, [as] being a TA, [I was] teaching the general chemistry labs, discussion sections, and inorganic labs... I loved having that exposure to teaching. [So, I began to teach here.] It worked out and I love it.

Description of Research Context

Research Site: River Sound High School

I conducted this study in the 2007-08 academic year at the River Sound High School (RSHS) located in the northeast portion of metropolitan Atlanta. Opening in 1994, the total student enrollment at this school was 3570 as of September 2007 and average attendance was 95%. The 2006-2007 student data showed that the diverse student population was made up of 57% Caucasian, 18% African American, 12% Hispanic, 10% Asian, and 3% multiracial. Approximately 3% of the students were ESOL (English Speakers of Other languages), 9% of students were in special education, and 20% of students were eligible for free/reduced lunch.

In the 2006 academic year, the average Scholastic Achievement Test (SAT) score of RSHS was 1540, which was above the district average of 1524, state average of 1472, and national average of 1511. To earn a regular diploma, students must pass both the district's High School Gateway Test and the Georgia High School Graduation Test (GHS GT). The school's averages on both the Science and the Science/Language Arts sections of the Gateway ranked second in the district. The passing rate of the GHS GT, which is a state curriculum-based test used to measure high school students' learning, was 96.1 % in English/Language Arts and 91.4 % in Mathematics. RSHS earned Adequate Yearly Progress (AYP) based on the results from the GHS GT. Among 708 students who graduated from RSHS, 91% were planning to attend college or post-secondary school.

RSHS has adapted a special curriculum, the Academic Knowledge and Skills (AKS), which was developed by the county. The science department of RSHS offers College Preparation (CP), Advanced Placement (AP), Honors, and Gifted science classes and consists of 29 teachers.

Instructional Context

Dorothy's honors chemistry class. Dorothy selected one of her four honors chemistry classes for the teacher inquiry project. She defined the purpose of this course as “to teach critical thinking through chemistry AKS” (email communication). Twenty-three students in this class were in tenth grade and one was in twelfth grade. Students’ ages ranged between 15 and 18. Among the 24 students, 15 were females and nine were males. The student population was made up of three African Americans, four Asians, two Hispanics, and 15 Caucasian. Four out of 24 spoke languages other than English at home. There was one hearing impaired student. At the beginning of this research, Dorothy described the characteristics of this class as follows:

Fifth period has 24 students in it. When I was first looking at their grades, most of them have made an A or B in biology. Most of them made an A in biology. It’s probably my brightest class of the three. They are very, very smart... There are a lot of strong personalities in there. What I would try to really work on that class to do is I said, “You’ve got to really work on the way you communicate with each other.” (Dorothy, Initial interview #1)

Lisa's gifted chemistry class. At the time of this study, Lisa taught three gifted classes and one AP class. For the teacher inquiry project, she selected third period gifted chemistry class. Linda defined the purpose of this course as “to teach critical thinking skills through chemistry content” (email communication). The 21 students were all in tenth grade and their ages ranged between 15 and 16. The student population was made up of four Caucasian males, two Indian males, 13 Caucasian females, one African American male, and one multiracial female. None was identified in special education programs. Lisa’s perception of this class was depicted in the following way:

They're very social. I think with the gifted kids... for years probably, they have been grouped together in these classes. So, I think they get to know each other quite well, so they end up being pretty social; pretty comfortable with each other really. They can be chatty, but the nice thing about it is they also have become aware of each other's quirks. Gifted kids can be really quirky, but they just really accept each other. I think probably because they're all a bit quirky, it's easier to accept the others. (Lisa, Initial interview #1)

Cindy's honors chemistry class. Cindy taught one gifted class, one AP class, and three honors classes, one of which was selected for the teacher inquiry project. Cindy described the purpose of this course in the same way Lisa did: "to teach critical thinking skills through chemistry content" (email communication). Cindy's 28 students were all in tenth grade and their ages ranged between 15 and 16. Among the 28 students, 18 were females and 10 were males. The student population was made up of 19 Caucasians, three African Americans, two Asians, and four Hispanics. Six out of 28 spoke languages other than English at home. None was identified as being in special education programs. Cindy portrayed the characteristics of this class in this way:

That class, I really love the energy in that class. They're all very smart kids. It's an honors class. A lot of them are tested as gifted in that class. They have a lot of great thinkers in there. They ask a lot of really good questions, mostly, and that's always good. They're usually very interactive. And they're a class where I asked all kinds of different things about themselves. They're all involved in something outside of school, so they're a very diverse class in that they like that they're involved in a lot of different things... They're great thinkers individually; they

just need to work on pulling their thinking together and working together more as a group. They're a really smart class. (Cindy, Initial interview #1)

Community-Based Inquiry Lesson

Before the project began, the three participating teachers worked with researchers (the author and major professor) to decide what aspects of classroom teaching they would investigate for the teacher inquiry project. That is, we identified a topic of interest that chemistry teachers thought about with regard to student learning. This approach of identifying a starting point of teacher inquiry is grounded in the literature of teacher research and action research (Capobianco, Horowitz, Canuel-Browne, & Trimarchi, 2004). Dorothy and Lisa came up with the idea of inquiring into their new project called Community-Based Inquiry Lesson (CBIL) that the chemistry teachers at RSHS just began to try as an innovative way of inquiry-based teaching. Since the CBIL was new to the teachers, they eagerly wanted to know how this new instructional strategy would impact their students' learning science. As a result, the CBIL came to function as a significant context of this research. In the following section, I provide detailed explanation of how the teachers developed the CBIL and three lessons that they implemented during one semester period.

How was the CBIL born? Dorothy and Lisa have implemented inquiry-based teaching for the past several years. They have done this in a variety of ways. They consider inquiry as the direction that science education should pursue: "I've always enjoyed doing inquiry in class. I think that's where we need to go" (Dorothy, Initial interview #1). Furthermore, these two teachers have played leading roles in several district-based professional development programs in which they have also emphasized inquiry.

In the spring of the year when I conducted this study, Dorothy and Lisa knew that they would again be teaching the professional learning workshop for high school chemistry teachers in the district so they sought a fresh way of teaching inquiry. A week before the workshop, Dorothy and Lisa read the book *Teaching Inquiry-Based Chemistry: Creating Student-Led Scientific Communities* by Joan A. Gallagher-Bolos and Dennis W. Smithenry (2004). The authors of this book illustrated a year-long chemistry curriculum which incorporated an inquiry spirit driven by the students with detailed examples. The curriculum consists of several projects in which the teachers allow the students to solve a problem with the whole class acting as a self-sufficient scientific community without the aid of the teachers. The two experienced participating teachers, Dorothy and Lisa, were fascinated with this approach to inquiry suggested by the book: “I thought it was very cool and really more real world for them [the students] to have to work as a whole team” (Lisa, Initial interview #1). As a result, they ended up teaching the professional learning workshop based on the method in the book hoping that teachers would teach their chemistry classes in that way. Dorothy and Lisa brainstormed and designed a project in which teachers who attended the workshop actually solved a problem as a scientific community. Cindy, the other participant in this research, was actually one of the attendants of the workshop and recalled the workshop in this way: “We actually, in the workshop, acted as the students ... we kind of had to work together as a class to solve these problems ... It was challenging for us as teachers, so it was kind of good to do that and see it from the kids’ side” (Cindy, Initial interview #1). All three teachers regarded the workshop as successful. They could not wait for school to start because they were eager to implement the same kind of lessons in their classrooms.

After the summer professional workshop, Dorothy, Lisa, and Cindy brainstormed ideas of how to turn their small group labs or recipe-written labs into a community-based project in which the students need to solve a problem. Finally, they developed three lessons that they called Community-Based Inquiry Lesson (CBIL) with the expectation that their students would learn to work as a team, communicate, and think critically. The three lessons were based on the labs that Dorothy and Lisa had used in a different way. Each lesson was a week-long project in which the students were given a mission to accomplish as a scientific community. In each project, the students had to elect classroom managers and assign a job to a group of students in order to effectively manage the whole class as a research community. In addition, students had to present their findings much like a scholarly meeting of a group of scientists. The teachers were role-playing as different characters from a company, the Occupational Safety and Health Administration (OSHA), a Board of the city, etc., and were keeping journals (and not giving directions) while the students were leading their classroom. After each CBIL, the teachers revisited what the students had learned from the project in a type of post-lab discussion. Following the suggestion of the book, the teachers spent the first week of school building their classroom communities by establishing climate and trust before moving to the CBIL.

Successful Scientific Community

1. You must have classroom managers when you are in charge of the classroom. Class managers help organize the class. You should have two class managers.
2. Everyone must take an active role in accomplishing a class task.
3. Nobody gets left behind. It is more important to stay together than to finish the job.
4. You have to be comfortable with being confused. Remember, you are all in the same boat. I wouldn't give you a challenge that I didn't think you could successfully accomplish together. It's supposed to be difficult, but it will always be doable if you cooperate!
5. Safety is enforced by everyone.
6. There are NO time extensions.
7. Each person must have data.
8. Each person must set up lab book- see log book guidelines.

Figure 1. Handout: Successful scientific community

They also provided the handout that showed what was expected for an effective scientific research community before the first lesson (see Figure 1). While implementing the projects, the teachers frequently had meetings after school.

SpinachCo Project. This was the first CBIL which was implemented in September. The students received the problem to solve as a scenario in which the SpinachCo company wanted to put spinach in vending machines in schools and businesses, assuming that if people could eat spinach at any time on the job, it would improve mental alertness and performance of workers by eliminating fatigue caused by the lack of iron. The mission of the students was to find the optimal conditions under which vending machines could be used to dispense spinach containing the largest feasible amount of iron. Thus, the students needed to consider both what and how certain variables would affect the amount of iron in spinach and make a claim of what conditions should be best to set up vending machines based on this data.

The teachers intended for their students to learn the names and other information related to scientific concepts (elements, ions, compounds, physical change, chemical change, homogeneous mixture, heterogeneous mixture, pure substances), to learn lab skills (measuring with a graduated cylinder for volume, using a balance to measure mass, using a Bunsen burner, using hot glassware, using a spectrophotometer), and to learn about experimental design (independent variables, dependent variables, control groups, repeated trials, quantitative data, qualitative data). Throughout the project, the students came up with additional variables to test such as temperature, humidity, packaging, storage, exposure to light, etc., and finally presented their ideas for the vending machine to the CEO of SpinachCo.

This project was totally open-ended in terms of experimental design, but since this was the first lesson, the students were given the procedure of how to extract iron from spinach as well

as how to measure the amount of iron using a spectrophotometer before they began the project (See the worksheet *Testing Food for Iron* in Appendix D). All worksheets used in the *SpinachCo project* are shown in Appendix D. Dorothy and Lisa had used a similar lab last year, but the lab was more cook-book style in that students brought any kind of food and measured the amount of iron in the food following the directions for actual procedures. This year, they adapted it to the open-ended CMIL.

Carter Center Nigerian Trip Project. The second CBIL, called the *Carter Center Nigerian Trip Project*, was implemented in October. The project was a part of the Water unit. In this unit, the students studied the concept of ionic compounds such as how to name ionic compounds and how to write chemical formulas of ionic compounds for one week. To do that, they also studied the periodic table, metals and nonmetals, atomic numbers, valence electrons, octet rule, anions, cations, monatomic ions, polyatomic ions, and charges of ions. Before the project, the teachers provided reading materials titled *Municipal Water Purification* and *Total Dissolved Solids* (TDS) as background information. These handouts were used as a ticket into the project; that is, the students were not allowed to go into the community if they had not read them and had not take notes on them.

In this project, the students also received a scenario of a trip to Nigeria in which they had to set up a water treatment center providing clean and safe drinking water for the people in the region. The students' missions were to come up with a way to get rid of the guinea worm as well as to come up with clear, colorless, odorless water that has few dissolved ions in it. They also had to think about how to transport all needed supplies to Nigeria. The scenario showed the students a real community issue that had been going on recently with the Jimmy Carter Center which is located in Atlanta. For the project, the teachers provided one 2L bottle of foul water

which was labeled “Nigeria” to each class. Through the project, each class brought up different procedures and methods to accomplish the mission of the project. One class followed the exact steps suggested on the handout with a little bit of tweak. Another class created their own filtration device with a regular water bottle by using charcoal and a sock. The other class used three processes for purification. At the final day of the project, the students presented the results to a representative from the Carter Center.

The teachers planned the project through which the students would apply what they had learned about the concepts of ions and classification of matter to solve the problem. In addition, they expected that the students would figure out that mixtures have different properties so that they have to use different separation techniques such as filtering, screening, chlorination, flocculation, settling, aeration, fluoridation, and distillation. Drawing on this project as a starting point, the teachers taught the concepts of suspensions, colloids, and solutions during the post-lab.

Dorothy and Lisa had been using a similar project with the title of the Foul Water Lab in which students had to clean polluted water as seven or more small groups. Actually, this lab is one of the most popular one used by chemistry teachers, as addressed in Lisa’s statement: “Chemistry teachers have been doing that for years. It’s written up in the ChemCom book. It’s just everywhere” (Lisa, Initial interview #1). Besides the community aspect, a unique feature of the *Carter Center Nigerian Trip project* this year was its connection with a real life experience. That is, the teachers tied the project with a real world problem, so that the students had a chance to think about varied issues related to health in addition to chemistry. All the worksheets and handouts used in this project are shown in Appendix E.

Moley Avogadro’s Statues Project. The third and last CBIL was implemented in November. The *Moley Avogadro’s Statues project* was a part of the Chemistry in Action unit in

which the students learned the concept of mole, different types of chemical reactions, and properties of different elements—metals, nonmetals, and metalloids. Before the students were invited to the project, the teachers provided a pre-lab assignment that addressed a lot of concepts the students would apply to complete the project (see Appendix F).

In the project, students received a scenario in which they were hired by the city of Atlanta to decide the best outdoor statue among five statue models that would stand in the Centennial Olympic Park. The sculptor Moley Avogadro designed five statues which made up different elements with different structures (The five models are shown in Appendix F). The mission of the students was to determine which statue would be most durable outside by testing chemical and physical properties of the substances used in creating the statues. Students were also given the information on the volume of each statue and prices of each substance per gram, so that they were supposed to consider the economic aspect by using that information. They were also asked to consider environmental issues. Students were allowed to make adaptations such as changing a structure.

To accomplish the goal, students tested a variety of chemical and physical properties of the substances. They came up with the ideas of measuring density; they tested hardness of metals; they reacted each metal with acid considering the effect of acid rain on the statue; they placed each substance in water to check the reactivity and solubility of it; they took a hammer and mashed metals; they exposed substances under the heat lamp all night to test the impact of heat; they tried to bend materials to see the malleability. Finally, each class chose one statue among five based on scientific evidence and presented their findings to a Board of the city director.

Again, Dorothy and Lisa had been using the same project for years as a lab activity in which students worked in small groups. This year they switched the small group lab into a

community-based project. In addition, they added a fifth statue which had not been included on the worksheet last year. All the worksheets and handouts used in this project are shown in Appendix F.

Sources of Data

To obtain an understanding of chemistry teachers' sense-making of student learning and their teaching practices through ongoing inquiry into their classroom, I used video as the primary source of data. Recent professional development research has used video as an artifact of classroom practice (Borko, Jacobs, Eiteljorg, & Pittman, 2008) because video enables teachers to slow down the teaching process to make it available for inquiry (Sherin & Han, 2004). In this study, I captured video of students' activities and teachers' instructional practices in the classroom and the chemistry teachers were asked to analyze and reflect on them through the teacher inquiry cycle by using Video Analysis Tool (VAT) (see Bryan & Recesso, 2006 for detailed description). Video clips on VAT provided participants with the source of inquiry. Chemistry teachers' reflective comments on the video clips allowed me to investigate how they made sense of students' learning and their own teaching through the scrutinized inquiry process.

For a more complete picture of classroom videotape, I observed each participant's classroom. Through direct observations, I was better able to understand and capture the context within which teachers and students interact. I wrote field notes at the time of observation, and wrote up "full field notes" which are "most complete descriptions of what occurred during the period of observation" (Esterberg, 2002, p. 74) as soon as possible after each classroom observation. Sometimes, watching video helped me to make full field notes by allowing me to catch the details of the classroom activities.

In addition, in-depth interviews with each participant were another primary source of data. In-depth interviews afford “access to the context of people’s behavior and thereby provides a way for researchers to understand the meaning of that behavior” (Seidman, 1998, p. 10). Specifically, I employed semi-structured interviews. That is, I used pre-established questions as well as follow-up questions and probes to clarify responses or to obtain additional information. The format of the interviews was relaxed, spontaneous, and open-ended, allowing for greater in-depth discussion. I took notes when appropriate, audiotaped all the interviews, and transcribed them. For the teacher inquiry project, I conducted five different types of interviews with the teachers: Initial interview, pre interview, post interview, reflective interview, and final interview.

Finally, if needed, I collected possible documents such as teaching materials, worksheets, and reading materials. In addition, email communications between participants and me were used as data. At certain times during the research a second researcher was also present. The second researcher served as a classroom observer, as an interviewer, and also as a person to examine the video using VAT with the teachers. Like me, this second researcher also took field notes and together we discussed the CBIL laboratories. These discussions could also be considered an aspect of the triangulation which is discussed in the next paragraph.

The triangulation of multiple sources of data and multiple methods for research (Patton, 2002) provided various perspectives for understanding aspects of teacher inquiry. In addition, the research findings are more likely to be trusted because of the use of triangulation of the methods and sources. This triangulation also can address problems with construct validity. In the session following, I explain how and when I gathered the above data sources through the project and what the purpose of each data source was in detail.

Procedures Related to Data Collection

I collected data from the fall semester of 2007 until the spring semester of 2008. The overall procedures of the data collection are depicted in Figure 2.

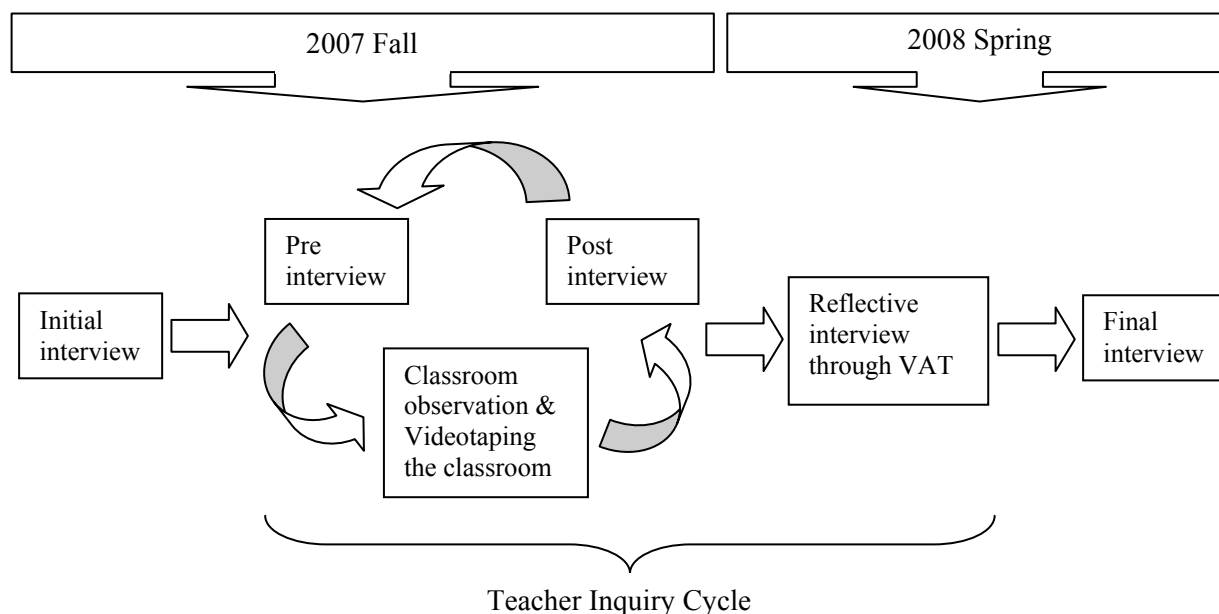


Figure 2. A graphic overview of the procedures of the data collection

At the beginning and the end of the study, I conducted interviews with each participant: initial interview and final interview. Through the teacher inquiry project, the teachers were asked to go through the teacher inquiry cycle which consists of four stages: pre interview, classroom observation & videotaping the classroom, post interview, and reflective interview through VAT. I originally planned these four stages to be combined as one cycle surrounding one observed class. However, each CBIL continued for at least consecutive seven days including pre- and post- lab, so that the teachers were not able to analyze and reflect on a videotaped class everyday due to the time limitation. Therefore, I collected video data, initial interview data, pre and post

interview data, and document data from the first three stages during the fall semester of 2007 and data related to teachers' inquiry through VAT from the last stage during the spring semester of 2008. The participating teachers implemented three CBILs during the fall semester of 2007 among which two projects—the *Carter Center Nigerian Trip Project* and the *Moley Avogadro's Statues Project*—were actually videotaped and analyzed through the teacher inquiry process. I summarize the entire timeline of data collection and sources of data in Appendix G. In the remainder of this section, I describe each process in detail.

Initial Interview

At the beginning of the study, I conducted an initial interview with each participant. The purpose of the initial interview was to understand each chemistry teacher by obtaining background information. In addition, the initial interview addressed each participant's perspective about student learning in general as well as student learning of chemistry in particular. It also provided information about their experiences of examining their own teaching practices and student learning. As previously described, the teachers decided the focus of the teacher inquiry project; they were eager to understand how the new instructional approach to inquiry, CBIL, influenced students' learning. Thus, the initial interview dealt with the questions surrounding the CBIL. The interview questions used in the initial interview are provided in Appendix H.

Teacher Inquiry Cycle (TIC)

After the initial interview, each participant was asked to go through a teacher inquiry cycle which consists of four stages. Throughout the cycle, chemistry teachers were invited to

participate in inquiry activities in order to answer the questions of “How do I know that my students are learning science in the context of CBIL?” and “How do I adopt my instructional practice with regard to student learning?”

Pre interview. I conducted a pre interview before I observed and videotaped the class whenever possible. During the interview, I asked teachers to specify the learning goal of the project. A precise and explicit learning goal is a necessary condition in order to know “what counts as evidence of students’ learning, how students’ learning can be linked to particular instructional activities, and how to revise instruction to facilitate students’ learning more effectively in future lessons” (Hiebert, Morris, Berk, & Jansen, 2007, p. 51). I also asked what they expected from their students each day as the project proceeded. Moreover, pre interview questions concerned each participant’s knowledge of students resulting from their prior teaching experience with regard to a particular concept such as students’ prior knowledge, misconceptions, and learning difficulties. I also asked how teachers would monitor students’ learning during the CBIL. The interview questions used in the pre interview are shown in Appendix H.

Classroom observation & videotaping the classroom. While the teachers implemented the second and third CBILs, I observed, audiotaped, and videotaped each participant’s classroom. Based on the class observation, I took field notes which I used for my analysis of videos as well as for the reflective interview. I also used an external microphone to audiotape the classroom, especially to pick up the teachers’ voices and any student talking nearby. In every class, I set up two or three video cameras to capture as many students’ actions and discussions as possible. For clarification, I used a classroom chart and marked the location of each video and the movement of video cameras if applicable. An example of a classroom chart is shown Appendix I. Then, I

transferred video to my computer, converted video to Window Media Video files using the PowerDirector Express software, and placed converted files in VAT using online VAT uploader.

Post interview. I conducted the post interview immediately following the classroom observation but prior to the reflective interview during which the teachers analyzed videos through VAT. During the post interview, I asked about the progress of the project, any teachable moments, teachers' awareness of students' learning, and the challenges they encountered. The post interview was based on teachers' retrospective views of the lesson, so that the information from this interview was sometimes used to compare with teachers' reflective comments through VAT later. The interview questions used in the post interview are shown in Appendix H.

Reflective interview through VAT. This interview was conducted after I finished the first phase data analysis. In the first phase data analysis, I segmented the videos into several smaller moments, which are called clips in VAT, by using the "create video clips" tool. Then, I inserted the reflective interview questions on VAT. This process is explained in the analysis section.

During the reflective interview, the teachers were asked to analyze and reflect on the clips. This interview was a kind of collaborative inquiry between a participant and a researcher in that I, as a researcher, worked with teachers to expand their thinking about the clips on VAT and looked at student learning more deeply. That is, a teacher and a researcher watched the video together and deepened the meaning of the moments. For instance, while watching a clip, the teachers were asked to answer the following question: "What was a student saying at that moment and why?", "What were you doing at that moment and why?", and "What evidence of student learning could you see in this clip?" I asked the teachers to describe the selected clip in as much detail as possible with the focus of individual student's learning. I also asked the teachers to think about how a particular instance of teaching facilitated or inhibited a particular

kind of learning. Thus, teachers tried to find answers to the question: “Were you thinking of any alternative actions or strategies at that time?” and “What will you do differently in the next lesson in light of your new understanding?” Although the general questions were predetermined by the researcher, teachers were thinking aloud when they watched the clips during the whole reflective interview process. In this regard, the format of the reflective interview was clinical (Clark & Peterson, 1986) because the actual questions varied from interview to interview depending on the substance of the video clips. The pre-established interview questions are shown in Appendix J with the video analysis results of the *Carter Center Nigerian Trip Project*.

Final Interview

At the end of the study, I conducted a final interview with each participant. The final interview provided questions that encourage teachers to reflect on the implementation of CBIL, their awareness of students’ learning during the CBIL, their experiences of teacher inquiry processes, and future intended use of VAT. The interview questions used in the final interview are shown in Appendix H.

Data Analysis

I spent an average of 20 days with each participant through this study. The whole process resulted in the accumulation of a total of 70 fifty-minute-long videos, almost 250 pages of interview transcripts, and other documents such as teaching handouts and my field notes. I analyzed the data collected in two phases. During the first phase, I analyzed the videos through VAT. Then, I analyzed the interview data and other documents in the second phase. Figure 3

gives a picture of the two phases of data analysis process along with the data collection procedures.

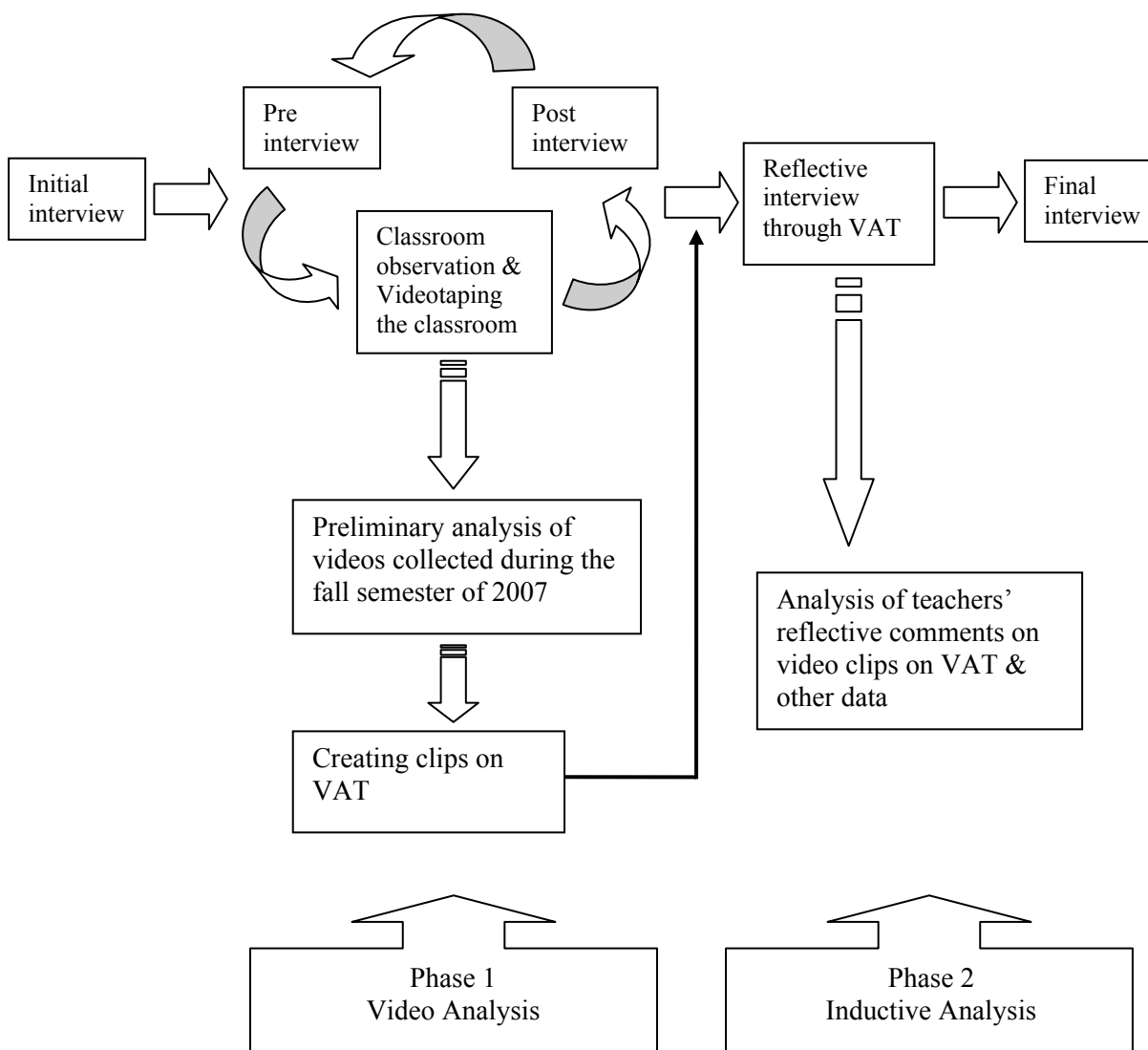


Figure 3. A graphic overview of the procedures of data analysis

First Phase: Video Analysis

The first phase of the data analysis involved my analysis of the video data. The focus of this study was not my understanding of students' learning or instructional practices but the

participating teachers' sense-making of their students' learning and their own teaching practices through the teacher inquiry process. Along this line, someone might ask why the video data were analyzed by me, the researcher, and not by the teachers. However, the teacher inquiry project is not the same as teacher research in which a teacher is supposed to be a principal investigator of the research. That is, in this study, the participating teachers and the researchers collaborated with the goal of generating conditions for teachers' expanded understanding of the classroom in which the CBIL was implemented. The first phase analysis helped the teachers to investigate their classrooms by reducing the massive amount of video data into a pertinent amount for them. In addition, I was able to obtain a more complete picture of the classroom videotaped through the video analysis process.

I began to analyze the videotaped classes during the fall semester of 2007 while I was collecting the data. Whenever I obtained the video as a digitized format on VAT, I watched the video and took notes about what happened in that videotaped classroom as a preliminary step of analysis. In this process, I focused on the following aspects of the classroom in the context of CBIL: when and where students expressed their ideas, understanding, learning difficulties and how and when teachers responded to students. To do this, I specially focused on interesting conversations that students had with one another or with a teacher, questions that students brought, unusual or unexpected methods that students used, or responses that students gave to questions, peers, or teachers. When needed, I transcribed students' discussions and teachers' talks on the videos verbatim.

Based on this preliminary analysis, I identified several key segments from the video and created clips on VAT. By watching the sequential clips on the video of each class, viewers (the teachers and researchers) were able to understand what happened in that class during the CBIL

project. That is, those clips produced an event map (Green & Wallat, 1981; Kelly & Crawford, 1997; Smithenry & Gallabher-Bolos, 2008) that included a timeline of identifiable moments of the classroom. Then, for each clip or a group of clips surrounding one event, I constructed questions for the reflective interview. These questions were inserted into VAT by using its annotation feature. The results of video analysis of the *Carter Center Nigerian Trip project* and the reflective interview questions associated with the clips are presented in Appendix J. The outcomes of the first phase data analysis were used for the reflective interview during the spring semester of 2008 as shown in Figure 3.

Second Phase: Inductive Analysis

The second phase data analysis involved my analysis of the interview data and document data. The preliminary analysis began while I was collecting data as I transcribed the interview data verbatim. However, I carried out comprehensive data analysis during the spring semester of 2008. To do that, I conducted inductive analysis utilizing grounded theory approach and constant comparative methods (Glaser & Strauss, 1967).

The purpose of inductive analysis is to “discover important patterns, themes, and interrelationships” in order to understand the meanings that exist in the phenomenon being investigated (Patton, 2002, p. 41). During the second phase analysis, I allowed the research findings to emerge from the frequent, dominant, and significant themes inherent in raw data without the restraints imposed by a particular theory or research. Grounded theory (Glaser & Strauss, 1967) seems to be a generic synonym for any kind of inductive theorizing in that the process of theory building is based on observation of the data themselves itself. The word “grounded” itself well expresses this idea. Strauss and Corbin (1990), themselves, articulated the

inductive features of grounded theory as follows: “A grounded theory is one that is inductively derived from the study of the phenomenon it represents. That is, theory is constructed, developed, and provisionally verified through systematic data collection and analysis of data pertaining to that phenomenon” (p. 23). Charmaz (2002) also pointed out that grounded theory methods offer a set of inductive steps that guide the researcher.

With the coding procedures (Strauss & Corbin, 1990) and the analytical framework offered by grounded theory in mind, I analyzed the interview data in several steps. The first step was “open coding,” sometimes called “initial coding” (Charmaz, 2000, 2002). Open coding was defined as “the analytic process through which concepts are identified and their properties and dimensions are discovered in data” (Strauss & Corbin, 1990, p. 101). For this, I carefully read and reread through the transcription several times for the accuracy of my interpretation as suggested by Coffey and Atkinson (1996). While reading, I played back the audiotaped interviews as well as classroom videos associated with teachers’ reflective comments. This process really helped me because it allowed me to recall as much as I could about the details of the participant and classroom situation. I developed open codes using line-by-line analysis (Strauss & Corbin, 1990) and simply wrote my codes in the margins of the transcription. In doing so, I used both *in vivo* codes as well as researcher codes. This rather laborious and time-consuming process resulted in the generation of many possible initial open codes on the transcriptions.

Next, I went back to the transcriptions and reduced overlap and redundancy among the open codes by identifying their similarities and differences. In addition, I clustered them into broader categories by comparing and contrasting them. I gradually modified and refined the preliminary categories through the analysis process. The initial coding categories were developed

based on each interview transcription with each participant as a separate case. Then, I began to conduct cross-case analysis in search of patterns that cut across individual cases (Merriam, 1998; Patton, 2002). The common patterns across the transcripts and participants reduced the number of significant categories and subcategories.

The next step of my analysis was “selective coding” (Strauss & Corbin, 1990), called “focused coding” (Charmaz, 2000, 2002), which allows researchers to construct “a set of relational statements that can be used to explain, in a general sense, what is going on” (Strauss & Corbin, 1990, p. 145). In this step, I tried to assign frequently reappearing preliminary categories and subcategories to the transcription. This attempt to assign the categories to the data was actually a test to find out the usefulness of the categories created. During this test, the coding categories can be modified, new categories can be developed, and old ones can be discarded (Bodgan & Biklen, 2003). Using similar process, Harry, Sturges, and Klingner (2005) also tested their themes in order to observe evidence of developed themes in the data and to find additional themes.

Through this process, I began to ask “what are the themes embedded in the conceptual categories and in my data?” That is, I tried to treat the various category clusters in a selective manner and to decide how they relate to each other and what stories they tell, based on my assumption that each category may have links or relationships with other categories. Harry et al. (2005) called this coding stage the “thematic” level in which the researcher begins to build a theory. Consequently, I developed several themes from the task of summarizing the content of predominant categories. These themes are discussed in the next chapter.

One of the fundamental methods I adapted through the whole second phase analysis was a constant comparative method. This method aims to generate substantive codes, categories, and

their properties, and finally theoretical constructs which form a theory that encompasses as much variation as possible (Hutchinson, 1990). When using constant comparison strategy:

The researcher begins with a particular incident from an interview, field notes, or document and compares it with other incident in the same set of data or in another set. These comparisons lead to tentative categories that are then compared to each other and other instances. Comparisons are constantly made within and between levels of conceptualization. (Merriam, 1998, p. 159)

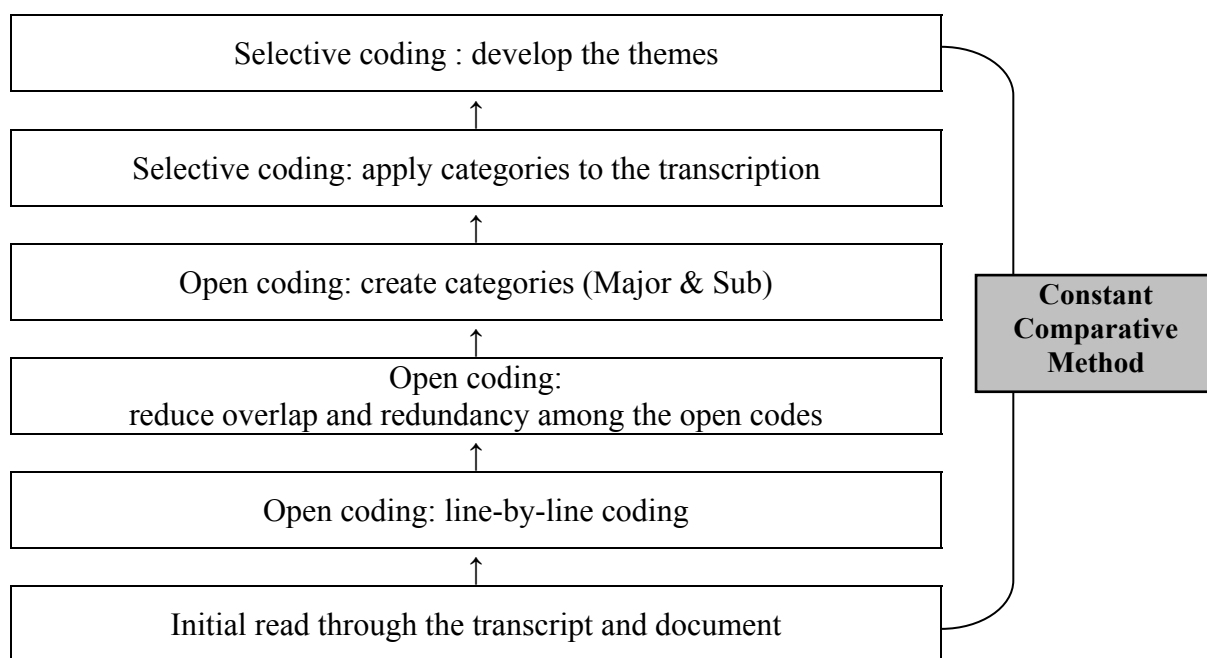


Figure 4. A graphic overview of the procedures of second phase data analysis

By being sensitized to similarities and differences of the data, I constantly compared elements such as basic incidents, emergent codes, categories, and themes. Hutchinson (1990) explained that the basic properties of a category or construct are defined by comparing similarities whereas coding boundaries are established and relationships among categories are clarified by comparing

differences. The process of constant comparison was embedded in the whole process of data analysis during the second phase. Figure 4 gives a picture of the second phase data analysis procedures.

Summary and Preview

Thus far, I have provided a description of the methodological framework which guides this study along with a rationale. Situated in a constructionist standpoint, I employed a qualitative case study approach in order to investigate three chemistry teachers' sense-making through the teacher inquiry project. Given the fact that the participating teachers would like to know the impact of the CBIL, I described the instructional context of the CBIL in detail. I used multiple sources of data from multiple methods of data collection such as videos, classroom observations, in-depth interviews, and documents. Then, I analyzed the data collected in two phases: video analysis through VAT in the first phase and the interview data and document analysis in the second phase. For the second phase analysis, I conducted inductive analysis utilizing a grounded theory approach and constant comparative methods. I present the findings resulted from these analysis procedures in the next chapter.

CHAPTER IV

FINDINGS

Chapter Overview

The purpose of this study was to examine the processes and outcomes of chemistry teachers' inquiry into their own classrooms in the context of the Community-Based Inquiry Lesson (CBIL), the community-based, open-ended inquiry instruction used in a high school. As described previously, students' classroom activities and teachers' approaches to instructional tasks were videotaped and analyzed through Video Analysis Tool (VAT).

Given the opportunity to participate in the teacher inquiry project, three chemistry teachers—Dorothy and Lisa who were experienced, and Cindy who was the first year teacher—scrutinized their CBILs through VAT. Teachers' questions for the teacher inquiry project—To what extent will the CBIL work? How will the CBIL impact students' learning in science?—were “researchable” in that those questions were “real, classroom-based, open-ended, of interest to the teacher, negotiated a tension, and pertained to teaching and learning” (Barnatt, Cochran-Smith, Friedman, Pine, & Baroz, 2007, p. 26). Thus the teachers' interests in research were merged into the goals of the overall project to create the set of research questions discussed here. This chapter addresses three research questions: (1) how do chemistry teachers make sense of students' learning of science? (2) how do chemistry teachers make sense of their approaches to instructional tasks with regard to student learning? and (3) How do chemistry teachers adapt and use teacher inquiry practices through VAT?

Chemistry Teachers' Sense-Making of Students' Learning

In this section, I address the way chemistry teachers became aware of what and how their students were learning within the CMIL. The findings suggest that through the teacher inquiry project using VAT, chemistry teachers could make sense of (a) students' hidden rationales behind their hands-on activities, (b) students' misconceptions *in situ*, more importantly a given student's particular misconception, (c) students' cognitive engagement, and (d) students' social interactions.

Window to See Students' Rationale behind Their Hands-on Activities

One of the difficulties that the teachers encountered while implementing the CBIL was the difficulty of catching what every student was saying and doing. Given the unique nature of the CBIL where the students were running the classroom, the teachers could not anticipate which direction the class would move. For instance, in the *Carter Center Nigerian Trip Project*, Dorothy's class divided themselves into eight groups with each trying to test different processes (e.g., filtration of water). Students kept discussing their ideas all around the classroom and moving around to find appropriate lab equipment. Some of them were sitting in front of the computer to do research or to prepare the PowerPoint presentations. These students went back and forth to collect data from each lab group. This was the picture that took place in the everyday classroom of the CBIL. At a glance, it seemed more chaotic than it was. Lisa depicted those aspects of CBIL in this way: "The class is a buzz with activity - with freedom and responsibility" (Lisa, Pre / post interview #8).

The role of the teacher recommended by Gallagher-Bolos and Smithenry (2004) presented further difficulties to the teachers who participated in the project. The authors

suggested that teachers in the CBIL provide minimal guidance to the students and take observational notes about what students were doing and saying. Dorothy, Lisa, and Cindy decided to accept this role at the beginning of the semester. However, as the sequence of CBIL events proceeded, they realized that modeling the role of taking notes hindered their sense-making of students' learning during the project even though it was intended to provide feedback to the students. This view is reflected in Lisa's statement:

Practically speaking, it was very hard to script sitting in one place in the room...

You've kind of got to sit down to type on your computer right, so it's hard to know what's going on in all aspects of the room. (Lisa, Final interview #14)

The above issue, in the context of wide open-ended inquiry teaching, was resolved while the teachers were going through the teacher inquiry cycle (see page 66). In every class, two or three video cameras were set up to capture as many students' actions and discussions as possible. The analysis and reflection of these videotaped CBILs provided the teachers with more chances to see and hear their students. Particularly, the teachers were able to discern students' creative ideas about their own lab designs, which were easily missed during the high level of activity in the classroom. The following two excerpts best illustrate how teachers came to perceive students' hidden rationale behind certain hands-on activities through close examination of video clips.

In Lisa's enactment of the *Carter Center Nigerian Trip Project*, the students set up the lab procedures as a result of whole class discussions on the first day of the project. The procedures included screening, filtering, flocculation, setting, and aeration. In order to filter dirty water, the students decided to use filter paper. However, it caught Lisa's eye that the students were using a brown paper towel for filtration. On the final PowerPoint presentation, students

mentioned that they used a brown paper towel in order to get rid of oil in water, and Lisa thought it was a good idea because of its affordability in Nigeria. During the post interview after the project was over, Lisa asserted why students were using a brown paper towel in the following way:

A kid just happened to discover it I think. The funny thing is it [using a paper towel] might have been because they hadn't remembered about the filter paper. I don't know if it was because they were lacking in a lab technique from before or whether they actively thought, umm, I wonder if this will do something. I'm sure there was someone in the class that remembered the filter paper; they were just trying to figure out a quick way. The filter paper might have been taking a long time and they just said – "What about this paper towel?" It's funny because sometimes it is the kids that aren't really super academic. The rest of them probably thought, "What the heck are you talking about? That's stupid." And then they did it and it kind of worked. That was kind of funny. I wouldn't have expected it. It was very practical and inexpensive, so I was proud of them for however they discovered it for really paying attention to their results and saying, this isn't very technical but it is working. (Lisa, Pre / post interview #5)

Lisa's claim demonstrates that she initially attributed the students' use of a paper towel to their lack of lab skills, tendency to get a lab done quickly, or nothing more than a mere accident.

Later on, however, when Lisa went through the reflective interview and scrutinized this project through VAT, she was astonished watching the following video clip:

Linda: I was looking for, like, how to separate oil in water on the Internet, and it said something like adding salt helps to separate oil and get rid of it quicker but I don't think we're gonna need to add anything to it.

Lucy: No.

Linda: What I was thinking is, you know how, if you have a paper bag or a paper towel or something and you get potato chips or something and the grease spreads out on it but doesn't go through it? What if you filtered it again and put a paper towel or something ...

Nancy: Like on top of the beaker?

Linda: Yeah. Like layers of paper towels.

Grace: Oh, that's a good idea!

Lucy: Or, just put it inside here [a funnel]...

(Video_V3 Lab, 10/03/2007)

This video excerpt revealed that the students possessed a clear-cut rationale for using brown paper towels based on their real life experiences. While conducting the experiment, the students realized that there was oil in the given water, but couldn't figure out how to get rid of it because oil still existed after initial filtration with a filter paper. Then one of the students, Linda, who took a role of communicator, came up with the idea of using a brown paper towel, which was grounded on a phenomenon that she had observed in daily life.

Reflecting on this moment, Lisa could make sense of why her students used a brown paper towel instead of a filter paper which was expected to be used. Actually, on this video clip, it was captured that Lisa passed near the lab group when this discussion occurred. Although it is

obvious that she always makes a great effort to perceive much about her students' learning through close observation of the classroom, this short segment reveals that a great deal more can be hidden in the context of open-inquiry lesson. Without the chance to revisit this event through the teacher inquiry project, she might not have figured out the underlying reason behind the brown paper towel. In addition, the opportunity to hear students' rationale allowed Lisa to modify the way she responded to this event. That is, she could delineate the cause of students' action based on evidence.

Another example was captured in Lisa's class when the *Moley Avogadro's Statues Project* was implemented. In order to decide which statue would be the most suitable outside, the students was supposed to consider the environmental effect on the statue. When the students discussed what tests they would conduct at the beginning of the project, one student brought up the idea of testing the influence of bird feces on the statue since the statue would be standing in the Olympic Park. The whole class was laughing, but they decided to accept that idea. The next day, the students made a solution with potassium salt and phosphate salt, which was considered to be similar to the properties of bird feces. They put diverse metals into the solution to test how metals would react with bird wastes. During the post interviews on the first and second day of the project, Lisa exhibited surprise with this idea:

Bird poop! They even talked about it because bird poop can definitely break down the statue. I thought that was satirical. (Lisa, Pre / post interview #7)

They tried to figure out bird poop... I thought that's interesting. (Lisa, Pre / post interview #8)

The first time that Lisa heard the students' idea of bird waste; it was just fascinating to her.

However, the video nicely captured the moment in which one student explained why they should consider bird wastes to other students.

Stacy: Let's start with the bird poop one...

Becky: So can we have our potassium ... or whatever it's called?

Stacy: Okay, guys for the bird droppings, what we're gonna do is, if we can, we're gonna heat the water, not to boiling or anything, just heat it up so it dissolves faster but also the bird poop...

Students: Why?

Stacy: So it dissolves faster and because when it comes from birds' bodies it's not cold. So....

Students: (Laughing) Are you sure?

Amy: Maybe it can cool down all the way down.

Grace: We need to modify a procedure... and write down more specific... I don't know the exact amount.

Amy: So it will be 20ml of water... and potassium salt and put it into water?

Grace: You know, there was a bridge in Mississippi... because the bird poop dried and the salt got... you know there is ammonia...it mixed with the salt in water. And the bridge collapsed. I was like that's amazing. Isn't that awesome?

(Video_V2 Lab, 11/09/2007)

This video excerpt showed how Grace brought up the idea of testing the impact of bird waste on the metals. Lisa reflected on this moment and said “I thought it was kind of novel and cute with the bird poop, but there really was a rationale for that” (Lisa, Reflective interview #12).

As illustrated so far, the teacher inquiry project played an important role for teachers in that it broadened their sense of making students’ thinking visible. In particular, the teachers confessed how difficult it was to recognize what was going on in the classroom in which students had so much freedom. However, as they went through the teacher inquiry cycle (see page 66), they were able to actually see and hear student’s creative rationales behind their actions, which might not have been discovered in more student-directed lab work. That is, the process of teacher inquiry through VAT provided teachers with a window to approach their students’ thinking. A later section of this chapter will discuss how teachers extended the uncovered students’ ideas into their new ideas for a future lesson.

Whose Misconception?

Based on the constructivist perspective of learning, researchers have conducted extensive studies exploring students’ knowledge, thinking, and ideas in order to help students learn science more effectively in a variety of science discipline areas (eg., Champagne, Klofer, & Gunstone, 1982; Driver, Guesne, & Tiberghien, 1985; Driver & Easley, 1978; Gunstone & White, 1981; Nussbaum & Novak, 1976; Osborne & Freyburg, 1985; Posner & Gertzog, 1982). These studies mostly focused on students’ prior knowledge, misconceptions, and conceptual changes, with the common findings that learning science is improved when teachers (1) focus on the knowledge that students bring into science classrooms, (2) use this knowledge as a springboard for instruction, and (3) monitor students’ conceptual changes (Appleton, 1997).

Interestingly, all three participant teachers were well acquainted with the term “misconception” and emphasized the awareness of their students’ misconceptions in planning and implementing the CMIL. For instance, when they planned the second CMIL, titled *Carter Center Nigerian Trip Project*, Dorothy described what kind of misconception she considered as one that her students might have: “One common misconception that students often have is that they can filter, like, salt water and it will take the salt out” (Dorothy, Reflective interview #7). This identified misconception was reflected in their CMIL in which one of the objectives was for the students to obtain water with few dissolved ions in it. That is, Dorothy and two other teachers wanted their students to think about the fact that ions would still be present in the water after filtering dirty water so that they would come up with processes in addition to filtering.

In addition, one of the main goals of all three teachers while doing inquiry lessons was to identify and correct students’ misconceptions. Cindy addressed how she was trying to achieve this goal:

I definitely play an active role when they are working, just clearing up misconceptions. ... When I hear that it’s something that’s completely incorrect, like a statement of a concept or process, I make sure that they know. I clear up those misconceptions. (Cindy, Initial interview #1)

Similarly, Lisa mentioned that one of the reasons she was keeping journals while doing the project was to record, and therefore accumulate knowledge of, students’ misconceptions: “There are many reasons that I wrote down everything they said; that was my job, to script. A lot of it was to figure out the areas where they had misconceptions or just had questions” (Lisa, Final interview #14). Moreover, she considered inquiry to be one of the best ways to detect students’ misconceptions:

That's why I love inquiry. I noticed that when we were doing the inquiry, I can't tell you how many misconceptions are identified that wouldn't be otherwise.

When you don't give kids directions... Sometimes I would catch the misconception and I would be able to say, "Oh~ I see why you have been doing it that way." So I love it for that. (Lisa, Initial interview #1)

It was evident that the teachers conceived that identifying misconceptions was important for students' learning science. In addition, they, especially Dorothy and Lisa, were able to anticipate possible misconceptions in a general sense based on their years of teaching experiences.

The teacher inquiry project through VAT spurred the teachers to be aware of students' misconceptions by allowing them to actually see students' misconceptions *in situ*. Specifically, the teachers were able to pinpoint a particular student who held a particular misconception because the video clips on VAT provided accurate and specific evidence. In other words, they could make a comment such as "*s/he* had this misconception" instead of "*they* had this misconception." Teachers' sense-making of individual students' misconceptions occurred when they analyzed and reflected on their videotaped CBIL through VAT during the reflective interview.

The following video excerpt was captured on the second day of the CMIL lesson titled the *Moley Avogadro's Statues Project* which was the third CBIL in Dorothy's class. In this class, the students discussed, as a whole class, how to test physical and chemical properties of diverse substances such as metals and non-metals that would be used in creating the statue. As a product of this classroom discussion, students came up with ideas about testing metals' reactivity with acid rain as well as water, hardness, density, and the effect of temperature on metals. This video

clip showed students' discussion about density. Sam was one of the class managers during this project.

Sam: Density is not gonna change. Density will not change because it's still the same thing and the density is the same for every metal at all.

Anna: How is the density the same? If it's...

Sam: The density of the material is always the same.

Lara: But, if there is less mass, then this would be less density.

Sam: No, it's not because it's the mass out of the volume. If less volume, it's gonna be less mass. The density of every material is always the same. Look in your book. It says density. It's never gonna change. If you create less volume, it's gonna be less mass. The density would never change. Ever.

Anna: How does it not change?

Sam: Because if the volume goes down, the mass goes down as well. So, those would balance each other out, as always the same.

Molly: Same portion, it's a ratio.

(Video, 11/08/2007)

As illustrated in their dialogue, the students, Anna and Lara, did not understand why density is always the same. The class manager, Sam explained first that density is an inherent property of substances, and then clarified the concept of density in terms of mass and volume. It was a challenge for Sam to explain it to his peers, but then he made a connection between the lab

activity and the textbook content. This clip only presented a part of their discussion, and after more than five minutes of discussion, Anna and Lara finally accepted and understood Sam's explanations.

While watching this video clip through VAT, Dorothy was able to discern who had a misconception and who had a scientific conception at a glance. She reflected on this clip in this way:

I loved the discussion on density when the kids got involved in that because that's a very big misconception that density changes. The fact that Anna and Lara were saying "The density does change," Sam and Molly were saying "No, it doesn't. The density is always constant." They worked it through, and Sam was being very patient when he was talking to Anna. So, she went and looked up in her book. I thought they were just going-on; content-wise that was really wonderful.

(Dorothy, Reflective interview #9)

This account above reveals that a closer look at students' discussion provided Dorothy with evidence that enabled her to articulate each individual student's thinking in relation to the concept of density. Through the discussion, the students fortunately solved the conflict themselves. Otherwise, Dorothy might have devised a scheme to help Anna and Lara. That is, teacher inquiry has the capacity to inform teachers and the potential for them to adjust their instruction based on individual students' misconceptions and ideas.

The segment below from Cindy's class and her inquiry represents this potential. On the second day of the *Carter Center Nigerian Trip Project*, the students discussed different means of accomplishing filtration such as a carbon filter, sand filter, coffee filter, and a filter paper. One of the students asked what a carbon filter was, so the teacher brought a bag of carbon powder. As

soon as Cindy showed it to the students, one boy, Tom uttered, “I thought carbon is a gas” (Video, 10/02/2007). Tom was sitting right in front of the teacher’s desk, but the class managers and teacher did not pay attention to what he was saying in the course of the project. This moment was, however, captured by one of the videos set up in the classroom.

Later on, when Cindy went through the reflective interview, Tom’s voice stood out for her. In the reflective interview, she expressed her disappointment caused by Tom’s misconception:

As far as the gas thing, that’s disappointing. I would hope that since we’ve gone over it enough, that he would know that it [carbon] is not... We’ve talked about which elements are gases and we went over the periodic table. They can even just look at the colors [on the periodic table] and figure it out. One of the classmates next to him said I can’t believe you... He gave him [Tom] a hard time about saying that carbon is a gas. (Cindy, Reflective interview #11)

From her comment, it becomes clear that scrutinized inquiry through VAT allowed Cindy to figure out that Tom, *not they*, had a misconception about the state of carbon, which could not be identified without watching the clip. Moreover, reflection on this segment led Cindy to think about the origin of Tom’s misconception: “I don’t know why he would think that. Maybe he’s thinking of CO₂” (Cindy, Reflective interview #11). Furthermore, Cindy sought to find a way to “clear up” Tom’s misconception even though she was not able to cope with this situation in the classroom:

Since this is only my first year teaching, I had not ever really thought about my students having that misconception before nor have I heard that before. My hope is that the student had a momentary lapse and just wasn't thinking when he made

that statement. In case that is not the situation, I would mention some of the things that I actually teach second semester about carbon; its uses and the different structures carbon can make, i.e. the difference between graphite and diamond.

(Cindy, email discussion)

The above statement implies that Cindy developed ideas about doing things differently at a later time, even though she did not have a chance to take that action during this semester. In addition, she, as a first year teacher, came to think about the possibility that students are inadvertently saying things which may not have any relationship to what they know or believe.

As discussed so far, chemistry teachers could make sense of their students' misconceptions *in situ* through VAT by studying the implementation of CBIL in their classrooms. More importantly, the inquiry project provided teachers with a foothold from which they were able to identify a student's particular misconception and to step forward with tailored instruction based on each individual student's learning needs. As criticized by Rodgers (2002), teachers' comments such as *they* have misconceptions, "depersonalize" students because each student has his or her own level of understanding of scientific concepts. Rogers (2002, p. 8) paralleled the fact that some teachers perceive students' learning collectively with the fact that some artists paint "with broad strokes and primary colors." The teacher inquiry process facilitated teachers to see beyond *they* and to ask "whose misconception?" which allowed them to be more attentive to individual students' learning of science.

Increased Awareness of Students' Cognitive Engagement

As discussed above, the teacher inquiry project helped the teachers identify individual students' misconceptions and students' rationales related to their actions within the hands-on

activities. In addition, through the scrutinized inquiry using VAT, teachers had opportunities to ponder how their students were cognitively engaged in the CMIL in three ways.

First of all, the teachers gained understanding of students' cognitive engagement by looking at the way they brought everyday life experiences into the CBIL. In the *Carter Center Nigerian Trip Project*, Dorothy, Lisa, and Cindy's three classes that I observed all came up with the idea of distillation in order to get rid of the guinea worm and to obtain water from which dissolved ions had been removed. However, this idea did not burst fully developed from one student but was a co-construction of understanding. For instance, in Dorothy's class, during the whole class discussion of how to clean the water, one of the classroom managers, Anna, remembered what she watched on the Discovery Channel. As soon as she mentioned, "Do you know the guy who... *Man vs. Wild?*", most of the students got excited and began to talk about the survivalist man on the television program. Anna continually referenced one episode in which the man was in the desert and how he obtained clear water from his urine. Then, one boy (John) explained the way he collected water to survive in the harsh desert climate. John's explanations included reference to aspects of the concepts of evaporation and distillation even though he did not use those terms. Based on the same method that he watched on the TV, John suggested putting the Nigerian water in the larger bowl, placing a smaller cup inside of the larger one, covering the top of the larger bowl, and then setting it outside. Another student disagreed with his idea with the reason that the temperature was not hot enough for evaporation. Finally, the other students said "Let's boil it." In this way, the students came to think about boiling dirty water. As they went through the lab activity, students became concerned about losing water through boiling, and finally they distilled water in realizing that the distillation apparatus would be effective for retaining the amount of water even though it was boiling.

During the teacher inquiry project, Dorothy reflected on several clips on VAT related to the topic of boiling and distillation. By doing so, she could actually “see how many of them have experiences [relevant to the activity] and how they can relate it to what they’re learning now” (Dorothy, Reflective interview #7). Furthermore, reflecting on these segments gave Dorothy a venue to make sense of how students actively engaged in reconstructing the series of ideas to design their experiment:

I thought that was so awesome because... They’re using their knowledge and pulling it together and relating it. That’s awesome. Some of them are really into the survivor shows and so how they would do the water. I didn’t know those kinds of shows were on. These are not things we had talked about. It’s so cool the way different people can participate and bring in their experiences and feel like they’re really contributing... So, boiling becomes now distillation, instead of just boiling.

(Dorothy, Reflective interview #7)

That is, Dorothy was able to make sense of how students utilized what they had known in the new context, developed their ideas, and constructed their own meaning about the concept of evaporation and distillation.

A similar discussion around the issue of boiling occurred in Lisa’s *Carter Center Nigerian Trip Project* lesson. In this class, the students already had the idea of boiling water at the beginning of the project, compared to Dorothy’s class in which the students’ idea of boiling came through the discussion. However, they could not figure out how to do it efficiently. Thus, some of the students argued about different ways to boil dirty water. The following transcript from a video excerpt captured a part of their discussion:

Amy: When you boil it, it's gonna evaporate.

Stacy: Should we evaporate it when you boil it, and then put like a cover or screen over it so it catches the evaporation?

Lucy: The condensation?

Stacy: Yeah. It evaporates and then condensates.

Jeff: Put a sponge or like..

Stacy: And then put like a bowl under it, so it catches it.

Lucy: What if we put it in a closed case and put it in a microwave?

Jeff: You can put a sponge.

Lucy: What if we microwave it? I mean...

Stacy: Then it will go all over the microwave wall.

Amy: Oh yeah, let's microwave it.

Stacy: But, if it evaporates...

Lucy: If you put it in a closed container with a little bit of stuff on the top.

Stacy: Then it will explode.

Lucy: When you make chicken soup, you put a covering over the top of the chicken soup and you put it in the microwave. You take it out. And then just...

Stacy: How you hold the top?

Lucy: I just use Saran wrap.

(Video_V3 Lab, 10/03/2007)

The dialogue captured within this video segment illustrates that the students brought up their personal experiences such as using a sponge and microwave and were engaged in negotiation their ideas by inferring, questioning, clarification, and elaboration.

Actually, Lisa was not able to overhear this conversation while it was going on in this lab group. Thus, she confessed, “It would have been nice to have known that that conversation went on, so that I could have really harped on that” (Lisa, Reflective interview #12) when she reflected on this segment. Through the inquiry, she identified not only what kind of life experiences the students brought up in the CBIL but also how they approached the concepts of evaporation and condensation: “I love all the science that I’m hearing. Actually this would have been neat to see because when I do post-lab I love to praise them for really innovative ideas” (Lisa, Reflective interview #12). Moreover, Lisa realized that students’ cognitive engagement through their own experiences led them to understand deeply not only the concept but also the method of distillation. Lisa’s reflection addressed this aspect well:

They are creating equipment. They’re all thinking about what needs to happen, even Jeff. He’s just trying to figure out a technique to get it out and said “Put a sponge on top.”... I love it that, even though like the whole [discussion of] “You know how the microwave gets all wet.” “Oh yes, let’s microwave it.” It’s so great that they have to go through that first, because then when I do show them this [distillation apparatus] is what some people have come up with and see how it works; then they get it because they’ve already been going through those steps in their head... So, when you show them the tube, they are like, “Oh, boom, I got it” rather than “What’s that...?” It just preps them... The fact that in these three days they’ve had to wrestle with all this stuff; then when one person finally comes up

with it or when you show them something, they are like, “That makes a lot of sense.” They have something to hang it on. (Lisa, Reflective interview #12)

This statement implies that Lisa became conscious about the fact that students’ discussion based on their own experiences provided scaffolding to their own learning. The above two instances exemplify the way teachers made sense of students’ cognitive engagement through inquiring into how students applied personal life experiences into the CBIL.

Second, the teachers understood students’ cognitive engagement by examining the way students transferred what they had learned in the previous lesson to the new situation. Most of this transformation perceived by teachers occurred in terms of the students’ experimental design. For instance, the VAT video captured evidence that the students frequently talked about dependent variables and independent variables when they solved a problem in the *Carter Center Nigerian Trip Project*. This happened in all three teachers’ classrooms. When the teachers analyzed and reflected on this second CBIL, they realized that students modeled what they had performed in the first CBIL, the *SpinachCo Project*. In the first project, the students had to consider different factors (independent variables) that would impact on the amount of iron (dependent variables) in spinach. Accordingly, when students carried out the second project, they were trying to transfer what they had done in the first CBIL in terms of experimental design. Dorothy’s statement illustrates well that she was able to think about this aspect of learning:

In the *SpinachCo* lab, [an] independent variable and [a] dependent variable is what we’re looking at. In this lab, with what we’re doing here, the independent variable is the different processes and the dependent variable could be the color, clarity, amount of water, etc. So, they brought in the things that they should have

learned from doing the *SpinachCo*. That's great. (Dorothy, Reflective interview #8)

An incident in Dorothy's class also illustrated that the students elicited what they had learned from the previous lesson and applied it to the current project. One of the missions that the students had to achieve in the *Carter Center Nigerian Trip Project* was to make clear and colorless water from the given foul water. In Lisa and Cindy's classes, the students did a visual test to check the clarity and color of the final water that they obtained. In contrast, the students in Dorothy's class requested to use a spectrophotometer to test these properties of water. Reflecting on how the idea of using a spectrophotometer had emerged in the class session, Dorothy was pleased with the fact that students were able to make a connection between what they had learned and what they were learning:

In the Spinach lab, we used a spectrophotometer to find how much iron was in it, based on how deep the red color was when the iron reacts with the thiocyanate. I think they were the only class that thought to use the spectrophotometer because we had used that in a previous lab... Realizing that if you have the different colors, you could test the color each step that way. That was a very, very good for transferring that knowledge. That was very exciting. (Dorothy, Reflective interview #8)

Overall, the teacher inquiry project enabled the teachers to closely look at students' discussion and performance in the CBIL, which in turn, helped them to articulate how students transferred their learning outcome from the previous lesson to a new lesson.

Finally, the teachers made sense of students' cognitive engagement by inquiring into how the students extended their scientific ideas to interrelated concepts. One example below gives us

a glimpse of how Lisa gained a chance to ponder students' knowledge expansion in the CBIL. The excerpt was captured in her *Carter Center Nigerian Trip Project*. On the third day of the project, one group of students (Lucy, Grace, and Susan) conducted the process of aeration. They discussed how to aerate water and decided to use a small pipette in order to blow air into water. One of the students in the other group, Stacy, passed by this lab table and noticed that their way of aeration was different from what she had thought was appropriate. Thus, Stacy explained what aeration was, why the use of a pipette was inappropriate, and how this group could adjust their actions. However, one of the group members, Lucy, was convinced that she was right instead:

Grace: What is aeration supposed to do?

Lucy: I think it's bacteria.. ...

Stacy: Wait, you guys. That's not gonna work that well. Hey Lucy, that's not gonna work that well because the filter... If you can squeeze all that stuff up, it's gonna go right back down. With the spray bottle or something, the stuff can't go through the little holes that the water goes through to spray. The hard stuff goes up the pipe to be sprayed, but it doesn't fit through the spray holes.

Susan: You send the water up to get to the air, not the air into the water?

Stacy: Yeah. That's not gonna work because if you take that stuff up and you push it back down, nothing's gonna be cut [removed]. That's not what you do. You spray it.

Stacy: That's not aerating because aerating is supposed to get it out.

Lucy: Aerating is supposed to get rid of the organic compounds... There's supposed to be some type of bacteria that's aerobic, and it's supposed to eat it [organic compound]. Well, I don't know if there are bacteria.

Stacy: Well the aeration says they spray it [water] into the air.

Lucy: You spray it through the air?

Stacy: Yeah.

Lucy: I thought... Then why is there a... tank that it shows in the picture? Is that just to see viewing?

Grace: What is it supposed to do?

Lucy: The oxygen is supposed to work with the aerobic bacteria... and then the aerobic bacteria eat any other organic substances in the container itself.

Grace: Okay

(Video_V2 Lab, 10/03/2007)

In this discussion, Stacy focused on the way to get rid of particles in water based on the method that was given in the reading assignment while Lucy focused on the biological aspect of aeration.

During the interview, one of the researchers casually asked Lisa if her students made an effort to do the biological part which can be related to this project. Without having seen this video clip, Lisa stated,

No, they didn't. That would have been cool... Because they had the guinea worm and they had all the research on the guinea worm itself... So they kind of had that.

But, no, they didn't think about analyzing it that way [connecting biological

concepts such as microbiology]. That would have been neat. (Lisa, Reflective interview #10)

This clip provided some supporting evidence that students were integrating biological concepts into their work while conducting the chemistry lab even though Lisa had not stated this as an expectation to the students nor did she expect them to add it. That is, giving students the freedom to investigate concepts for themselves provided them the opportunity to investigate a wider range of interrelated concepts. By doing so, students could expand the borders of their scientific knowledge. Lisa's reflection on this segment illustrated that she could see her students extended their knowledge into other science disciplines by conducting research during the CBIL:

Aeration - sometimes water sprayed into the air to remove odor and improve its taste. She [Lucy] must have done some other research because if you're gonna remove odor, then it is gonna be an organic [compound]. She said it [aeration] is supposed to destroy organics and whatever. It was neat that she was relating the whole aerobic reaction to it [aeration], that it somehow must consume or decompose or affect that organic molecule and it won't remove it... That's a lot of why we like to do water quality and this kind of stuff because there is that biology tie-in. (Lisa, Reflective interview #12)

The student's (Lucy) understanding of aerobic bacteria did not come as the result of her teacher saying, "Today we are going to talk about aeration and related biology concepts." And the teacher, by reflecting on the video segment, realized that her students were actively engaged in the CBIL in such a way that their learning extended beyond the normal chemistry curriculum.

Taken all together, as a result of the teacher inquiry project using VAT, these chemistry teachers became more conscious of their students' cognitive engagement within the CBIL. This

sense-making occurred when the teachers investigated how students applied real life experiences to the project, how students transferred what they had learned into the new context, and how they expanded their scientific knowledge.

Teachers' awareness of students' cognitive engagement when conducting an inquiry project is meaningful in the sense that oftentimes, science teachers regard the fact that students are engaged in hands-on activities as a sign that learning is occurring. In a study of beginning primary teachers' pedagogical content knowledge, Appleton (2003, p. 17) pointed out this aspect: "There seems to be the assumption that if an activity is any good then students will learn whatever the activity is about simply by doing it." He gave a warning regarding this viewpoint, asserting that instructional sessions that only depend on activities without thinking about learning outcomes could be "a distortion of discovery learning." In this regard, it is necessary that science teachers pay careful attention to what students learn from "hands-on" activities when they implement inquiry lessons. As discussed above, the chemistry teachers in this research had an opportunity to investigate not only their students' hands-on performances but also their cognitive engagement through the process of teacher inquiry.

Not Just Cognition, But Students' Social Interaction

So far, through the teacher inquiry process, the means by which chemistry teachers made sense of students' learning in the CBIL has been discussed in terms of students' cognitive characteristics. However, teachers in this project also gained understanding of students' learning in terms of social interactions. It was natural for participating teachers to take the students' social interactions into consideration through the inquiry in that one of the primary goals of the CBIL was for students to learn to work together as a scientific community. For instance, based on her

three years work experience as an analytical chemist, Cindy described the goal of the CBIL in this way:

I think it's important for them [students] to learn how to work in a group and as a community in the real science world. Scientists don't work individually. We do talk to each other and we do collaborate. I think that's important for them to develop those skills with each other. (Cindy, Initial interview #1)

As implied in the above passage, the teachers expected that collaboration as a whole team could provide a real life "science" experience for the students to make them. Lisa's statement revealed the social aspect of the CBIL's learning goals as well:

I think the whole notion of that [CBIL] really, if you would've worked for an engineering firm or even in a research lab, there's a whole team of people. That is real life... So, it's to give them a sense of real world and I really think kids can learn from each other quite well... I just like that community feel. (Lisa, Initial interview #1)

With this goal in mind, the teachers paid great attention to their students' social interactions and development throughout the teacher inquiry. As a result of the data analysis, four aspects of the student interactions will be examined: (a) increased participation and active role taking, (b) collaborative interaction, (c) ownership of learning, and (d) dysfunctional social dynamics.

Increased participation and active role taking. One of the salient aspects of students' social development was their increased participation and active role taking in the CBIL. Specifically, teachers noticed that many of their passive, quiet students were actively engaged in the project. For instance, in Dorothy's class, there was a student (Alyssa) who wore a hearing aid and did not receive much attention from other students. The video segments captured evidence of

how Alyssa proposed ideas and played a leading role by drawing a data table on the board in front of the classroom. Dorothy described how classroom dynamics were changed around Alyssa with her increased involvement:

I saw students that were ready to step forward this time... Alyssa is one of my students that's hearing impaired. She really stepped forward a lot today, contributed and jumped in. A couple of people said, "Alyssa! Why don't you get up there and do that?" I'm very pleased to see her brought into things because she has a lot to offer. And I'm glad the students were recognizing that too. (Dorothy, Reflective interview #7)

By examining several clips featuring this student, Dorothy validated that the CBIL had a positive impact on students' social growth through "some people stepping forward in leadership roles who hadn't done that in the past" (Dorothy, Pre / post interview #5). In the same way, Cindy reflected on how her students became active participants in the CMIL as follows:

I thought it was fun to see the progression of all of them [students] throughout the different activities that we did over the semester. Just to see how some kids stepped up and took charge that I didn't think would be really involved. I thought it was really good for them especially after the first one [CBIL]. First, they're still kind of waiting for somebody to take over and somebody to do something and then they realize, we're in charge and we have to make something happen. I thought that was kind of fun for me to watch that process. I think it gives them a little bit more real world experience of somebody's not always gonna hold your hand and lead you through everything. (Cindy, Final interview #13)

The teachers' recognition of this phenomenon (i.e., students who did not typically participate in an inquiry lab became actively involved in the CBIL) further influenced the change of teachers' perceived image of students. One example captured in Lisa's class illustrates this aspect well. One day during the third CBIL, Lisa noticed that a student (Katy) acted differently than usual. Lisa described the normal characteristics of Katy as "a smart girl, but often absent because of illness and comes off as a total slacker" (Lisa, Pre / post interview #6). It was the first day of the project, so the students were discussing job assignments. One of the students pointed out one problem with working on the PowerPoint; people who had made the presentation file in the previous project did not have a chance to be involved in the lab experimentation. Almost immediately, Katy piped up and said, "You know, making the template really doesn't take a lot of time. So perhaps the PowerPoint people could quickly make the template and then serve another role until there's information to put back in." Katy was in charge of making a PowerPoint file in the second CBIL, so she knew how to deal with this issue. Reflecting on this moment, Lisa mentioned,

She works so well in this [CBIL]. Believe it or not... [she] wasn't trying to be a slacker at all. I really thought that was neat. ... Katy, she was just impressed me today. She was also saying "Listen guys, we don't need five people on the communication, that's just a waste of time." So again, it was such a different image of her. I loved it. (Lisa, Pre / post interview #6)

This statement implies that Lisa's perception about Katy was changed by a closer look at the manner of Katy's involvement. This closer look was facilitated by both the teacher inquiry project and the CBIL structure.

Research shows that teachers have a tendency to believe in what is often called “fixed abilities” of students; they put students in the categories such as “*high and low ability* or *auditory, kinesthetic, or visual learners*,” leading the teachers to adapt instruction to those perceived abilities (Soutuerland & Gess-Newsome, 1999, p. 141, italics in original). When such categorization is not open to ongoing revision, it can interfere with students’ learning because teachers do not encourage students’ progress beyond the perceived and subsequently “fixed” abilities. In this regard, it is important for teachers to have a flexible view of students. In this research, through the scrutinized inquiry, teachers became more aware of their students’ active participation in the CBIL and as a result, the situation was created through which teachers were able to re-envision and thus revise their perceived image of students.

Collaborative interaction. Another insight that emerged from the teacher inquiry project was teachers’ awareness of students’ collaborative interaction in the CBIL. Some of the video excerpts and classroom segments shown in the above sections addressed the way students worked in a collaborative manner so that they learned from each other or solved problems they encountered during the project. For instance, the conversation around the concept of density which occurred in Dorothy’s class during the *Moley Avogadro’s Statues Project* illustrates that students elaborated and corrected misconceptions through the use of verbal interaction and discussion among class members (see page 88). The other example is the discussions around the issue of boiling and distillation during the *Carter Center Nigerian Trip Project* (see page 92 and 94). By negotiating different ideas among other students, the students were able to reach the idea of how to boil the dirty water efficiently. If they would have approached each other in an adversarial manner, it might have been difficult for them to come to this conclusion. Lisa confirmed this social aspect of CBIL as follows:

The wonderful new dimension to the community-based is that the kids have so many more resources because they have each other. Even beyond just each other, as they go along, I think they discover even more resources as they just are all thinking together. (Lisa, Initial interview #1)

That is, the fact that students collaborated with each other led to the creation of new ideas and also new learning opportunities as a result of the realization of new resources. Both of these activities were the result of being given the autonomy to work together.

Through the teacher inquiry process, the teachers were provided a means to notice that positive interactions among students were going on in every corner of the classroom: students exchanged their ideas as a whole group, explicated the lab procedure to other lab group members, explained the findings to the students who made the PowerPoint file, and presented their conclusions to the whole community. Lisa's reflection on the forty-second video clip in which two students were working on a filter paper exemplifies teachers' awareness of students' collaboration:

I thought it was interesting that Lucy was just trying to ram that filter paper in there. Then, I loved it that Christina just picked it up and folded it and of course Lucy was watching. I love it how they learn from each other. (Lisa, Reflective interview #11)

In addition, the teachers noticed that students' collective interactions were increased as the CBIL went through. The following two excerpts addressed this aspect:

They're being very respectful of each other. For the most part... they were listening and participating. Last time [in the first CBIL], they didn't pay attention. (Cindy, Pre / post interview #2)

In the first lab, they are very smart and very opinionated. [But] they were so mean to each other. They would just shout and not listen to each other's ideas and just go on. People [who] were quiet - they just ignored them even though they had the best ideas. This time, they respected that and they listened to it. ... In this lab [the second CBIL], they worked well together. They were helpful, they were supportive, they went around; there wasn't any yelling and fussing. They really made a growth. Therefore, they listened and had a lot more ideas. (Dorothy, Reflective interview #9)

By analyzing and reflecting on the progression of CBILs, it became evident for the teachers that students were getting better at listening more to other students' ideas and responding to others with respect.

Ownership of learning. The structure of the teacher inquiry project facilitated the teachers' awareness of students' ability to accept responsibility for their own learning in the CBIL. Identified evidence of students' ownership of learning included conducting outside research and volunteering to contribute. In Cindy's class of the *Carter Center Nigerian Trip Project*, students spent a great deal of time reporting what they had researched for the project. Their research had turned up a great deal of information related to water treatment systems that had not been provided by the teacher. By reviewing several instances depicting students' discussion of research findings, Cindy confirmed that CBIL helped her students take responsibility for their learning:

I think it [CBIL] requires students to play more of an active role versus just essentially following a recipe and going through the motions of a lab. I think it forces most of them to really be active participants and take ownership of their

learning versus playing a more passive role like a lot of traditional, cookbook chemistry labs can be. (Cindy, Pre / post interview #5)

Students in all three teachers' classrooms actively conducted outside research in order to accomplish the mission of the projects. Thus, they came up with their own solutions without being given a significant amount of directions.

Another example of students taking responsibility was captured in Dorothy's class during the same project. While discussing several procedures, students not only thought about possible ways of filtering but also volunteered to bring needed materials such as a spray bottle. By reflecting on this segment, Dorothy stated, "It's so cool the way different people can participate and bring in their experiences and feel like they're really contributing. And that's the whole idea behind this [CBIL]" (Dorothy, Reflective interview #7). The next day, students brought spray bottles and sifters for lab. Through the opportunity to design their own lab procedures and to make their own decisions, students began to strengthen their sense of responsibility for their own learning.

Consequently, the role of students and teachers was changed as the CBIL proceeded. Dorothy addressed this change in the following way:

I think they did stop looking at me as the authority. They did learn to rely on each other. They learned to respect a lot of people in the class, quiet people, people who are loud all the time. One boy in one of my classes is a class clown, but he is so smart and people didn't know that beforehand. They learned to realize that there are a lot of artistic people who pulled together and did the PowerPoints. They found a new role in the classroom. Normally they don't have a good role. So the class pulled together well. (Dorothy, Reflective interview #9)

That is, as students were taking ownership of their learning, they were getting more independent and began to depend on each other instead of relying mainly on the teachers.

The opportunity to notice students' ability to accept responsibility for their own learning can be a measuring stick for the teachers to make sure the new instructional approach of the CBIL was successful. The three chemistry teachers believe that student learning best occurs "when you [a student] go out and seek things on your own" (Dorothy, Initial interview #1), "when they [students] kind of come to their own understanding" (Lisa, Initial interview #1), and "when they [students] are actively involved in their own learning and have to investigate a solution to a problem" (Cindy, Initial interview #1). Based on this belief, they intended to offer the best learning opportunities to their students to work and learn through the CBIL. In return, they expected that students would cultivate an understanding of the ownership of learning along with a sense of what it means to have intellectual autonomy with regard to that learning. The teacher inquiry project provided the teachers with a window to look at and study how this goal was accomplished in the CBIL.

Dysfunctional social dynamics. A final insight emerging from the teacher inquiry project differs from the other types of social interaction discussed so far. As the CBIL proceeded, the teachers also identified negative social dynamics which contrast sharply to the positive aspects shown above.

One of the teachers' concerns at the beginning of the CBIL was that students did not know how to work with each other collaboratively. Dorothy's reflection addressed this issue:

In the first inquiry lesson that we did with the spinach company, they argued more points [than other classes]. They would argue with each other. But, they would

almost get insulting. They haven't learned how to discuss something without becoming personal. (Dorothy, Initial interview #1)

Likewise, the students' social interactions sometimes hindered students with regard to verbalizing their creative ideas in front of the whole class. Lisa described how social dynamics could negatively influence students' discussion:

In this class, I know I have some very bright kids in here and can think really well. The class managers that are selected are always the very academic kids because the ones that think real well are the goofballs. It's the truth, so no one wants them to be the class manager. So the goofballs that really think well don't have any opportunity, and they immediately put themselves in a passive role. ... Then, this kid is shot down and they think, as a teenager, "Okay that's a dumb idea and I'm not gonna bring it up again." That's what's happening. (Lisa, Pre / post interview #7)

It is important to reiterate the point that the students developed their social interaction skills as the CBIL proceeded.

The other negative issue resulted when some of the students showed a passive attitude and did not want to participate in the project. The video segments captured some of them just wandering around the lab tables or copying down research findings from others. When teachers reflected on those moments, each of them responded differently to these moments. For instance, Cindy was very disappointed and did want to give a little bit more direction to the students in the future: "I suppose giving them a little more guidance or maybe giving them a list of possible things they could use or have access to and kind of give them some more ideas" (Cindy, Reflective interview #11). On the other hand, Lisa considered this to be a normal part of the

teaching: “Everybody really participating, that’s hard. We always know, in every activity that we do, whether it’s teacher-led, whether it’s individual inquiry, whether it’s class inquiry, you always have kids that choose not to participate” (Lisa, Pre / post interview #5). She further expected that “the peer pressure and the excitement of the lab [CBIL] will motivate more kids to be involved rather than not involved” (Lisa, Pre / post interview #5).

The most salient dysfunctional social dynamics noticed by the teachers were the way one or two students, usually a class manger, influenced the outcome of the project. For instance, in the third CBIL, Lisa realized that the class managers were so bossy that they overly controlled the project. On the first and second days of the *Moley Avogadro’s Statues Project*, the whole class could not move on to the actual lab because the class managers held the class, spent so much time on assigning jobs to the students, and continued discussion about the procedures. Reflecting on this project, Lisa stated,

They [class managers] micromanage everything. If [I] send them [students] to lab and the class managers are walking around, delivering balances... It was still very passive. [I thought] you [class manager] spent all this time getting groups and why don’t you let them [other students] go? I am like “Oh, man...!” It’s really almost like the class managers are impeding [the other students’ progress]. (Lisa, Pre / post interview #7).

This type of leadership of the classroom managers appeared in other teachers’ classrooms as well. In Dorothy’s second project, one of the classroom managers, Anna, was domineering from the start. Throughout the *Carter Center Nigerian Trip Project*, Dorothy was able to notice several times that Anna’s understanding and action dominated the decision making process. For instance, during the whole class discussion, one student, David proposed the idea of using a

centrifuge to settle the foul water. However, Anna ignored his idea and said, “Just let it settle. Just like, you go to the beach, you get sand and water, and you let it sit there, and the sand will eventually sink at the bottom” (Video, 10/01/2007). Neither of the ideas was scientifically incorrect, but Dorothy’s reflection on this segment below gives us a glimpse of how lab procedure would have been different if Anna accepted his idea:

I think that [David’s idea] was awesome. We have a centrifuge and I wish he would have followed through with it. I’ve talked to him a little bit about that. I said, “You have really great ideas. You need to stick with them a little bit longer.” She [Anna] didn’t really understand what he was saying. It was obvious she didn’t [understand], and he didn’t pursue it. He’s got to learn to become a leader and pursue it because he has great ideas often. Sometimes we get off on a tangent, but I have a centrifuge that would have separated that water, the large particles very easily. No one’s ever tried that before. That would have been cool. (Dorothy, Reflective interview #7)

This class segment showed that class managers in the CBIL could have a negative impact on the movement of the whole class as well as limit the progress of the project.

As discussed so far, teachers became more aware of students’ social interactions and development in the CBIL in terms of students’ participation, collaborative interaction, ownership, and dysfunctional social dynamics. It was evident that students’ learning in the CBIL both affected and was affected by those social appearances, positively and negatively. Teachers’ sense-making of underlying social interactions among students allowed them to draw a whole picture of their students’ learning in the CBIL with their sense-making of students’ cognitive learning.

Chemistry Teachers' Sense-Making of Their Own Teaching Practice

In the preceding section, I discussed how chemistry teachers made sense of the way students were learning within the context of the CBIL, an instructional technique through which students took initiative and the teachers held back their words and actions. In this section, I address how the teacher inquiry project influenced teachers' understanding of their own teaching practice, especially, how their gained understanding of students' learning was in line with their sense-making of their teaching practice. Through the teacher inquiry project using VAT, the chemistry teachers (a) discovered potential teachable moments, (b) modified the CBIL, (c) sought out a better way to explain a specific science concept, (d) became aware of their pedagogical orientation, and (e) revisited, broadened, and deepened their science content knowledge.

Turning Concealed Moment into Teachable Moment

As illustrated above, the teacher inquiry project provided the teachers with more opportunity to see and hear what students were saying and doing in the CBIL by disclosing every corner of the classroom through VAT. In doing so, the chemistry teachers were able to notice students' creative ideas and to articulate students' thinking. This increased awareness then served as a resource for teachers' teaching in the future.

For instance, by revisiting the *Carter Center Nigerian Trip Project*, Lisa came to a deeper understanding of her students' innovative rationale for using a brown paper towel, as seen in a previous section (see page 82). However, her inquiry did not stop at detecting the students' hidden thought. Lisa extended this moment into a new way of teaching when she reflected on this moment:

This would be a neat follow up to see what kind of paper towel. What kind of paper? Is it any kind of thing with cellulose in it? Would it work with a fabric towel? Would it work with filter paper? Is it wetting it, leaving it dry, oiling it? Even in something as simple as this, they really can have a million different experimental designs and really go into a neat lesson about independent and dependent variables and all that. You could spend all year on that. You could talk about polymers and you could just go on and on and on and on. That might be a neat method to teach, within which to teach. (Lisa, Reflective interview #12)

Her explanation makes it clear that scrutinized inquiry inspired Lisa to come up with new ideas for future labs based on her gained understanding of students' concealed thought.

In addition, the teachers identified a number of moments during the reflective interview which they could not catch in the middle of the classroom. While reflecting on these video clips, the teachers expressed their desire that they could have used them in their post-lab or that they would use them in the future lesson. On the second day of the same project in Lisa's class, the students argued whether they would put chlorine in water to get rid of the guinea worm. Some of them strongly recommended not adding it because then the water would not be drinkable due to the chlorine. Finally, the students concluded not to use chlorine. When reflecting on this class, Lisa discovered that one student, Katy was starting to mumble in the back of the classroom. A close look at Katy revealed that she was proposing the idea of diluting chlorine. However, her idea was ignored by her peers in the class; no one paid attention to what she was saying. Lisa thought Katy's idea would have been accepted if she had a strong voice in the classroom, and this could have been a good "teaching moment" to address the concept of solution and molarity:

If they would have stayed a little bit more on Katy's thought... Of course, they haven't learned anything about molarity or solutions or anything... This would have been neat to be seen and have this conversation before the post-lab because then I could have said to them... I could have used that as a teaching moment... I could use that to them teach solutions; which of course I don't teach until the second semester. I change my order all the time. But that would have been a neat foreshadowing or prelude to what we'd talk about next semester. So that's pretty cool. I didn't know this at all. They never let this enter into their PowerPoint nor did they think to say, these are some of the thoughts we had and these are some of the reasons we chose not to use [chlorine]. There was really a lot more thinking than they presented. (Lisa, Reflective interview #11)

Lisa's statement obviously confirmed that it was difficult for the teachers to make sense of or even recognize all students' contributions in the open-ended inquiry context. It also implies that if she could have heard Katy's suggestion during the lab, she would have addressed how Katy's idea was related to the concept of solution and molarity during the post-lab.

Overall, the teachers were able to perceive students' hidden rationale for certain actions and detect students' thinking that was not manifested during the enactment of the CBIL. Consequently, they transformed their own awareness of concealed moments into potential teachable moments in which they could design a new lab or establish a connection between students' ideas and chemistry concepts and, in turn, support students' learning. That is, through the teacher inquiry project, exposed students' ideas functioned to serve as stepping stones for the teachers' new ideas for future classes.

Modify the CBIL

The chemistry teachers adjusted their CBIL for the next school year based on lessons learned from their students who were inquiring into and conducting the enactment of it. This modification occurred in two ways. First, the teachers' careful attention to the students' performance had an effect on teachers' adjustment of the CBIL. In each project of the CBIL, the teachers gave a pre-assignment to the students such as reading material and pre-lab questions, as illustrated in the method section. In the *Carter Center Nigerian Trip Project*, the students were provided a reading worksheet titled *Municipal Water Purification* as background information before the project. On the handout, 10 processes of water treatment were demonstrated with a picture; the procedures were 1) screening, 2) pre-chlorination, 3) flocculation, 4) settling, 5) sand filtration, 6) post-chlorination, 7) optional further treatment, 8) aeration, 9) pH adjustment, and 10) fluoridation. The teachers expected that this reading worksheet would be used as a tool for the students to "start thinking about different things that they do" (Cindy, Reflective interview #10).

However, while analyzing and reflecting on the way the project was enacted in the classroom, Dorothy realized that the students followed the ten processes on the worksheet exactly. The class managers led the whole class discussion in order of the suggested steps on the handout. The same situation happened in Cindy's class. By reflecting on the moment in which the students discussed screening methods through VAT at first, Dorothy stated "I think it's funny that they started with that. That was the first process on that handout, so they felt compelled to start with that. I'm disappointed about that" (Dorothy, Reflective interview #7). As she went to the reflective interview, it became clearer that the students followed the given steps even though they diversified the variables in some of the procedures. Accordingly, Dorothy began to think

about *why* the students performed in that way. Her concerns were described in the following reflection:

Unfortunately, a lot of students, especially at this point, are still into “The teacher said this, so that’s what she wants me to do.” They used it [the reading handout] as they thought they had to do all those procedures. So, I want to think about different ways to do this in the future. I didn’t want them to go step by step and do all those. ... So, what I’ve got to figure out is a way to give them that information without them thinking that’s a procedure. (Dorothy, Reflective interview #7)

This indicates that the students regarded the suggested processes as a standard that they had to follow. That is, the reading worksheet was misused by the students and lost its original purpose of providing a starting point.

The above statement also showed that Dorothy began to think about *how* she could resolve this issue so that the students could design their own lab procedures and not follow her suggestions as a prescription. As she went through the reflective interview through VAT, Dorothy came up with a new idea of implementing this project:

Since I gave it [the reading handout] to them, I think they thought I wanted them to follow that. I think if I would have just given the objective of the lab to remove the guinea worm to do this [project], without any processes.... I think I’m gonna have them do their own research. Just give them the objective and say “Here’s your objective for this lab, research what you think would be helpful.” Everybody do a page of notes, find anything you want to on it, then come back and maybe write down on a piece of paper your three major ideas you found out. Then take those up, give them to the class leader, have the class leader go home, and pull it

together and come back and start the discussion.... Then maybe after they'd done that, maybe come back and say "Well here's our water treatment that works. This is just for your own information. Now, you design." (Dorothy, Reflective interview #9)

This reflection provides a picture of how Dorothy came to realize the need for modification of the *Carter Center Nigerian Trip Project* and how she would restructure this CBIL next year based on her sense-making of students' performance—she will not provide the reading worksheet next time.

Along a similar line, the fact that the students performed with insufficient lab skills at the first *SpinachCo Project* of the CBIL prompted the teachers to develop a new way of implementing the project. The *SpinachCo Project* required the students to become skilled at several different lab techniques such as using a graduated cylinder and a balance for measurement, a Bunsen burner, hot glassware, a spectrophotometer, etc. Reflecting on the project, the teachers realized that students struggled with some of these lab skills even though they had demonstrated them before the project:

As far as, with the lab procedure, I went over it. What I had done was I showed them how to go through that particular lab [skill], but some of them were still having difficulties when they were trying to do it on their own. So, I go over that with them a little bit more. (Cindy, Initial interview #1)

Because it [the *SpinachCo Project*] was a complicated lab procedure... They didn't know how to fold their filter paper. Why would they? So a lot of the stuff I was having to... (Lisa, Initial interview #1)

As a result, one of the teachers, Dorothy came up with the idea of having different lab stations where students could practice some of the varied lab techniques. Actually, when the project was implemented, Dorothy fell behind the other teachers in her teaching schedule, so she was able to learn from other teachers that the students had showed their difficulties with using lab equipment. Therefore, she set up several mini-lab stations the day before the project as a pre-lab, and the students visited each station in order to practice how to use different lab equipment. Dorothy's trial of using a mini-lab before the class went to the first CBIL ended in success in that the students got their hands-on the lab skills that they needed for the project. Consequently, all three teachers expressed their desire to use the mini-lab stations before the *SpinachCo Project* next year. Again, teachers' sense-making of students' performance in terms of lab skills prompted their pursuit for restructuring of the CBIL.

Second, the increased awareness of students' social interactions, especially dysfunctional social dynamics, influenced the teachers' decision to pursue the CBIL in a different way. As discussed previously (see page 111), the teachers became conscious of the fact that the thought and action of one student could play an important role in the outcome of the project. Specifically, as they began to pay attention to the social dynamics in the classroom, they realized that in some cases, a class manager was "impeding" the progress of the project. This recognition led the teachers to seek to find a different way to run the CBIL. For instance, Lisa considered the way to assign a class manager a little bit further in advance next time:

I think what I would like to do is give them [students] their class managers earlier.

Because what's happening is... In some ways, if we could give them the class managers a little bit early, then they could kind of be mulling it [the project] around in their head. The class managers can start to think of stuff. On the other

hand, I don't know, it might backfire if I do that. It might be that the class managers come in and take the inquiry out of it because they've had days to think about it and they say, "Okay, this is what we're gonna do" and that wouldn't work. I don't know. I'm kind of thinking out loud right now. ... I think I would just be more cognizant of that [social dynamic] and maybe do a little bit more coaching with the class managers. Maybe have like a little powwow with the class managers. ... But I don't know if that's the best for that individual kid. You've got to be careful about how you jump in there. It's about that community dynamic.

(Lisa, Pre / post interview #5)

By thinking aloud while examining the CBIL, Lisa reevaluated the role of a class manager illustrated in the book *Teaching Inquiry-Based Chemistry: Creating Student-Led Scientific Communities* and began to adjust the CBIL depending on the makeup of her own class. That is, realizing the social effects on students' learning within group contexts, Lisa became to think about modification of the CBIL as a way to bring her students back on the right track even though she was uncertain about the impact of the change.

In addition, Lisa worked out a way to consult with the class managers about their roles in the CBIL:

If there wasn't gonna be good learning going on, we were prepared to try and equip the leaders [class managers] with a few more tools that they weren't thinking about. Like, "Why don't you all exchange e-mails? Why don't you do this?" Or just pull the leaders aside and say, "Do you understand what the mission is? Let's kind of talk this through." And give them some ideas. (Lisa, Reflective interview #10)

This implies that Lisa came up with detailed methods for advising the class managers as she went through the teacher inquiry project.

Furthermore, a close look at social dynamics in her class stimulated Lisa to design a new approach for the students to evaluate the CMIL. Since Lisa came to notice the underlying social influences on the CBIL, she thought the students also needed to reflect on this aspect of their own learning. The following idea came to Lisa's mind in the middle of the reflective interview:

Maybe get them [students] to even brainstorm about the pros and cons of working as a huge community. In that sense, they can say the pro is that we've got more people to do more work, we wanted to do more trials, we wish that we could have had more time to research, we wish we could have had more time to do this, this, this and this. They could see those are the pros. Then the cons, of course, if they haven't worked as a community yet, they'd just have to anticipate it; but if they write down the cons, then they can be more prepared to deal with them. We could even say, okay, let's have a third column. How would you manage these cons and turn them into positives? Just give them a little bit of that training to get them to think about the group dynamic and that it can be a con. They're not clued into all the problems that could occur. Again, sometimes you just have to let them experience it. But, I think that would be a good exercise to include next year that I didn't include this year, actually just looking at the dynamic; not just the chemistry. (Lisa, Reflective interview #11)

That is, Lisa believed that the new instructional strategy would provide the students an opportunity to reflect the merits and demerits of the CBIL so that they could deal with

dysfunctional social dynamics better. This new idea illustrates how Lisa would reshape the CBIL for the next school year based on her sense-making of social aspects of students' learning.

By and large, the teacher inquiry project offered the teachers opportunities to analyze and reflect on their own classroom in which the CBIL was implemented. These opportunities were transformed into the learning opportunities for teachers to better understand their own students' learning. As a result, they were able to come up with new ways of implementing the CBIL by restructuring it or making new additions to it in order to support their students' learning.

A New Way to Explain Science Content

So far, I addressed how the teachers transformed their understanding of students' learning into their teaching practice by connecting students' thinking into teachable moments and modifying the CBIL. In addition, the chemistry teachers utilized the teacher inquiry project not only to reflect on students' learning but also to scrutinize, analyze, and adjust their own instructional practice. Although the teacher role was more passive in the CBIL as compared with the traditional lecture class or teacher-guided inquiry class, the teachers were able to capture images of themselves teaching a pre-lab or post-lab through VAT.

Reflection on actual teaching practices led the teachers to look for a way to make their teaching better in terms of explanations. This aspect is represented in the following two segments from Cindy's class and her reflection on them. One of the assignments during the *Carter Center Nigerian Trip Project* was to make a chart in which students filled out information on the ten water treatment plan processes based on the reading worksheet, including the purpose of each step, classification of water before and after each step, and changes concomitant with each step. On the day Cindy introduced the project, she allowed the students to spend half of the class time

making this chart. During that time, the students debated whether the flocculation process is associated with a chemical change or a physical change. Then, the following discussion occurred.

Mary: If it's a chemical and physical, can we have both?

Cindy: What do you guys think?

Mary: I don't think so, but...

Cindy: Which one are you looking at?

Mary: The third one, flocculation.

Cindy: What makes something a chemical change versus a physical change?

Students: (Mumbling)

Cindy: If it's a chemical change, you can't change it back. You know, *if it's changing chemically, it's a chemical change*. So, technically...

Sean: This [flocculation] is taking clay out of it [water].

Cindy: So, you're just removing clay... are you really chemically...

Sean: We are using a bunch of chemicals though.

Cindy: Are you talking about the flocculation one? The chemical reaction's occurring *if you are changing the chemicals* within that solution or that water mixture, *it's chemical change*. But, sometimes you might see a change in the physical appearance, but that's because *the solution is changing chemically*.

(Video, 09/27/2007, emphasis added)

This video excerpt illustrated that the students did not understand that the process of flocculation is a chemical change in which aluminum sulfate and calcium hydroxide react to form aluminum hydroxide. Some of the students considered flocculation to be a physical change because they could see a sticky, jelly-like material (aluminum hydroxide) which traps the colloidal particles. Thus, Cindy explained the concept of chemical change to the students, but she continued to explain a chemical change by using the words “*changing chemically*” in the discussion.

Reflecting on this segment, Cindy came to deeply think about why the concept of chemical change was difficult for the students to understand:

I think sometimes the combination of when there's a chemical change but something physical happens along with it, like with the flocculation reaction, you make a new substance but there's a precipitate that's formed, a solid. So they're like, well that's something physical, you see something physically new, but it's because... Sometimes they get confused. It's really both. There's a new chemical substance and yes, you see something new physically, but it's a chemical change because you've made something new. So I think they get thrown off sometimes if it's a chemical reaction where there's color change or something like that. (Cindy, Reflective interview #10)

Cindy's assertion is supported by other research findings that many students do not understand that a chemical change is characterized by the formation of a new substance having different properties from the original substance (Driver, Squires, Rushworth, & Wood-Robinson, 1994) and that students frequently use the term “chemical change” to explain changes in physical state or in colors between reactant and product (Loughran, Mulhall, & Berry, 2002).

In addition, Cindy realized that her way of explaining the concept of chemical change was not appropriate and stated,

I think also, as I'm watching that, why didn't I just say, "You make a new substance, something different." because that would have been... As a new teacher, I'm learning. Sometimes I'll explain something one way over and over again and then finally I'll say it in a different way and they'll say, "Oh, well that makes sense." I'm thinking, "I wish I would have said that to begin with." So, maybe if I had just said even that, that might have helped them to understand that.

I think I probably could have explained it better too. (Cindy, Reflective interview #10)

Cindy's reflective comment reveals her desire to have explained the concept of chemical change as a change that results in the formation of new substances. Although Cindy knew the scientifically accurate concept of chemical change, she did not sufficiently bring it into her teaching practice. Without the opportunity to revisit this teaching moment through the observation of her own teaching, she might have not considered a change in her teaching regarding this specific incident.

Another excerpt also portrays that Cindy became aware of the need to modify her explanations of science concepts. On the next school day, following the event described above, the whole class as a group checked out the chart that they had worked on the day before as individuals. The students discussed whether the properties of water would allow for them to classify it as a heterogeneous mixture, a homogenous mixture or as a pure substance before and after each water treatment process. By the time the students completed the chart, Cindy asked a

question to the whole class and began to clarify the concept of a heterogeneous mixture, homogenous mixture and pure substance.

Cindy: Does everybody understand the difference between homogeneous and heterogeneous? What's the difference?

Sean: Homo is the same, hetero is different.

Cindy: Let's break it down. What do you start off with at the beginning?

Students: Hetero..

Cindy: A heterogeneous mixture. What makes something a heterogeneous mixture?

Marry: You can see the different things in it.

Cindy: Right, *you can see the different things in it*. So when is it a homogeneous mixture?

Students: chemical... can't see...

Cindy: *You can't see, you know that's... Like solutions*. If you have water with salt or chlorine or something dissolved in it, and *it looks like one thing*, then it's a homogeneous mixture. So how do you know when you have a pure substance?

Hillary: You are taking everything out.

Cindy: *If it's just one pure thing...* What are examples of pure substances?

Sean: Kool-Aid..

Elizabeth: No.

Cindy: So Kool-Aid [is] what?

Students: Homogeneous mixture.

Cindy: Homogeneous mixtures. *Homogeneous mixtures are solutions*. So pure substances... What are the two examples we talked about in class?

Sean: *Water*.

Cindy: Water's an example. What is water?

Students: Compound. Element.

Cindy: *A compound*.

Hillary: So are all compounds pure substances?

Cindy: Right. If you're treating water, what would have to be the only thing left for it to be a pure substance?

Elizabeth: Just H₂O, nothing else in it.

Cindy: It'd have to be H₂O and couldn't have anything dissolved in it.

(Video, 10/01/2007, emphasis added)

Cindy started this conversation because she “heard a couple of people [students] say the wrong thing” and the purpose was “making sure they understood what the differences were between all of them [heterogeneous mixture, homogenous mixture and pure substance]” (Cindy, Reflective interview #10). Therefore, as shown the above segment, Cindy explained a heterogeneous mixture as a mixture in which “*you can see the different things*”, a homogeneous mixture as a mixture that “*you can't see...*,” and “*looks like one thing*”, and a pure substance as “*it's just one pure thing*”. She also discussed some of the examples.

During the reflective interview, Cindy and two researchers discussed the concept of a mixture because the way she defined a heterogeneous mixture and homogenous mixture as a

mixture in which we can/not see something was considered an insufficient explanation. One researcher mentioned, “The word I would add into that is - you can see a distinction between parts [in a heterogeneous mixture] as opposed you cannot see a distinction between the parts [in a homogeneous mixture].” That is, he pointed out that a homogeneous mixture has definite and consistent properties while a heterogeneous mixture has inconsistent and non-uniform composition. Finally, Cindy concluded, “I guess maybe I could have worded that better” (Cindy, Reflective interview #10).

As illustrated so far, the teacher inquiry project provided the teachers with the opportunity to scrutinize their own teaching practices. Consequently, they were able to think about modification of teaching practice—in this case, better explanation of a science concept—with specific evidence of their teaching. Specially, Cindy, comparing to Dorothy and Lisa, gained more opportunities to be aware of better approaches to explain a specific science concept through the inquiry. It is plausible that because Cindy was in her first year of teaching, she did not have a varied repertoire of instructional approaches to teach a specific concept. Oftentimes, Cindy expressed the perception about herself as “a new teacher” (Cindy, Reflective interview #10, Reflective interview #12, Final interview #13) and said “I still don’t feel confident whenever I’m covering something new. I feel a little bit better by the end of the day. By seventh period, I feel like I’ve gone through my lesson” (Cindy, Reflective interview #10). In this regard, it is expected that the opportunities to analyze and reflect on their own teaching practice broaden new science teachers’ knowledge for teaching in terms of various explanations of a specific science concept.

Finding Pedagogical Orientation

While working with the participating teachers through the teacher inquiry project, I, as a researcher was able to identify their orientation to teaching and learning in general as well as their orientation to science teaching and learning. For instance, all three teachers' dominant view about students learning science was that students learn science best through hands-on: "I think that they learn by doing" (Dorothy, Initial interview #1); "I think that doing labs and activities is the best way" (Cindy, Initial interview #1); "Doing it and coming to their own conclusions" (Lisa, Initial interview #1). However, what's more about teacher inquiry was that the teachers were able to recognize their orientation to teaching and learning not as a result of being told by a researcher but finding it for themselves through the reflective and analytical process of inquiry. The following teaching moment and Lisa's reflection illustrated how she came to think about why she used a particular teaching strategy.

In the *Carter Center Nigerian Trip Project*, the students were given another reading worksheet titled *Total Dissolved Solids* (TDS) and were supposed to take notes from it as a pre-assignment before they would initiate the project. The teachers provided the TDS handout because one of the learning goals of the project was for the students to learn the concept of ions. When Lisa introduced the project, she reminded the students of this handout, and the whole class discussed anions, cations, monoatomic ions, and polyatomic ions. Then, Lisa provided another small handout on which there were ten questions and explained its aim. This moment was captured in the below segment.

Lisa: The other things I want you to think about when you re-read it [TDS handout] are these questions. Actually this is what I'd like you to do

this weekend. This is not due until Monday. This weekend, I want you to not look at your [TDS] handout. I want you to open up your lab book to where you took notes from the dissolved solids before. I want you to see if you can answer the questions.

Jeff: What if we cannot answer the questions?

Lisa: Then if you cannot answer the questions, then this is a self-assessment of how well you take notes. A lot of you can read, I know you can make out words and things like that, but a lot of you don't read very well with content, right? You get overwhelmed with picky little details. You miss over really big details or you miss out, more importantly, you miss out on the big point. So this can help you. Once you try to answer these questions, they all have to be answered in your lab book. The ones that you can't answer, then you need to go back and fill in your notes with the handout and then answer. By the end on Monday, you should have really good notes on this handout and ten completed questions in your lab book. Everybody understand? You can write all this if you want to, due Monday, in lab book.

(Video, 09/29/2007)

While watching this video clip through VAT, Lisa stated that she intended to teach a study skill by making the students answer the ten questions based on what they learned from the TDS handout: "Obviously in the last segment, I was trying to just talk about study skills in the context of total dissolved solids" (Lisa, Reflective interview #10). That is, Lisa had known that some of

the students had difficulties with grasping the point when they faced scientific reading so she tried to cultivate their ability to make a connection between what they read and what they learn in the CBIL. Answering the question of how often she uses this type of pedagogical approach, Lisa mentioned, “I don’t really focus on pedagogical [approaches]... I don’t focus on that that much” (Lisa, Reflective interview #10).

However, continued reflection on the use of this teaching strategy led Lisa to become conscious of the fact that she was frequently teaching study skills to her students, as depicted in her statement:

But now that I think about it, I do a lot of test-taking strategy and it’s usually when it comes up. For instance, I’ll be going over a quiz or just reviewing and I’ll make up a question. I try and teach them how to think their way through. So I do a lot of that, that I probably hadn’t been conscious of, and every once in a while I do this kind of stuff about taking notes. That one [providing 10 questions and having the students answer] was very deliberately planned, the way it was. I didn’t want to distract them. I didn’t want them to start working on it right then, but I did want to call their attention to their own study skills. (Lisa, Reflective interview #10)

Lisa described not only what type of teaching strategy she had used at the given moment but also realized she had been using that particular teaching strategy. That is, Lisa had a preference to teach study skills and test-taking strategies through note-taking methods with the aspiration that students could develop their thinking skills.

As illustrated in Lisa’s example, teachers made sense of their own pedagogical orientation as they went through the teacher inquiry project. Research supports that teachers’

orientation to teaching and learning influences their teaching practice. For instance, in the study of ten primary science teachers' subject matter knowledge and beliefs, Smith and Neale (1989) reported that a conceptual change orientation toward science teaching had an impact on both the form and the content of the lessons. Along similar lines, Kember and Gow (1994) illustrated how two types of orientations to teaching (knowledge transmission and learning facilitation) of lecturers affected the quality of student learning at the institutions of higher education. In this regard, the teacher inquiry project was meaningful for the chemistry teachers in that it promoted their self-awareness of pedagogical orientation.

Revisiting Science Content Knowledge

The teacher inquiry project resulted in the chemistry teachers' knowledge of science content being broadened and deepened in two ways. First of all, investigation of student learning, which was the main focus of the project, prompted the teachers to revisit their science content knowledge. The following two examples illustrate how a closer look at students' discussion during the enactment of the CBIL served as a springboard for the teachers to broad their content knowledge.

On the first day of the *Carter Center Nigerian Trip Project*, the students in Cindy's class discussed the aeration process of water treatment. They debated whether aeration caused a physical or chemical change. One group of the students argued that aeration process is a chemical change because they could not put the exact odor back after eliminating the odor of foul water whereas the other group of the students insisted that it is a physical change because they would get rid of the stuff that causes a bad smell. Some of the students asserted that both

changes occurred with the aeration process. Finally, the class decided every student would conduct research about aeration that night.

Reflecting on this segment through VAT, Cindy confessed that she did not know whether aeration is a physical or chemical change and came to think about which of the students' ideas would be correct:

... when they were debating that, I thought I could see it debated [on] both sides. I guess if you're removing, if you're aerating it, you're evaporating out or releasing out odors or any chemicals that cause odors or whatever they're trying to do with it. That could be chemical, but it's a physical process. I didn't even know. I'm trying to think actually now when they researched it, what they ended up coming up with. I was kind of curious when they researched it what they were gonna end up with. I would probably more classify it as physical, but I'm not sure what they came up with. I thought it was interesting they had such a long debate about it.

(Cindy, Reflective interview #10)

This statement reveals that Cindy did not remember what research findings her students brought up even though the project was over. It also shows that Cindy's concept of aeration was unclear until this moment she was watching this clip. It is also clear that she was not considering aeration as a tool to impact the biological makeup of the contaminated water.

Later on, when Cindy went through the reflective interview second time, VAT offered another segment captured in the second day of the project, in which the class manager asked the whole class to share what they found about aeration process. One student presented her research which says aeration could be both a physical change and a chemical change. Along with her research she presented scientifically accepted explanations, and the class accepted this idea. By

inquiring into students' discussion that occurred in the classroom, Cindy gained a more accurate concept of aeration.

While the above story portrays the ways student discussion itself served as a resource for the teachers' broadened knowledge of science concepts, the next account gives us a glimpse of how students' discussion spurred the teachers to expand their science knowledge. During the *Carter Center Nigerian Trip Project*, Lisa heard some of the students discussing how they needed to use chlorine in order to eradicate the guinea worm, one type of pathogen. The students' conversation raised a question to Lisa, so she brought up this issue in the afterschool meeting. As described in the methods section, the participating teachers had a meeting after school several times while implementing the CBIL in order to plan the project together and check the progress of students' learning. During the meeting, the following conversation occurred:

Lisa: Would you classify the guinea worm as a pathogen? What's the definition of a pathogen?

Anything that is... I always thought a pathogen was more microscopic permanently, not like [the guinea worm that grows into 2-3 inches]... I don't know. But, that's just a biological thing. So they [students] kept referring to that [the guinea worm is a pathogen]. And I was like...

Dorothy: You didn't think it was right?

Lisa: I just didn't know. I didn't know enough to question it and I didn't want to get into...

Dorothy: The other thing we had going on...

Lisa: They kept thinking the chlorine would kill the guinea worm because chlorine is supposed to kill pathogens. You see what I'm saying?

(Afterschool meeting 2, 10/04/2007)

As soon as Lisa asked the question to other teachers, she was thinking aloud to herself and expressed her idea that the guinea worm is not a pathogen because it grows from microscopic larvae into 2-3 inch long size adult. Since the participating teachers were all chemistry teachers, none of them was able to answer to the question that Lisa had come up with. Therefore, they actively sought out means to answer the question of whether the guinea worm can be classified as a pathogen. As part of this research, Lisa sent an email to one of the AP biology teachers at the school. Finally, they came to know that a pathogen is defined as a biological agent that causes disease to its host and includes bacteria and viruses as well as parasites such as guinea worms. This story clearly shows that careful attention to students through the teacher inquiry project demanded the chemistry teachers expand their understanding of biology so that they could broaden the boundaries of their knowledge of science.

Second, reflection on their own teaching practices provided the teachers with the opportunity to revisit their knowledge of science content. In the post-lab of the *Carter Center Nigerian Trip Project*, Lisa explained the concept of suspensions, colloids, and solutions and how to distinguish these three by introducing the Tyndall effect. She prepared three beakers contained different types of mixtures and a flashlight to show the Tyndall effect. First, Lisa explained the definition of Tyndall effect by saying "The Tyndall effect is when you shine light and the light kind of detects the size of the particles." Then, she demonstrated that the beam of light can be detected in the beaker filled with dirty water (suspension) and cannot be detected in

the beaker filled with tap water (solution). From the demonstration, she explained the definition of suspensions and solutions. Next, Lisa diluted dirty water by adding tap water until it looked like clear water, called it a “colloid”, and again shined a flashlight into it. Then, the following conversation occurred.

Lisa: This is called the Tyndall effect. This has what we call a positive Tyndall effect because you can see the beam of the light is going through it [a colloid].

Does this [foul water] have a positive Tyndall effect?

Students: Yes.

Lisa: Yes, you can see the beam of the light is going through it.

Does this [tap water] have a positive Tyndall effect?

Students: No.

Lisa: No. So, solutions which have the smallest particles that are totally dissolved have a negative Tyndall effect. Colloids, which can look like water... (diluting again) Can you see the Tyndall effect?

(turning on the light of the classroom) This is what I want you to see.

They [tap water and a colloid] look identical just with our eyeballs, right? Do not be deceived.

(turning off the light of the classroom) Can you see the Tyndall effect?

Students: Yes... Oh... Cool... Yes, right there...

Lisa: This (pointing out the beaker contains diluted water) could be classified as a colloid. You could say a really murky colloid approaching a

suspension. Okay? But there are colloids that look totally clear. They have a great clarity, but you can see the Tyndall effect. So, always think about having one more test.

(Video, 10/09/2007)

As shown in this conversation, Lisa regarded a colloid as a mixture that sometimes could have the appearance of a solution, but contains very small invisible substance dispersed throughout another. To confirm her explanation, she diluted muddy water several times and actually demonstrated that a flashlight went through the diluted water which looked like a solution while it didn't go through the real solution.

When Lisa revisited this moment through VAT, she confessed the fact that she was not sure about her explanation of colloids:

I have to admit something to you too. I don't know if I was right about the colloid thing. I was teaching to the test. I have to be honest with you. I've always described a colloid as something that you can't see with your eyes but you can see with light. Is that the true definition of a colloid? (Lisa, Reflective interview #13)

Even though she had taught the concept of suspensions, colloids, and solutions for several years, Lisa began to revisit those concepts by reflecting on her way of teaching it. In addition, this clip reminded Lisa of the fact that Dorothy's teaching those concepts differed from hers when she had observed Dorothy's class. The perceived differences between Dorothy and Lisa were summarized as follows:

I've noticed that when Dorothy is teaching her kids, that she'll have something that looks slightly murky and she'll expect her kids to call it a colloid. Like she

gives them the three and she says “Classify these.” Her kids know one’s a suspension, one’s a colloid, and one’s a solution. My gifted kids would probably think I’m trying to trick them. They were like “Oh.... I don’t know. There are two solutions...” (Lisa, Reflective interview #13)

To Lisa, colloids and solutions could have the same appearance because the particles in colloids are invisible. On the other hand, Dorothy taught that colloids could be distinguishable with ones eyes. Finally, Lisa regarded the slight differences between Dorothy’s and her concepts of colloids as an issue of the scope of definition and expressed her desire to reexamine those concepts.

I thought maybe my definition of a colloid is too narrow. I just kind of assumed that if Dorothy calls it a colloid, that must be a slightly broader definition. You can refer to something that’s just... You think it’s a solution but you can just tell a little bit, you can just sense it with your eyeball, that it’s a colloid. Does that make sense? I have to make myself go there. (Lisa, Reflective interview #13)

The teaching moment and the reflective comment reveal that Lisa had a scientifically accurate concept of colloids. Yet, reflecting on her own teaching prompted Lisa to be more cognizant of what she understood about those chemical concepts.

As discussed so far, the chemistry teachers revisited, broadened, and deepened their science content knowledge through the teacher inquiry project. Investigation of both students’ discussion occurred in the CBIL and their own teaching practice functioned as a catalyst for this. There is no question that teachers’ knowledge of science content is a vital element of effective science teaching. Roth and Chen (2007) point out that “teachers’ science content understandings influence and often limit the ways in which they engage students in learning science” (p. 3).

Empirical findings from the Akerson, Flick, and Lederman's (2000) study supported the importance of teachers' content knowledge in combination with experience. They reported that experienced teachers with strong science content knowledge better elicited and addressed student ideas than an intern teacher who had weaker science content knowledge. In this vein, it is necessary for science teachers to continuously fortify their knowledge of science content throughout a teaching career. This research demonstrates that teacher inquiry can provide teachers with a means to revisit their content knowledge.

Chemistry Teachers' Use of Video Analysis Tool (VAT)

In the two previous sections, I discussed how chemistry teachers made sense of their students' learning and their own teaching through the teacher inquiry project. One of the unique characteristics of the teacher inquiry project in this study was its use of VAT which provided the teachers with a window to look at their own classrooms from a variety of angles both physically and perceptually. In this section, I address the issues surrounding teachers' use of VAT.

Enhanced Reflective Practice

It was evident that VAT provided the teachers with enduring records of the classroom so that they were able to examine students' learning and their own teaching in the CBIL more closely. This process of teacher inquiry through VAT provided a venue for promoting chemistry teachers' reflective practice.

The perspective of regarding teaching as reflective practice and the development of teachers as reflective practitioners has come to be widely accepted in the community of teacher education for the professional growth of teachers (Calderhead & Gates, 1993; Coble & Koballa,

1996; Cruickshank & Metcalf, 1990; Doyle, 1990; Ginsburg & Clift, 1990; Sprinthall, Reiman, & Thies-Sprinthall, 1996; Valli, 1992a, 1992b, 1993). A reflective teacher is “one who is able to analyze their own practice and the context in which it occurs ... is able to stand back from their own teaching, evaluate their situation, and take responsibility for their own future action (Calderhead, 1992, p. 141). That is, through the process of reflection on learning and teaching, teachers can improve their teaching practices.

In this study, VAT offered the teachers numerous opportunities to reflect on their own classrooms. The stories illustrated in the previous two sections indicate that the teachers were able to identify a number of things they had not noticed when they were in the classroom by analyzing the videotaped segments on VAT. As a result, they came to reflect on those moments critically. In addition, during the reflective interview, the teachers were encouraged to describe the clips on VAT in as much detail as possible and to justify their interpretations about the segments. In doing so, they became more attentive to students’ actions and thinking. In turn, they gained awareness of students’ learning which will influence their instructional approaches.

The comparison between teachers’ journals and their reflective interview comments provides more clear supporting evidence that teacher inquiry through VAT promoted their reflective practice. Three teachers in this study originally planned to write journals while the students led the classroom in compliance with the advice of Gallagher-Bolos and Smithenry (2004). The exemplary journal entries written by Gallagher-Bolos and Smithenry are descriptive and reflective in that they wrote about what they heard and saw as well as about what they thought at the moment. Thus, the teachers in the project expected that keeping journals would help them to make sense of what was going on in a classroom that truly incorporated inquiry-based learning.

However, as discussed above, it was not easy for them to take notes because first, they could not hear or see everything happening during the project, and second, they preferred to move around the classroom while students were doing lab. The following comments addressed the concerns that three teachers had surrounding this issue:

With 28 students, you can't hear everything. (Cindy, Reflective interview #12)

I didn't take a lot of notes. That's interesting because in some ways I like this role of taking notes, but I really like being in the lab with them [students]. Today was a day where they really, "We need this, we need that." It was harder to take notes.

(Lisa, Pre / post interview #8)

I couldn't script and write down what I wanted to be writing down because I was running back and forth to get them [students] supplies so much. (Dorothy, Initial interview #1)

The result of these difficulties was reflected in the amount of journal entries that the teachers were keeping every day. Although the teachers made an effort to be deliberate about what was going on during the project, their journals clearly show that it was challenging for them to take notes when the students were doing hands-on activities. In fact, most of the journals were written when the students were sitting in front of the desk and discussing as a whole group, and the length of teachers' journals diminished as the project proceeded over time. The records of the classroom in VAT supplemented teachers' written journals by allowing them to be released from the dual task of teaching and reflecting on teaching and learning without losing the classroom moments. That is, the teachers had more chance to reflect on students' learning rather than to act on and to engage in fine-grained analysis of the classroom when they watched the segments on VAT.

More interestingly, the differences between the content of teachers' journals and reflective comments (produced after seeing video of those sessions) for the same classroom moments demonstrate how VAT spurred them on to reflection. For instance, Figure 5 shows Dorothy's journal and reflective comments in response to the same event in the classroom in which the students came to think about boiling water through the whole class discussion during the *Carter Center Nigerian Trip Project*. The detailed picture of this event was illustrated in the above section (see page 92). The journals that Dorothy took in the classroom were descriptive in that the focus was on who said/did what. On the other hand, Dorothy's comments during the reflective interview were more interpretive in that she came to think about how the students brought their own experiences into the classroom and co-constructed their own meaning. That is, through the inquiry process using VAT, she was able to be more analytical and reflective about what happened in the classroom.

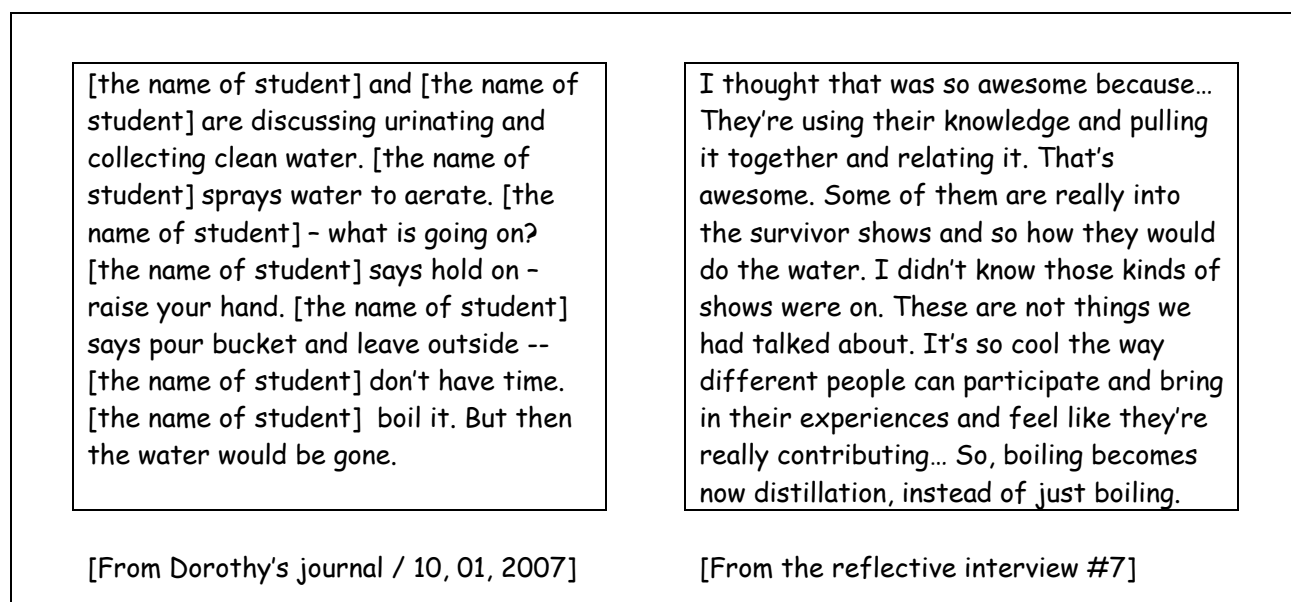


Figure 5. Comparing Dorothy's journal and reflective interview

The other example is captured in Figure 6. Cindy's journals and her reflective interview comments resulted from her watching students' discussion on the second day of the *Carter Center Nigerian Trip Project*. In the class, the students discussed and presented the outside research findings that they had conducted. The contents of the Cindy's journals on this day demonstrate that she wrote down students' utterances as they were in detail. However, it does not show Cindy's thinking about what the students were saying.

Later on, when Cindy went through the reflective interview and watched the same moments through VAT, she did not describe what the students said but expressed her thinking about these moments as shown in the right side of Figure 6. Her first reflective comment indicates that Cindy articulated the purpose of making the students conduct outside research before the lab in the CBIL. The second reflective comment displays her affective responses to the students' performance such as her satisfaction and feeling of lack of students' time management. The last reflective comment reveals that Cindy was able to assess her students' improvement by reflecting on those moments. If Cindy had not revisited these moments through VAT, she might not have thought about those aspects beyond students' discussion of outside research.

- Next, the CM asks class about research they were supposed to do last night... class discusses ideas...

- Who came up with filtration ideas? I read something about using water bottles to filter... I read something about boiling water...CM mentions a procedure that involves stuffing a bottle with cotton, sand, gravel, coffee filter at the bottom then place this over a jar and collect the water that filters through. What about chlorination? How much is safe to add?

- Did anyone research aeration? Is it a chemical or physical change? Website says it's both... that is the conclusion we came to so let's add this in our notebooks.

- Did anyone research the guinea worm? How can we get them out of the water? Maybe we should boil the water.

- Did anyone research anything else about filtration? I found something about sand filtration... tells us how to use it...says it is good for small communities...shows us how to do it.

- Did anyone research Nigerian water? They get the guinea worm from fleas in the water.

- I researched something on chlorination...I researched why chlorine is added to the water anyway...chlorine byproducts in water can cause asthma...

- Did anyone research the conductivity apparatus? No...

- Someone researched how the guinea worm affects you.

[From Cindy's journal / 10, 02, 2007]

1) [By letting the students do research,] the hope is that they find ideas of things that are already being done and give them ideas of things they can actually do in the lab, more in-depth knowledge than what the book that they used to get the different water treatment processes. Hopefully through the research, they're able to find more in-depth applications of those different processes and ways they can modify them to a smaller scale in the lab or put them in series or different things like that.

2) I like that they researched so in depth. I was very happy with the amount of research they did on this project. I think they probably could have compiled their research in a more time efficient manner. They really did spend a lot of time going through each thing. It didn't seem like quite everybody had researched. Maybe some people saved their research and if anybody had the same thing they didn't have to raise their hand. But, I guess they could have compiled it in a quicker fashion, so they could have gotten started on the lab soon.

3) In terms of they did research, they discussed a little bit more as a class and they were all more involved; whereas with Spinach Co they didn't do any research and they really didn't put together much of a presentation. They just kind of all waited around for the managers to tell them what to do and the managers didn't really know what to do themselves. So they just kind of didn't do anything. They did a lot better job this time being more involved in doing the research.

[From the reflective interview #10]

Figure 6. Comparing Cindy's journal and reflective interview

The two cases above do not imply that the teachers were not reflective while they were in the classroom. They might have not had enough time to write down their own thinking; they might have wanted to keep the record of students' conversations and actions as much as possible. However, keeping journals *in* the classroom in the context of wide open-ended inquiry did not allow the teachers to be deliberate about what was going on in the classroom. Rather, they were quite pressed with keeping record of students' comments. Although it was not the original intention of this study to compare teachers' journals which were taken *during* classroom teaching with teachers' interview comments which were mentioned *outside* classroom teaching, this kind of comparison implies that VAT affords a different avenue for the teachers to reflect on classroom events. The video provides the teachers with a unique view of the classroom which is also a post-lesson view so they are already familiar with what has happened. These findings do suggest that the reflections generated as result of watching the video are powerful in aiding the teachers understanding of what happened during the class.

In summary, the use of VAT in the teacher inquiry project provided the teachers with more opportunities to reflect on their own classrooms by allowing them to access accurate representations of their own actual classroom. Furthermore, the process of watching classroom moments through VAT promoted teachers' reflectivity by leading them to think about the goal of the lesson, their own thinking, their teaching practices, the reason for students' actions, their students' learning, etc. The results of other studies support this finding that the use of video in teacher education facilitates teachers' reflective thinking through self-examination of their own classroom (Borko, Jacobs, Eiteljorg, & Pittman, 2008; Yerrick, Ross, & Molebash, 2005). Finally, teachers' sense-making of students' learning and their own teaching practices were informed by their reflection.

Successes

At the beginning of the project, the three teachers were informed of the use of VAT. All of them regarded videotaping classrooms and analyzing them as a potentially meaningful practice for their improvement as teachers regardless of their prior experiences of using video. Cindy was a first year teacher at the time of this study so she had not used video to examine her own classroom before: “I just started teaching in January. I haven’t had a lot of experience with that [video]” (Cindy, Initial interview #1). However, she expected that VAT would function as a medium for capturing the complexity of the classroom that she might have overlooked:

To use video? I guess as far as videotaping the students and then kind of going back, I think it would be helpful because you can’t always... There’s only one of me, especially seventh period, 28 of them, so I can’t always know exactly what’s going on everywhere in the room. I think that having a video and playing back and seeing maybe things that I missed or didn’t pick up on the first time around would be helpful. (Cindy, Initial interview #1)

On the other hand, the two other teachers, Dorothy and Lisa, had previous experience of using video with their successful applications for National Board Certification. When they went through the National Board Certification process, they had to videotape and analyze their teaching for making portfolios. Although Dorothy and Lisa did not use a special video annotation tool such as VAT, they were familiar with the use of video from the past experience. Their retrospect of using video was described in the following two excerpts:

I used the video when I did my National Boards. I had to analyze my teaching with the videos and several things from that. That was good. I like doing it. ... I

did an inquiry lesson and I did a lesson on questioning which I taped and watched myself and evaluated things that happened. (Dorothy, Initial interview #1)

I did that [video] with National Board. It was really very, very interesting. ... It was really kind of cool to learn that that kid was actually aware of his learning and had this coping skill to kind of help. It's interesting. (Lisa, Initial interview #1)

Dorothy and Lisa remembered what they were able to learn from watching and analyzing classroom videos so they were positive about using VAT in the teacher inquiry project. Before the project, Dorothy already perceived the fact that “it [video] being used a whole lot to enhance teaching” (Dorothy, Initial interview #1). In addition, Lisa was enthusiastic about using VAT in this research because the teacher inquiry project did not have any evaluative aspects in it whereas she had to submit the result of video analysis to others to receive the National Board Certificate: “Especially with National Board, I know I’m sending this video in for others to see. So I think that made a difference too. ... I think it would be really cool to watch from start to finish [of the project]” (Lisa, Initial interview #1). That is, all three teachers were fascinated by the teacher inquiry project in order to see how effective the CBIL would be, particularly, by the use of VAT at the beginning stage of this study.

As the teachers went through the teacher inquiry cycle and the reflective interview process, they reported several advantages of using VAT in their investigation of the CBIL. First, all teachers considered the fact that VAT provided them with a window to see the multifaceted aspects of the classroom to be one of its most valuable benefits:

I think it [VAT] is beneficial to watch the kids and to see some of the things that I miss. Especially during that, I was journaling, so sometimes I would be typing something they’d just said and I would miss things they were saying while I was

typing. It was hard to get everything down that they were saying and doing at all times. Even classroom activity, that's something simple where I'm going around and helping different groups, I think it would be beneficial to see, while I'm helping certain people, what everybody's doing. Is everybody working? Are they helping each other? Get an idea of what's going on. Sometimes I wish I had several pairs of eyes to watch all of them. (Cindy, Reflective interview #10)

Cindy's comments reveal that VAT met her initial expectation that using video would help her to recognize more things that happened in the classroom. The quote below confirmed how VAT allowed the teachers to catch classroom activities while they were keeping journals or working with a small group of students during the project:

It's hard to know what's going on in all aspects of the room. The video is a good tool for that. It's very hard for me to sit in one place when there's so much going on. So I found myself walking around, but then, by the end of class, I'd look around and I wouldn't have very many notes. ... The video helps keep track of some other things going on. (Lisa, Final interview #14)

In particular, Lisa considered the use of video to be "extremely useful" in the context of the CBIL because "There's so much going on in the room at once, and it [CBIL] is not at all teacher-focused, so I do not know what's going on in the room all at once" (Lisa, Final interview #14). Dorothy stated that through VAT, she was able to hold and analyze the classroom moments which otherwise would have vanished as soon as she observed in the classroom: "Watching the video is kind of neat... When you just are in class, you're focusing real quickly on what they're doing. Being able to analyze certain things is kind of neat" (Dorothy, Reflective interview #8).

In relation to the first aspect, another advantage the teachers perceived was that VAT helped them to better understand students' learning in the CBIL by allowing them to "see where their thoughts are going; see what they're thinking about and what they're talking about" (Dorothy, Final interview #10). Dorothy stated,

By watching the videos, it was kind of fun to see the kids in action again. It was kind of fun to say "Yeah, they did that." I really get to know kids a lot better a lot quicker. ... Chemistry is kind of a scary topic for some kids. So seeing the clips is good to remind me of the good things they did and the things they got; seeing them use the spectrophotometer; seeing them focus on limiting a certain number of variables; seeing how they were trying to do all that. It was exciting to see them in lab situations and coming up with ideas and seeing what they could do.

(Dorothy, Final interview # 10)

That is, the teachers were able to focus more on what students *learned* from the activities rather than what they *did* during the project. In addition, the teachers regarded VAT as offering more chances to make sense of *individual* student's learning:

When you're just doing it in the classroom, you just see the overall view and which way they're going. But here [VAT], I can see and start focusing on the individual and see how to work on their strengths; how to use their strengths and how to bring them up in other areas. So it's very interesting. (Dorothy, Reflective interview #7)

Through VAT, the teachers also could see "the facial expressions of kids if for some reason I'm not able to see it" (Lisa, Final interview #14) and "how they've changed in their interactions with the class" (Dorothy, Reflective interview #7). The increased awareness of students' gestures and

social interactions consequently gave the teachers deeper insight into how their students learned in the CBIL.

Finally, the teachers valued that VAT could be used as a learning tool in a variety of ways. For instance, Cindy straightforwardly addressed how the use of video triggered her motivation to learn more about teaching and learning science:

It [watching my classroom through VAT] is good, it's good. I definitely...

Especially seeing things again, I know when I don't feel of doing a good job with relating a concept or teaching a particular class. That's just something I'm learning. I guess seeing that kind of reinforces that there are a lot of, a lot of I still need to learn. (Cindy, Reflective interview #10)

The lesson learned through the scrutinized inquiry process using VAT influenced the way teachers adapted their instructional practices:

I think that after having gone through it [teacher inquiry project] and seeing what was successful and what was challenging for the students [on VAT], I think I'd have a little better of an idea how to modify certain labs or certain activities to make it so that it's challenging for them [students] but not frustrating. (Cindy, Final interview #13)

In addition, the teachers considered VAT to be a learning tool for other teachers. Specifically, Dorothy and Lisa, who had played principal roles in professional development programs, came to think about how they would use VAT for beginning teachers. They described the potential of VAT in coaching new teachers in the following way:

You know where it [VAT] really might be a cool tool is when... I think I might use it even more to mentor someone. (Lisa, Final interview #14)

When I teach professional learning now, almost everyone says I wish you had video clips to show of what you mean and how you do this and how you handle this for new teachers. ... It [VAT] would be good for teacher training. If you can get some good cuts for “This is what’s going on. You don’t always know it, but here you can see things to be thinking about.” It’d be great for new teachers, showing them the stuff that they’re doing. (Dorothy, Final interview #10)

Their reflective comments imply that Dorothy and Lisa believed that new teachers can improve their teaching practices by videotaping and analyzing classrooms through VAT.

Furthermore, the teachers perceived the possibility of using VAT with their students’ learning: “I think analyzing the videos can be very informative for the teacher and for the students” (Dorothy, Final interview #10). When the teachers went through the reflective interviews and watched clips on VAT, they oftentimes expressed their desire to show those clips to the students. For instance, Dorothy analyzed the clip in which the students discussed the process of flocculation during the *Carter Center Nigerian Trip Project*. The clip clearly captured that some of the students asked the amount of aluminum sulfate and calcium hydroxide that they needed to use, but the class did not come to a conclusion on this issue. Reflecting on this segment, Dorothy stated,

It’s so funny. I’d love to show them the segment now and have them analyze because they know so much more now. We’ve been doing, for the whole last six weeks, chemical reactions. They know exactly how to determine the amounts.

(Dorothy, Reflective interview #7)

Since the project had been implemented one semester before Dorothy watched this segment, the students knew how to write chemical reactions, how to balance equations, and how to calculate

the amount of reactants and products at the time she reflected this moment. Thus, Dorothy thought it could be a learning experience to show this clip to the students and make them rethink and solve this problem again so that they could realize what they had learned and how they could apply it back to the project.

Later on, in the middle of the final interview, Dorothy came up with an idea to actually make the students use VAT in the CBIL or other types of inquiry labs:

You have another students group watch a student's group and say "This is what they did in lab. What do you think about what they're thinking? How were their thoughts running?" If you did something like that and if you had a tool like a hand-held TV where they could easily watch each others and comment on that. If every group knew they were being videotaped and they had to identify a section of the clip. Find a two minutes section of the clip that you're really proud of the discussion that went on here. We show those to the class. Show that to me. Put together a presentation where you show me evidence of your discussion techniques or your critical thinking when you're trying to solve a problem. That would be a fun way to use it too where the kids use the tool to prove that they are... good thinking. (Dorothy, Final interview #10)

That is, Dorothy wanted the students to use VAT to notice a variety of thoughts of their peers as well as to create clips by themselves as evidence of their performances and thinking. Her idea suggests that VAT could be an effective learning and teaching tool in the inquiry classroom.

As discussed so far, there was a general state of expectancy about VAT among three teachers at the beginning of the study. As the teacher inquiry project continued, the teachers also identified several advantages of VAT; it provided the teachers with "several pairs of eyes" in the

context of open-ended inquiry classroom; it turned teachers' focus more to the students' thinking and learning; and it could be used as a learning tool for themselves, for other teachers, and even for their students.

Challenges

Although the teachers reported advantages of using VAT in the teacher inquiry project, they also noted that reflecting on the captured segments on VAT required a great deal of effort in terms of time. Through the teacher inquiry project, finding appropriate time to analyze videos was a big barrier for both teachers and researchers. Recalling the National Boards Certificates process, Dorothy and Lisa stated,

I liked doing it [using video], it's just incredibly time consuming, watching it and doing it. It's just not worth the time it takes. (Dorothy, Initial interview #1)

It [using video with National Board] was really very, very interesting but, tedious to go back and find stuff. (Lisa, Initial interview #1)

Based on the teachers' prior experiences, they were concerned that videotaping and analyzing the classroom would be extremely time consuming from the beginning of the project: "I would have to videotape almost everything I do and then go back and find pieces. Looking for it would be awful, awfully, time-consuming" (Dorothy, Initial interview #1). Considering their concerns about time issues, I took charge of technical parts of using VAT such as videotaping the classroom, converting files, uploading captured video, and selecting clips. By doing this, the teachers saved the time needed to be trained how to use VAT.

Nonetheless, setting up the time for reflective interviews through VAT became increasingly difficult as the semester progressed. The reason for this condition might be

explained in two separate cases. In the case of Dorothy and Lisa, their work load as department heads was too heavy to take time off to conduct the teacher inquiry project using VAT.

Consequently, they confessed at the final interview, “It’s just so time consuming looking at all the clips” (Dorothy, Final interview #10) and “It’s kind of hard to find the time to go back and look at all that stuff” (Lisa, Final interview #14). Finally, as to the question of their willingness to use VAT or videos for investigating their own classrooms in the future, Dorothy and Lisa answered,

Unfortunately, it [using videos] is not practical enough because there are just not that many hours in a day to be able to do something like that. ... I think it [VAT] could be used on a limited scale just mainly because of the time. Time is a really big issue and it’s getting even more of an issue. (Dorothy, Final interview #10)

That was what I was about to say, right? Do you find the time? I would hope that I would. I don’t think that I would use it [VAT] all the time because you just couldn’t. (Lisa, Final interview #14)

Their statements clearly indicate that teachers would need support in terms of time in the daily life of teaching for successful outcomes from this kind of teacher inquiry project using videos.

On the other hand, Cindy was struggling with day-to-day survival in the classroom as a beginning teacher so it was never easy to find extra time for inquiring into her own classroom using VAT. For instance, Cindy and the researchers set up the time for the reflective interviews after school or during her planning time. However, for Cindy, the planning time was originally planned for observation of other experienced chemistry teachers to learn about teaching a specific subject. Therefore, spending her planning time reflecting on videos itself laid a burden on Cindy. Her concern was depicted in the following statement:

I don't know if it's just me or what. The stress level... it's any other thing that has to be done. Even just today, initially we were going to test in AP. I normally watch Lisa in AP, so I can make sure I know what I'm doing when I teach AP... So anyway when I can't watch her, I'm always a little frantic, just making sure. We try to keep things consistent between the two classes. So it's always a challenge. (Cindy, Reflective interview #12)

The fact that Cindy analyzed and reflected on videos on VAT instead of observing Lisa's class that day was challenging her. Cindy's overwhelming struggle learning about teaching science and the world of teaching influenced her confidence and attitude toward using VAT in the teacher inquiry project as well:

As far as for me, for my teaching style, I think it would be - as painful as it is to watch - beneficial to see. I usually know. I can tell. I still don't feel confident whenever I'm covering something new. I feel a little bit better by the end of the day. By seventh period, I feel like "I've gone through my lesson." It's a good thing you don't film first period because it's probably a total disaster. (Cindy, Reflective interview #10)

The case of Cindy implies that using VAT in the teacher inquiry project should be concomitant with special support for beginning teachers.

Another emerging issue in relation to the time was the time lag between video recording in the classroom and video analysis on VAT. As discussed in the methods chapter, I videotaped the CBIL when the teachers were implementing it during the fall semester of 2007. Then, the teachers and researchers collaborated in reflecting on the videotaped lessons during the spring semester of 2008. This process introduced a gap between the time when the teachers were

actually teaching lessons and the time when they were inquiring into those lessons. Therefore, sometimes the teachers had difficulties making sense of the clips on VAT even though they were able to access the classroom moment as it happened because they had to remember before and after a specific moment for comprehensive sense-making. The reflective comments below represent this aspect:

I don't remember enough about it to know if they're trying to force it in here or if they are doing it. I don't remember them doing it wrong. I don't remember. It's been too long since they've done that. (Dorothy, Reflective interview #7)

I can't remember if they went back and changed it if it was different. I can't remember what the results were. (Cindy, Reflective interview #12)

It is possible that the teachers would not have problems with remembering the lesson taught if they had watched the videotaped classroom from the beginning to the end. However, that was practically difficult for them due to the time constraints as previously discussed. Although I created the clips that constructed an event map on VAT to show an overall flow of the project, the way teachers reflected on them indicates it might be more effective to initiate reflection on the actual classroom practices without delay.

In addition, the teachers perceived this time lag as a drawback of using VAT. Although the teachers made more sense of their students' learning in the CBIL and consequently developed new ideas of teaching through the process of inquiry, they did not have opportunity to use what they had learned from watching videos on VAT in the classroom. Lisa addressed,

I will say it [using VAT] probably would have been better to have done it closer to when the labs were being done because I found myself sometimes trying to remember what was really going on in the class or why what I was seeing was

going on in the class. But probably more importantly, to see something that you didn't know and have no way to use it. At this point, it's like, it's been a long, long time away, so I can use it to improve my teaching for next year; which is very valid. But, I would have loved the double whammy of being able to use it with my students this year. I'm sure I'll find a way. (Lisa, Final interview #14)

That is, for practicing teachers, it is important to utilize the product of their classroom inquiry using VAT as a teaching source in the classroom. Lisa's statement indicates that there could be an optimal time for teachers' reflection on their classroom when video is used as a tool. This research finding provides empirical evidence to support the assumption suggested by Rich and Hannafin (in press) that "limiting time lags between video capture and analysis may become especially important to support teachers' reflection: the longer (and the more effort) required to initiate analysis, the longer (and potentially less likely) a teacher will use the system to analyze and reflect on practice." Overall, the challenges that the teachers addressed in using VAT in the teacher inquiry project revealed unsolved issues regarding what could be the best circumstance for the teachers to conduct classroom research and to use video tools such as VAT.

Summary and Preview

In this chapter, I have presented the findings of this research project that investigated how chemistry teachers made sense of their students' learning and their own teaching practices within the CBIL throughout the process of teacher inquiry project by using VAT. I have also reported the successes and challenges that they perceived in relation to the teacher inquiry project, specially, to the issues surrounding VAT.

The findings illustrate that the teacher inquiry project joining with VAT provided the teachers with a window to see and hear students' innovative rationales behind their actions,

which might not have been noticed in this student-directed classroom. Through the opportunities to make students' thinking visible, teachers expanded their sense-making of students' learning by changing their attribution of students' activities. Teachers also were able to pinpoint a particular student's misconception and to come up with the ideas to tailor their instruction based on individual student's learning needs. In addition, teachers made sense how their students cognitively engaged in the CBIL in various ways. First, the scrutinized inquiry enabled the teachers to make sense of how students brought up and applied their personal experiences in the CBIL and how the negotiation of meaning based on their own experiences scaffolded their own learning. Second, they were also able to articulate the way students transferred what they had learned earlier to the new learning context by closely looking at their discussion and performance in the CBIL. Third, teachers gained understanding of how students expanded their learning beyond the normal chemistry curriculum. Besides the cognitive aspects, the teachers became more aware of the ways students socially interacted in the learning communities. Through the inquiry process, teachers were able to notice the students' social progress in that many of their formerly inactive students enthusiastically participated in the CBIL, students collaborated with each other, and students took an ownership of their own learning. On the other hand, teachers came to consider the influence of occasional dysfunctional social dynamics on students' learning.

In line with gains made with regard to sense-making of students' learning, these chemistry teachers made sense of their instructional practices through the teacher inquiry project. As described, video records on VAT allowed the teachers to notice students' hidden thinking and actions that were not manifested during the enactment of the CBIL. As a result, teachers began to think about the ways to transfer these discovered moments that they detected into potential teachable moments at a later time. In addition, the opportunities to closely examine students'

performance and social dynamics in the CBIL stimulated the teachers to think about a new way of implementing the CBIL by restructuring it or making new additions to it in order to support their students' learning. Throughout the reflective and analytical process of inquiry, chemistry teachers also made sense of themselves teaching in general and teaching science in particular. In general, they became aware of their pedagogical orientation to teaching and learning by themselves, not by being shown by a researcher. In particular, they sought to modify their teaching practices such as finding a better way to explain a specific science concept. Moreover, careful attention to students' discussion and their own teaching practices through the teacher inquiry project led the teachers to revisit their knowledge of science content. Consequently, they were able to elaborate their subject matter knowledge.

The teacher inquiry project using VAT helped the chemistry teachers make sense of their students' learning and teaching practices with evidence that was unambiguous. Specially, video records on VAT played an important role in the current project in that they offered the teachers more opportunities to reflect on their own classrooms by showing moments that were not noticed while the class was in session. In addition to increased amount of reflection, VAT improved teachers' reflective practices in terms of content. The evidence of enhanced teachers' reflectivity was clearly represented in the comparison of their journals and reflective comments. The teachers also reported the benefit of using VAT while they conducted the teacher inquiry project. The greatest advantage of using VAT found in this research was the fact that it provided the teachers with a window to see what was going on in the classroom in which students took a leading role. Teachers also perceived that VAT helped their sense-making of students' learning. Finally, they valued that VAT offered learning opportunities to themselves and recognized its

potential as a learning tool for other teachers and for their students. Nonetheless, the teachers addressed the challenges in using VAT, and much of the concerns were related to time issues.

In the next chapter, I briefly recapitulate the study and discuss those findings within the context of current scholarship. I also provide implications for professional development programs and teacher preparation programs. Finally, I suggest future research agendas.

CHAPTER V

DISCUSSION AND IMPLICATIONS

Revisiting the Study and Chapter Overview

The underlying perspective of this study is that teaching science is both a complex and uncertain activity whose nature is shaped by the immediacy and idiosyncrasy of particular situations. On a daily basis science teachers have to make decisions about *their own* teaching practices in order to make immediate responses to *their own* students in *their own* classrooms. Oftentimes, those decisions begin with challenges, dilemmas, tensions, and questions that science teachers encounter in the never-static moments of teaching. And these decisions are necessary even though the teachers plan a lesson, foresee a possible path of the lesson, and expect certain outcomes from the lesson. But this perspective of how on-the-spot decision making unfolds for science teachers suggests a rationale for the study. Teachers need to conduct ongoing inquiry into their own classroom instruction as a means to make informed decisions as well as to learning from teaching (Cochran-Smith & Lytle, 1993, 1999a; Hammer, 1997; Loughran, 2006; Phelan, 2005; Rosebery & Puttick, 1998).

Beginning with this point-of-view, I investigated the way chemistry teachers made sense of their students' learning and their own teaching practices when they joined the teacher inquiry project by using Video Analysis Tool (VAT). Specifically, three research questions guided the study:

- (1) How do chemistry teachers make sense of students' learning of science?
- (2) How do chemistry teachers make sense of their approaches to instructional task with regard to student learning?
- (3) How do chemistry teachers adapt and use teacher inquiry practices through VAT?

To answer those questions, I employed a qualitative case study approach (Erickson, 1986). At the beginning of the study, three participating teachers chose the focus of the project; they decided to closely examine their own classroom in which Community-Based Inquiry Lessons (CBIL) were implemented. I, as a researcher, facilitated the teacher inquiry activities by videotaping two projects of the CBIL, producing clips on VAT, and watching and reflecting the clips on VAT with the teachers. In order to understand sense-making actions by the chemistry teachers, I collected various types of data through multiple methods such as videos, interviews, classroom observations, and documents to confirm the trustworthiness (Guba & Lincoln, 1989). Prior to publication, I will send the findings of this study to all participating teachers for feedback and modifications as a member check. I conducted my data analysis in two phases. The first phase data analysis included video analysis to create the clips on VAT, which produced an event map of the classroom activities (Green & Wallat, 1981; Kelly & Crawford, 1997; Smithenry & Gallabher-Bolos, 2008). For the second phase data analysis, I conducted inductive analysis utilizing grounded theory approach and constant comparative methods (Glaser & Strauss, 1967).

In the following sections of this concluding chapter, I discuss the major findings of this study and draw implications for teacher education for both in-service and pre-service teachers. Finally, I present possible directions for further research.

Discussions and Implications of the Study

The findings of this study reveal that the chemistry teachers became more aware of their students' learning of science in the both cognitive and social aspects through the teacher inquiry project. The teachers revisited the classroom moments of the CBIL by examining video segments of the events using VAT and were therefore able to make sense of those moments in a way that was unique to their experience as teachers. Specially, the teachers in the current study created an opportunity for their whole class of students to follow their collective ideas in order to solve a scientific problem. And the students did this without the typical directions normally given by the teachers. This form of open-ended inquiry created a chaotic classroom context in which there was too much activity for the teachers to attend. As the teachers went through the teacher inquiry cycle using the edited video, they were able to perceive not only previously unseen students' actions but also perceive previously unrealized aspects of students' thinking and reasoning. The opportunities to notice more things that had happened in the classroom prompted teachers to focus more on students' learning which was the main focus of the teacher inquiry project. Through the process of inquiry, these chemistry teachers made sense of the range of misconceptions that individual students had brought into the classroom. The teachers also gained understanding of how the students cognitively engaged in the CBIL by examining the ways students applied, transferred, and expanded their experiences and knowledge to the new learning situation. In addition, they became conscious of how students' social interactions in the learning community influenced the process and outcome of students' learning.

The findings reported above support the claim that teachers need an obvious focus, guideline, or scaffold for effective inquiry activities (Borko, Jacobs, Eiteljorg, & Pittman, 2008; Roth & Chen, 2007; Stein, Simith, Henningsen, & Silver, 2000). Through the teacher inquiry

project, I, as a facilitator, made an effort to turn the chemistry teachers' attention to students' actions, talks, ideas, and understanding by asking questions. As a result, all participants, even a beginning teacher, deeply reflected on the issues related to students' learning. This is significant in that teachers' perception and judgment of students are major factors for successful instruction (Hammer, 1997). By challenging teachers' "typical focus on the activities and teacher actions in science lessons" (Roth & Chen, 2007, p.8), the current teacher inquiry project led the teachers to be aware of students' cognitive and social status in relation to the learning of chemistry to which they would not have otherwise been able to attend.

In addition, the research findings demonstrate that the chemistry teachers justified and modified their own instructional practices in terms of their gained sense-making of students' learning. By identifying unexpected moments and innovative students' ideas, the chemistry teachers came up with ideas for transforming those moments and thought into potentially teachable moments. A close look at the students' learning stimulated the teachers to think about why the students acted in certain ways, and this inquiry also provoked them to modify the CBIL in new ways to improve students' performance. Examining students' discussion served as a catalyst for the teachers to revisit, expand, and intensify their own science content knowledge. Although the major focus of the teacher inquiry project was aimed at the study of students' learning in the CBIL, the chemistry teachers asked themselves deep questions about their own teaching practices as well. By scrutinizing and analyzing their own instructional approaches, the teachers became conscious about their pedagogical orientation and sought out different ways of teaching chemistry. Those findings offer empirical support to Hiebert, Morris, Berk, and Jansen's (2007) argument that when teachers acquire information regarding student learning as a

result of inquiry into their practice, teachers will make instructional decisions based on this evidence rather than only using evidence acquired through their perceptions.

The findings which form a relationship between teachers' sense-making of students' learning and their own teaching practices support the empirical studies that characterize teaching as a form of inquiry. For instance, Kang (2007) reported that 14 elementary in-service teachers gained more understanding of students' learning of science in terms of conceptual change pedagogy as a result of engaging in action research. The teachers in her study also considered that action research provided an opportunity to reflect on as well as change their teaching practices. The book by Rosebery and Warren (1998) includes many cases that illustrate how elementary and middle school teachers made sense of their students' learning and their own teaching practices while participating in the inquiry-based approach professional development program called the *Video Case Studies in Scientific Sense Making Project*. In these two studies, the outcome of teacher inquiry was explained by the researchers. On the other hand, the studies of Bell (1993), Hammer (1997), Hampson (2000), and McGonigal (1999) illustrated the way teachers made sense of their own students' learning and teaching using their own voices as the primary tool for writing about their classroom inquiry. All these studies reported teachers' positive learning experiences.

Besides confirming the positive outcomes from teacher inquiry projects with regard to understanding students' learning and teachers' instructional practice, this study contributes support for existing bodies of knowledge on teacher inquiry in several additional ways. First, the current study addresses the *process* of chemistry teachers' sense-making with regard to both learning and teaching science as they have gone through this teacher inquiry project rather than focuses on just the outcomes of teacher inquiry. As mentioned previously, literature on teacher

inquiry, including studies dealing with both teacher research and teacher action research, reported that instructional experiences in which teachers engaged in inquiry activities of their teaching, enhanced teachers' understanding of the classroom. In some cases, researchers made this assertion based on teachers' reflective comments on their experiences with the inquiry activities without establishing that the teachers also had a clear picture of their classroom. For instance, investigating elementary teachers' inquiry-based action research experiences, Cox-Petersen (2001) concluded that "teachers gained substantial knowledge related to science teaching and learning" (p. 110). Although this study provided significant excerpts from the data base (open-ended survey and written reports by teachers) as evidence, it did not show *how* these teachers became to know better about either teaching or learning of science when they conducted inquiry in their classroom. The current study illustrates *what* the teachers learned from the teacher inquiry project as well as *how* their learning processes occurred throughout the teacher inquiry project. In doing so, the study provides a more sophisticated picture of the teachers' learning as a result of their classroom inquiry experiences.

And further, with relation to this, this study provides an insight into the activity of inquiry into teaching and learning, specially, into the scope of teacher inquiry. Similar to the physics teachers in Hammer and Schifter's (2001) study, the chemistry teachers in this study focused on diverse aspects of students' learning varying from their rationale, misconceptions, cognitive engagement to their social interactions within the student groups of the CBIL. This finding supports Hammer and Schifter's claim that the scope of teacher inquiry is much broader than educational research that focuses on a specific area of interest because teachers' concerns about students are altered "from student to student, class to class, and day to day" (2001, p. 454). In the study being reported here, an inquiring ever-changing situation of the CBIL required the

chemistry teachers to interpret their students' actions in a variety of ways even though they were given the focus of students' learning. Hammer and Schifter regarded that this broad scope of teachers' awareness reflects their "intellectual resources they have immediately available for interpreting students' knowledge and reasoning" (2001, p. 445). This study did not measure the chemistry teachers' intellectual resources such as their experiences, knowledge, beliefs, attitude, perceptions, pedagogical expertise, etc., but the breadth of their reflective comments and sense-making indicates that the teacher inquiry project facilitated the teachers' ability to utilize them for conducting classroom inquiry.

Third, the current study is unique in that the teacher inquiry project was implemented in the normal setting. Review on the literature about in-service teacher inquiry revealed that most of the teacher inquiry reported by researchers was situated in degree-awarding programs (e.g., Briscoe & Wells, 2002; Kang, 2007) or funded professional development programs (e.g., Rosebery & Puttick, 1998). In contrast, the teachers in this study genuinely decided to conduct the teacher inquiry project when they gained the opportunity. There was no obligation demanded externally such as making a portfolio which is usually required in such programs. Therefore, this study addresses the way teacher inquiry preceded in regular circumstances of science teaching. This unique context of the project implies that teachers' willingness and commitment to engage in classroom research should be considered as an important factor in developing "a stance of inquiry" (Ball & Cohen, 1999).

On the other hand, it was evident that the use of VAT played an important role in this study. There is a growing consensus regarding the value of using video for teachers to examine their own classroom (Brophy, 2004; Sherin & van Es, 2005). Research showed that many professional development programs that included teacher inquiry activities as a component used

a video as a tool for collecting classroom data (Borko et al., 2008; Rosebery & Puttick, 1998). In the current study, the video record on VAT exposed a lot of things that were passed over by the teachers throughout the project. It also enabled the teachers to seize the particular moment in the classroom so that they were able to use it as data instead of relying on memory. Shulman (2002, p. 62) asserted “one thing that makes learning from experience terribly difficult is that experience is like dry ice: it evaporates at room temperature. As soon as you have it, it’s gone.” In this study, the dry ice of classroom moments was “frozen” by VAT. Thus, the chemistry teachers took the time to closely examine and construct interpretations of their student learning and their own teaching practices in the CBIL. As a result, teachers’ sense-making through the teacher inquiry project was firmly grounded in evidence, which formed groundwork for teachers’ future lesson.

In addition, the findings of this study reveal that the teacher inquiry project using VAT provoked teachers’ reflection in terms of both amount and content. The increased opportunities for reflection were a direct result of how the VAT was used to capture more segments which otherwise were not identified or had rapidly faded from the teachers’ memories. But the increased opportunities for reflection were also a result of the teachers’ commitment to allot separate time for reflective interviews. The journals recorded by the teachers during the implementation of the CBIL demonstrated that it was not a simple task for them to create a space for reflection while teaching. The teacher inquiry project, which proceeded by using VAT along with stimulation of the teachers to respond to question prompts, enabled the teachers to take a step back from their teaching moments and encouraged their attention to students’ learning and their own teaching practices. By doing so, the teachers began to think about many taken-for-granted moments with critical and reflective eyes, and in turn came up with new ways of

implementing their instruction. This study did not directly evaluate teachers' reflective thinking or measure their level of reflectivity. However, considering the fact that the most mature level of reflective thinking involves reasoning in order to make decisions, considering contexts in which experiences were undertaken, and possibly changing practices (e.g., Hatton & Smith, 1995; Sparks-Langer, Simmons, Pasch, Colton, & Starko, 1990; Ward & McCotter, 2004), the process of teacher inquiry provided the teachers with a venue for developing reflective practices. This finding also supports the claim that these teacher inquiry projects have a potential for encouraging reflection by teachers (Carr & Kemmis, 1986; Sparks-Langer & Colton, 1991; Zeichner, 1986, as cited in Hatton & Smith, 1995).

Finally, why was it meaningful for the participating teachers to engage in the teacher inquiry project? The process of teachers' sense-making related to students' learning and their own teaching practices demonstrates that all three teachers learned more about their students, their own teaching, and the successes and challenges of the CBIL as they went through the project. Someone might consider the learning outcome of these teachers as having gained some sort of practical knowledge. However, Cochran-Smith and Lytle (1993, 1998, 1999a) argued that the distinction between formal, theoretical, or scientific knowledge for teaching, which comes from authorities outside of teaching profession, and a practical, personal, or craft knowledge, which is generated from teachers, is not appropriate in considering teacher inquiry. Rather, they insisted on the need for "a fundamental reconceptualization of the notion of knowledge for teaching" (Cochran-Smith & Lytle, 1993, p. 43). Drawing on McEwen's (1991) work, Cochran-Smith and Lytle (1998) place teacher inquiry within the perspective that leads from the assumption that "practice is practical *and* theoretical (italic in original, p. 30). That is, when teachers inquire into their own classroom, they make sense of it by using their own idiosyncratic,

emic perspectives, and this process generates both theoretical and practical knowledge. In any event, this knowledge about “the extraordinarily complex domain of teaching” (p. 31) produced by teacher inquiry is more helpful and applicable for teachers themselves. The aim of this study was not an analysis of the forms and domains of teachers’ knowledge. However, the teachers’ sense-making of the classroom shows how they generate their authentic knowledge for teaching that enlightens new insights of teaching and learning science through the teacher inquiry process.

Implications for Teacher Education

It should be noted first that it is difficult to generalize this qualitative case study of three chemistry teachers. However, based on the experiences of these teachers and the researchers who conducted the study, I offer the following suggestions for science teacher education.

First, the current study suggests that science teachers need a regular opportunity to engage in the inquiry into the classroom for better understanding of their students’ learning and for validating their teaching practices with regard to those students’ learning. Specially, in the science classroom in which students engage in open-ended inquiry such as CBIL, teachers usually cannot predetermine the flow of students’ learning and exact form of lessons in advance. Hammer (1997) called teaching science in that situation “discovery teaching” in the sense that science teachers have to “discover how student engage the materials and what they might accomplish” (p. 502) in a particular situation to inform their instructional decisions. The strong emphasis on student inquiry in the science education reform era (e.g., NRC, 1996) demands science teachers to be well grounded in a stance of inquiry into their own classroom. Teaching from a stance of inquiry enables science teachers to “read” teaching and learning (McDonald,

1992) in complex and ambiguous circumstances so that they can adapt their instructional approaches in order to facilitate students' learning.

In addition, such inquiry opportunities for science teachers need to establish a clear focus around meaningful topics (Wilson & Berne, 1999) considering the fact that teachers showed frustration in making meanings to miscellaneous aspects of classroom when they were first invited into the inquiry activities (Stein et al., 2000). The focus of the teacher inquiry project in this study was students' learning in the CBIL based on the participating teachers' interests as well as the research's belief that teaching should be guided by evidence of each students' learning. Research has illustrated that pre-service or beginning teachers have a tendency to focus more on themselves than on students' learning when they have a chance to investigate their own classroom (Davis, Petish, & Smithey, 2006). Others suggested the possibility that even experienced teachers do not pay attention to the moments in which students need support for learning because their teaching practice are based on "ready-to-apply routines" (Krull, Oras, & Sisak, 2007, p. 3). In the current study, the teachers showed both of these patterns. When Cindy, who was a first year teacher, took part in the first reflective interview, the first thing she noticed on VAT was herself and said "I didn't know I did 'hum' so many times" (Cindy, Reflective interview #10). On the other hand, Lisa, who had 17 years teaching experiences, confessed that she was so used to teaching the same topics that sometimes it was not easy for her to perceive something as new:

I think I'm starting to get a little bored myself with some of the topics we're choosing. If you had asked me the previous question [about teachable moments] some years ago, I probably would have had a million things to say, but like, I've seen it all. So it's hard to... I don't think it's fair to the students that I'm no longer

impressed. ... But, I'm getting out of the honeymoon phase. (Lisa, Final interview #14)

That is, being attentive to students was not a simple task for both a beginning and experienced teacher. However, through this study, the video records on VAT and researchers' facilitation led the teachers constantly to turn their attention to students' learning in the CBIL. In this regard, it is clearly needed to set up the focus to examine when teacher inquiry activities are planned.

Second, the findings of this study suggest that teachers need to receive various types of supports in conducting classroom inquiry. For the systematic and intentional teacher inquiry, teachers need to access means that assist them to collect and analyze classroom data. The current study shows that VAT served as an effective tool for teacher inquiry in that it allowed the teachers to collect classroom data such as the actions and talks of students and teachers *in situ*. The videotaped classroom moments provided a foundation for close inquiry into students' learning and teaching practices.

The researchers also provided supports for enacting the teacher inquiry project by helping the procedures of classroom data collection and facilitating reflective interviews. The important role of facilitators in teacher inquiry is addressed in many empirical studies (Borko et al., 2008; Briscoe & Wells, 2002). For instance, Borko and her colleagues reported that the facilitators, who chose the analytic focus of the workshop, selected the clips from videos, and framed the conversations among teachers, positively impacted on professional development using video from teachers' own classroom. In addition to the support from outside the teacher community, collegial supports from other teachers enhance teacher inquiry (e.g., Kang, 2007; Rosebery & Warren, 1998).

In relation to teachers' "intellectual resources" (Hammer, 1997; Hammer & Schifter, 2001), researchers proposed to provide education theories of learning to the teachers to support their sense-making of students' learning (Hammer, 1997; Hammer & Schifter, 2001; Rosebery & Puttick, 1998). Actually, the reflective comments of participating teachers in the study implied many learning theories such as conceptual change learning, community of learners, cognitive and social constructivism, inquiry learning, etc. even though they didn't clearly mentioned them. This suggests that teachers need support in employing those theories as an analytical lens for their sense-making of the classroom.

The tools such as VAT, facilitators, and learning theories as intellectual resources support the procedural aspect of teacher inquiry. On the other hand, the current study suggests that teachers need extensive contextual support to carry out classroom inquiry. The findings clearly showed that the major concern of chemistry teachers was time to conduct inquiry in relation to VAT in the normal conditions of teaching. Cox-Petersen (2001) also reported that time was the most challenging aspect for pre-service teachers who participated in inquiry-based action research experiences. In this regard, it is suggested that teachers' loads should be reduced to make time for classroom inquiry (see Hammer, 1997, for a similar suggestion). Stokes (2001) emphasized the need to integrate time for inquiry into the school day, rather than burden teachers with additional after-school work. In addition to time issue, Stokes argued that the school context should be changed to support teacher inquiry by criticizing the fact that "most teachers experience precious little support in their workplaces for critically inquiring into their practices. "Professional culture of inquiry" remains less a reality than a phantasmagoric idea" (p. 142).

While teachers need all of the above supports for effective inquiry, the experiences of Cindy in this study also suggest that support for beginning teachers should be differentiated from

that for experienced teachers. With the self-perception of “a new teacher”, Cindy often expressed her devastating level of stress throughout the teacher inquiry project: “I had reservations in the beginning because I knew I was already feeling overwhelmed at the beginning of the year” (Cindy, Final interview #13). Research shows that beginning teachers face massive problems and needs during their first year of teaching. For instance, six environmental difficulties commonly reported by beginning teachers were (1) difficult work assignments, (2) unclear expectations, (3) inadequate resources, (4) isolation, (5) role conflict, and (6) reality shock (Gordon & Maxey, 2000). In addition, beginning science teachers have particular subject-related concerns such as inquiry lessons, laboratory instruction, and understanding of the nature of science among students (Luft & Patterson, 2002; Luft, Roehrig, & Patterson, 2003). Therefore, in order to aid beginning science teachers to fully embrace the notion of teaching as a form of inquiry, the issues and needs they encounter should be resolved at the same time they engage in teacher inquiry.

Third, this study suggests an agenda for pre-service teacher preparation programs even though the participants of the study were all in-service teachers. That is, pre-service science teachers need to practice and develop a stance of inquiry. A teacher education program cannot deliver what teachers should know and be able to do as a predetermined set of knowledge or skills to pre-service teachers no matter how well designed the program is because of the nature of teaching. The integrated knowledge that science teachers need is developed over time, so pre-service teachers need to learn how to learn from and within their classroom. The opportunities to examine students’ learning and their own teaching would allow pre-service science teachers to learn how to perceive specific classroom moments as a chance of learning about their knowledge of science, student learning of science, and instructional approaches. Teacher educators may use

student teaching experiences or cases as a learning tool for cultivating the stance of inquiry of pre-service teachers. In doing so, pre-service teachers can perceive themselves not as a “consumer of knowledge about teaching” but as a “producer of knowledge about teaching” (NRC, 1996, p. 72).

Suggestions for Further Research

I suggest many different avenues of future research based on the findings of this study. One area of investigation would be further exploration of the nature of teacher inquiry. The current research addresses the process of chemistry teachers’ sense-making of students’ learning and teaching while they engaged in the teacher inquiry project and what they learned from those experiences. The findings are presented as a result of cross case analysis, but I could sense that there existed differences in the way each teacher made sense about their own classroom. Thus, it would be valuable to investigate how the “intellectual resources” that each teacher possesses, such as their experiences, knowledge, beliefs, attitude, perceptions, pedagogical expertise, commitment, etc., influenced on this sense-making process and the learning outcomes of teacher inquiry. This effort could address whether beginning teachers’ and experienced teachers’ approach teacher inquiry differently.

In addition to the individual level, future research should deal with the contextual factors that may influence teacher inquiry. The findings of this study have found both success and challenges that the participating teachers encountered when they engaged in the teacher research project. Therefore, the question we may need to ask is: What would be the optimal conditions for science teachers to conduct classroom inquiry, that is grounded in the day-to-day realities of classroom practice? To answer this question will help those who design and implement

professional development programs or pre-service teacher preparation programs which consider teacher inquiry as an important component for teacher learning. Another area of possible research in relation to student learning includes the relationship between characteristics of students and the process and outcome of teacher inquiry. Research on teacher inquiry on both individual and contextual level will provide a holistic and clear picture of teachers' sense-making and learning through teacher inquiry.

A second area of future research deals with the use of video in teacher inquiry into their own classroom. The current teacher inquiry project used VAT as a special tool that increased the feasibility of collecting classroom data and that enabled the teachers to reflect and analyze specific moments of the CBIL. The findings show that there were significant differences between teachers' reflection through VAT and through journals, which were taken in the classroom. Even though the work in the field of professional development that incorporated video usually reported the benefits of using video in teacher learning (e.g., Borko et al., 2008; Sherin & van Es, 2005; Sherin & Han, 2004), there is a dearth of research that compares how video artifacts and other types of artifacts influence teachers' inquiry activities and reflection. Therefore, it would be beneficial to explore how using videos in teacher inquiry causes different results of teacher learning in contrast to using other types of artifacts in order to confirm the advantage using a video tool such as VAT.

In this study, I, as a researcher and facilitator, videotaped the classroom activities and analyzed the video data as the first step for teacher inquiry considering the time limitation. Although I made an effort to create clips on VAT, which showed the flow of the CBIL not by choosing a significant moment for me, it is possible that my subjectivity acted on the process of selecting classroom moments. Therefore, future studies might consider the ways in which

particular moments are selected for deep analysis and reflection. In relation to sense-making of students' learning, it would be valuable to examine what science teachers count as evidence of students' learning when they are given an opportunity to create clips on VAT. It would be also interesting to see if there are differences in selecting a specific instant for inquiry between teachers and researchers. Those attempts will expand our understanding of how science teachers make their instructional decision in relation with the evidence of students' learning through the inquiry process. In addition, further research might consider the time lags between video recording in the classroom and the video analysis on VAT. As mentioned in the finding chapter, the teachers expressed concern with regard to the time lags throughout the project that caused them challenges in examining the classroom moments comprehensively. Therefore, such studies might investigate whether and how the opportunities to analyze and reflect on the classroom practices more readily would affect teacher inquiry.

A third area of possible research which the current study suggests is the influence of teacher inquiry on their actual teaching practices and students' learning. The findings of this study reveal that chemistry teachers became more aware of what and how their students learned in the CBIL. In addition, they developed ideas about teaching the CBIL differently although they did not really have a chance to put the ideas into action. How the teachers would transfer their gained understanding of learning and teaching science into actual instructional practices was beyond the scope of this study. Thus, future research needs to include the issues of the product of teacher inquiry in terms of improvements in teaching and learning, which are the ultimate goals of educational research.

Concluding Remarks

By doing this kind of learning [through the teacher inquiry project], I get to know the personalities of the kids; I get to know their strengths and weaknesses as far as leadership roles; I get to see how their ideas flow; I kind of get to see their misconceptions; I get to see how many of them have experiences and how they can relate it to what they're learning now. I really kind of get a world-wide view of their perspective and how they learn and what experiences have shaped their learning and how they use their experiences to make those connections in building for transfer. I think that's the most beautiful thing of this [project]. It is so fun to see [through VAT]. (Dorothy, Reflective interview #7)

What Dorothy had learned through the teacher research project was not an application of the knowledge she obtained during her pre-service teacher preparation programs or professional development programs. Rather, it was Dorothy's own sense-making of her students in her classroom while drawing upon her intellectual and professional resources. Her reflective comments encapsulate what the participating teachers learned in and from their experiences of engaging in classroom inquiry.

By illustrating the processes of three chemistry teachers' sense-making, this study suggests that teacher inquiry can be a means for science teachers to expand their sense-making of students' learning, which is among the most, if not the most, essential factors to facilitate students learn science with understanding. Being responsive to students' current understandings, difficulties with learning, rationales behind actions and their group dynamics is not an easy task,

especially in a student-centered classroom in which students are engaged in an inquiry approach to learning science. However, the current study provides an insight for us into how teacher inquiry with video technology can support science teachers' understanding of students in a complex and dynamic context of teaching science. Moreover, the teacher inquiry project demonstrates it can be a viable tool for science teachers to monitor and adapt their teaching practices in response to recognition of students' strengths and weaknesses.

This study was my inquiry *about* chemistry teachers' inquiry. Throughout the study, I made an effort to make the process and outcome of teacher inquiry explicit. It led me to see the potential of teacher inquiry in supporting teacher learning and improving teaching practices. In doing so, this study added to the knowledge base of teacher inquiry. On the other hand, this study was chemistry teachers' inquiry *for* themselves. With their own motivation to know the influence of new inquiry lessons on students' learning, the teachers made an effort to make students' learning and their thinking visible throughout the teacher inquiry project. The inquiry-generated sense-making was valuable and powerful for them because it was specific to their students, context, and themselves. The unique insider perspectives and voices of teachers also contributed to the knowledge base for teaching.

By conducting research *about* and *for* teachers, I tried to build a partnership between research and teaching, between researchers and classroom teachers, and between theory and practice. I, as a former chemistry teacher, consider teacher inquiry as promissory in building our knowledge base for teaching and learning as well as in actuating teaching practices and student learning. I look forward to "a day when collaboration between the academy and the classroom teacher is a commonplace of professional science teaching" (McGoey & Ross, 1999, p. 120).

REFERENCES

- Abell, S. K., & Bryan, L. A. (1997). Reconceptualizing the elementary science methods course using a reflection orientation. *Journal of Science Teacher Education*, 8, 153-166.
- Abell, S. K., & Cennamo, K. S. (2004). Video cases in elementary science teacher preparation. In J. Brophy (Ed.), *Advances in research on teaching: Vol. 10. Using video in teacher education* (pp. 103-130). Oxford, UK: Elsevier.
- Akerson, V. L., Flick, L. B., & Lederman, N. G. (2000). The influence of primary children's ideas in science on teaching practice. *Journal of Research in Science Education*, 37(4), 363-386.
- American Association for the Advancement of Science (AAAS). (1993). *Benchmarks for science literacy*. New York: Oxford University Press.
- Anderson, L. M., & Bird, T. (1995). How three prospective teachers construed three cases of teaching. *Teaching and Teacher Education*, 11(5), 479-499.
- Appleton, K. (1997). Analysis and description of students' learning during science classes using a constructivist-based model. *Journal of Research in Science Teaching*, 34(3), 303-318.
- Appleton, K. (2003). How do beginning primary school teachers cope with science? Toward and understanding of science teaching practice. *Research in Science Education*, 33, 1-25.
- Assessment Reform Group. (2002). *Assessment for learning: 10 principles*. London: Assessment Reform Group.
- Ball, D. L. (2000). Working on the inside: The using one's own practice as a site for studying teaching and learning. In A. E. Kelly & R. A. Lesh (Eds.), *Handbook of research design*

- in mathematics and science education* (pp. 365-402). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.
- Ball, D. L., & Cohen, D. K. (1999). Developing practice, developing practitioners: Toward a practice-based theory of professional education. In L. Darling-Hammond & G. Sykes (Eds.), *Teaching as the learning profession* (pp. 3-31). San Francisco, CA: Jossey-Bass.
- Banilower, E. R., Heck, D. J. & Weiss, I. R. (2007). Can professional development make the vision of the standards a reality? The impact of the National Science Foundation's local systemic change through teacher enhancement initiative. *Journal of Research in Science Teaching*, 44(3), 375-395.
- Banilower, E. R., Smith, P. S., Pasley, J. D., & Weiss, I. R. (2006). The status of K-12 science teaching in the United States: Results from a national observation survey. In D. Sunal & E. Wright (Eds.), *The impact of state and national standards on K-12 teaching*. Greenwich, CT: Information Age Publishing.
- Barnatt, J., Cochran-Smith, M., Friedman, A., Pine, G., & Baroz, R. (2007). *Inquiry on inquiry: Practitioner research and pupils' learning*. Paper presented at the annual meeting of the American Educational Research Association, Chicago, IL.
- Bell, D. (1993). With an eye on the mathematical horizon: Dilemmas of teaching elementary school mathematics. *Elementary School Journal*, 93, 373-397.
- Black, P., & Wiliam, D. (1998). Inside the black box: Raising standards through classroom assessment. *Phi Delta Kappan*, 80(2), 139-148.
- Bodgan, R. C., & Biklen, S. K. (2003). *Qualitative research for education: An introduction to theory and methods*. (4th Ed. pp. 147-184). Boston: Pearson Education Group.

- Borko, H. (2004). Professional development and teacher learning: Mapping the terrain. *Educational Researcher*, 33(8), 3-15.
- Borko, H., Jacobs, J., Eiteljorg, E., & Pittman, M. E. (2008). Video as a tool for fostering productive discussions in mathematics professional development. *Teaching and Teacher Education*, 24(2), 417-436.
- Borko, H., & Putnam, R. T. (1996). Learning to teach. In D. C. Berliner & R. C. Calfee (Eds.), *Handbook of educational psychology* (pp. 673-708). New York: Simon & Schuster Macmillan.
- Boz, N., & Boz, Y (2008). A qualitative casestudy of prospective chemistry teachers' knowledge about instructional strategies: Introducing particulate theory. *Journal of Science Teacher Education*, 19, 135-156.
- Briscoe, C., & Wells, E. (2002). Reforming primary science assessment practices: A case study of one teacher's professional development through action research. *Science Education*, 86, 417-435.
- Brophy, J. (Ed.). (2004). *Advances in research on teaching: Vol. 10. Using video in teacher education*. Oxford, UK: Elsevier.
- Bryan, L. A. (2003). Nestedness of beliefs: Examining a prospective elementary teacher's belief system about science teaching and learning. *Journal of Research in Science Teaching*, 40(9), 835-868.
- Bryan, L. A., & Abell, S. K. (1999). Development of professional knowledge in learning to teach elementary science. *Journal of Research in Science Teaching*, 36(2), 121-139.
- Bryan, L. A., & Recesso, A. (2006). Promoting reflection with a web-based video analysis tool. *Journal of Computing in Teacher Education*, 23(1), 31-39.

- Calderhead, J. (1992). The role of reflection in learning to teach. In L. Valli (Ed.), *Reflective teacher education: Case and critiques* (pp. 139-146). Albany, NY: State University of New York Press.
- Calderhead, J., & Gates, P. (1993). Introduction. In J. Calderhead & P. Gates (Eds.), *Conceptualizing reflection in teacher development* (pp.1-10). London: The Falmer Press.
- Capobianco, B., Horowitz, R., Canuel-Browne, D., & Trimarchi, R. (2004). Action research. *The Science Teacher, March*, 49-53.
- Carpenter, T. P., Blanton, M. L., Cobb, P., Franke, M. L., Kaput, J., & McClain, K. (2004). *Scaling up innovative practices in mathematics and science*. Madison, WI: Wisconsin Center for Educational Research / National Center for Improving Student Learning and Achievement in Mathematics and Science.
- Carr, W., & Kemmis, S. (1986). *Becoming critical: Education, knowledge and action research*. London: Falmer Press.
- Carter, K. (1990). Teachers' knowledge and learning to teach. In W. R. Huston (Ed.), *Handbook of research on teacher Education* (pp. 291-310). New York: Macmillan Publishing Company.
- Charmaz, K. (2000). Grounded theory: Objectivist and constructivist methods. In N. Denzin & Y. Lincoln (Eds.), *Handbook of qualitative research* (pp. 509-535). Thousand Oaks, CA: Sage.
- Charmaz, K. (2002). Qualitative interviewing and grounded theory analysis. In J. Gubrium & J. A. Holstein (Eds.), *Handbook of interview research* (pp. 675-694). Thousand Oaks, CA: Sage.

- Champagne, A. B., Klofer, L. E., & Gunstone, R. F. (1982). Cognitive research and the design of science instruction, *Educational Psychologist*, 17(1), 31-53.
- Chen, C., Schwill, K., & Wickler, N. I. (2007). *The use of videocases in in-service teacher professional development: The STELLA project*. Paper presented at the annual meeting of the National Association Research in Science Teaching, New Orleans, LA.
- Clarke, A., & Erickson, G. (2003). Teacher inquiry: A defining feature of professional practice. In A. Clarke & G. Erickson (Eds.), *Teacher inquiry: Living the research in everyday practice* (pp. 1-6). New York, NY: RoutledgeFalmer.
- Clark, C. M., & Peterson, P. L. (1986). Teachers' thought processes. In M. C. Wittrock (Ed.), *Handbook of Research on Teaching* (3rd ed., pp. 255-296). New York: Macmillan.
- Coble, C. R., & Koballa, T. R. (1996). Science Education. Handbook of research on teacher education. In J. Sikula, T. J. Buttery, & E. Guyton (Eds.), *Handbook of research on teacher education* (2nd ed., pp. 459-484). New York, NY: Association of Teacher Educators.
- Cochran-Smith, M., & Lytle, S. L. (1993). *Inside/outside: Teacher research and knowledge*. New York, NY: Teachers College Press.
- Cochran-Smith, M., & Lytle, S. L. (1998). Teacher research: the question that persists. *International Journal of Leadership in Education*, 1998, 1(1), 19-36.
- Cochran-Smith, M., & Lytle, S. L. (1999a). The teacher research movement: A decade later. *Educational Researcher*, 28(7), 15-25.
- Cochran-Smith, M., & Lytle, S. L. (1999b). Relationships of knowledge and practice: Teacher learning in communities. *Review of Research in Education*, 24, 249-305.

- Coffey, A., & Atkinson, P. (1996). *Making sense of qualitative data: complementary research strategies*. Thousand Oaks: Sage Publications.
- Cox-Petersen, A. M., (2001). Empowering science teachers as researchers and inquirers. *Journal of Science Teacher Education*, 12(2), 107-122.
- Crockett, M. D. (2002). Inquiry as professional development: Creating dilemmas through teachers' work. *Teaching and Teacher Education*, 18, 609-624.
- Crotty, M. (1998). *The foundations of social research: Meaning and perspective in the research process*. SAGE Publications.
- Cruickshank, D. R., & Metcalf, K. K. (1990). Training within teacher preparation. In W. R. Houston (Ed.), *Handbook of research on teacher education* (1st ed., pp. 469-497). New York, NY: Association of Teacher Educators.
- Davis, E. A., Petish, E., & Smithey, J. (2006). Challenges new science teachers face. *Review of Educational Research*, 76(4), 607-651.
- Dewey, J. (1933). *How we think: A restatement of the relation of reflective thinking to the educative process*. Boston: D. C. Heath and Co.
- Doyle, W. (1990). Themes in teacher education research. In W. R. Houston (Ed.), *Handbook of research on teacher education* (1st ed., pp. 3-24). New York, NY: Association of Teacher Educators.
- Driver, R. & Easley, J. (1978). Pupils and paradigms: A review of literature related to concept development in adolescent science students. *Studies in Science Education*, 5, 61-84.
- Driver, R., Guesne, E., & Tiberghien, A. (1985). *Children's ideas in science*. Milton Keynes: Open University Press.

- Driver, R., Squires, A., Rushworth, P., & Wood-Robinson, V. (1994). *Making sense of secondary science: Research into children's ideas*. New York: Routledge.
- Eisenhower National Clearinghouse (ENC) for Mathematics and Science Education. (2000). *Ideas that work: Mathematics professional development*. Columbus, OH: Author.
- Erickson, F. (1986). Qualitative methods in research on teaching. In Wittrock, M. C., (Ed.), *Handbook of research on teaching* (3rd ed., pp. 119-161). New York: Macmillan Publishing Company.
- Esterberg, K. (Ed.). (2002). *Qualitative methods in social research*. Boston: McGraw Hill.
- Feiman-Nemser, S. (1983). Learning to teach. In L. Shulman & G. Sykes (Eds.), *Handbook of teaching and policy* (pp. 150-170). New York: Longman.
- Fischler, H. (1999). The impact of teaching experiences on student-teachers' and beginning teachers' conceptions of teaching and learning science. In J. Loughnan (Ed.), *Researching teaching: Methodologies and practices for understanding pedagogy* (pp. 172-197). London: Falmer Press.
- Freidus, H., Feldman, S., Sgouros, C. M., & Wiles-Kettenmann, M. (2005). Looking at ourselves: professional development as self-study. In J. Brophy & S. Pinnegar (Eds.), *Advanced in research on teaching: Vol. 11. Learning from research on teaching: Perspective, methodology, and representation* (pp. 377-409). Sand Diego, CA: Elsevier Inc.
- Gallagher-Bolos, J. A., & Smithenry, D. W. (2004). *Teaching inquiry-based chemistry: Creating student-led scientific communities*. Portsmouth, NH: Heinemann.
- Geddis, A. N., Onslow, B., Beynon, C., & Oesch, J. (1993). Transforming content knowledge: Learning to teach about isotopes. *Science Education*, 77, 575-591.

- Ginsburg, M. B., & Clift, R. T. (1990). The hidden curriculum of pre-service teacher education. In W. R. Houston (Ed.), *Handbook of research on teacher education* (1st ed., pp. 450-465). New York, NY: Association of Teacher Educators.
- Glaser, B., & Strauss, A. (1967). *The discovery of grounded theory: Strategies for qualitative research*. Chicago: Aldine.
- Gordon, S. P., & Maxey, S. (2000). *How to help beginning teachers succeed*. (2nd ed.). Alexandria, VA: Association for Supervision and Curriculum Development.
- Graham, N. (2004). Relating classroom teaching to student learning: A critical analysis of why research has failed to bridge the theory-practice gap. [Electronic version]. *Harvard Educational Review*, 74(3), 273-306. Retrieved June 12, 2007 from <http://www.edreview.org/harvard04/2004/fa04/f04nuth.htm>
- Green, J., & Wallat, C. (1981). Mapping instructional conversations: A sociolinguistic ethnography. In J. Green & C. Wallat (Eds.), *Ethnography and language in educational settings* (pp. 161-205).
- Guba, E. G., & Lincoln, Y. S. (1989). *Fourth generation evaluation*. Newbery Park, CA: Sage Publications.
- Gunstone, R. & White, R. (1981). Understanding of gravity. *Science Education*, 65, 291-299.
- Hammer, D. (1997). Discovery learning and discovery teaching. *Cognition and Instruction*, 15(4), 485-529.
- Hammer, D., & Schifter, D. (2001). Practice of inquiry in teaching and research. *Cognition and Instruction*, 19(4), 441-478.

- Hammerness, et al., (2005). How teachers learn and develop. In L. Darling-Hammond & J. Bransford (Eds.), *Preparing teachers for a changing world: What teachers should learn and be able to do* (pp. 358-389). San Francisco, CA: John Wiley & Sons, Inc.
- Hamlyn, D. W. (1995). Ethnography, history of. In T. Honderich (Ed.), *The oxford companion to philosophy* (pp. 242-245). Oxford: Oxford University Press.
- Hampson, B. (2000). The strength of ideas in construction projects: A teacher's window of perception. *Research in Science Education*, 30(3), 269-287.
- Harry, B., Sturges, K. M., & Klingner, J. K. (2005). Mapping the process. An exemplar of process and challenge in grounded theory analysis. *Educational Researcher*, 34(2), 3-13.
- Hashweh, M. Z. (2003). Teacher accommodative change. *Teaching and Teacher Education*, 19, 421-434.
- Hatton, N., & Smith, D. (1995). Reflection in teacher education: Towards definition and implementation. *Teaching & Teacher Education*, 11(1), 33-49.
- Hiebert, J., Morris, A. K., Berk, D., & Jansen, A. (2007). Preparing teachers to learn from teaching. *Journal of Teacher Education*, 58(1), 47-61.
- Hill, H. C. (2004). Professional development standards and practices in elementary school mathematics. *Elementary School Journal*, 104(3), 215-231.
- Hutchinson, S. (1990). Education and grounded theory. In R. Sherman & R. Webb (Eds.), *Qualitative research in education: Focus and methods* (pp. 123-140). London: Falmer.
- Kang, N. -H. (2007). Elementary teachers' teaching for conceptual understanding: Learning from action research. *Journal of Science Teacher Education*, 18, 469-495.
- Kelly, G. J., & Crawford, T. (1997). An ethnographic investigation of the discourse processes of school science. *Science Education*, 81(5), 533-559.

- Kember, D., & Gow, L. (1994). Orientations to teaching and their effect on the quality of student learning. *The Journal of Higher Education*, 65(1), 58-74.
- Kennedy, M. M. (1999). A test of some common contentions about educational research. *American Educational Research Journal*, 36, 511-541.
- Kramp, M. K. (2004). Exploring life and experience through narrative inquiry. In K. DeMarrais & S. Lapan (Eds.), *Foundations for research: Methods of inquiry in education and the social sciences* (pp. 103-121). Mahwah, NJ: Lawrence Erlbaum.
- Krull, E., Oras, K., & Sisask, S. (2007). Differences in teachers' comments on classroom events as indicators of their professional development. *Teaching and Teacher Education*, 23(7), 1038-1050.
- LeCompte, M. D., & Preissle, J. P. (1993). *Ethnography and qualitative design in educational research* (2nd ed.). San Diego, CA: Academic.
- Le Fevre, M. D. (2004). Designing for teacher learning: Video-based curriculum design. In J. Brophy (Ed.), *Advances in research on teaching: Vol. 10. Using video in teacher education* (pp. 235-258). New York: Elsevier.
- Leinhardt, G. (1988). Situated knowledge and expertise in teaching. In J. Calderhead (Ed.), *Teachers' professional learning* (pp. 146-168). London: Falmer Press.
- Leinhardt, G., Putnam, R. T., Stein, M., & Baxter, J. (1991). Where subject knowledge matters. In J. Brophy (Ed.), *Advanced in research on teaching: Vol. 2.* (pp. 87-113). Greenwich, CT: JAI Press Inc.
- Lewison, M. (2003). Teacher inquiry. In E. P. St John, S. A. Loescher & J. S. Bardzell (Eds.). *Improving early reading and literacy in grade 1-5: A resource guide for programs that work*. Thousand Oaks, CA: Corwin Press, Inc.

- Loughran, J. (2006). *Developing a pedagogy of teacher education: Understanding teaching and learning about teaching*. London and New York: Routledge.
- Loughran, J., Mulhall, P., & Berry, A. (2002). *Attempting to capture and portray science teachers' pedagogical content knowledge: Chemical Reactions*. Melbourne: Faculty of Education, Monash University, Australia.
- Luft, J. A., & Patterson, N. C. (2002). Bridging the gap: Supporting beginning science teachers. *Journal of Science Teacher Education*, 13(4), 267-282.
- Luft, J. A., Roehrig, G. H., & Patterson, N. C. (2003). Contrasting landscapes: A comparison of the impact of different induction programs on beginning secondary science teachers' practice, beliefs, and experiences. *Journal of Research in Science Teaching*, 40(1), 77-97.
- Magnusson, S., Krajcik, J., & Borko, H. (1999). Nature, sources and development of pedagogical content knowledge. In J. Gess-Newsome & N. G. Lederman (Eds.), *Examining pedagogical content knowledge* (pp. 95-132). Dordrecht, the Netherlands: Kluwer Academic Publishers.
- Marton, F. (1994). On the structure of teachers' awareness. In I. Carlgren, G. Handal, & S. Vaage (Eds.), *Teachers' minds and actions: Research on teachers' thinking and practice* (pp. 28-42). London: Falmer Press.
- Mayer, D. P. (1999). Measuring instructional practice: Can policymakers trust survey data? *Educational Evaluation and Policy Analysis*, 21(1), 29-45.
- McCutcheon, G. (1980). How do elementary school teachers plan? The nature of planning and influences on it. *Elementary School Journal*, 81, 4-23.
- McDonald, J. P. (1992). *Teaching: Making sense of an uncertain craft*. New York: Teachers College Press.

- McEwen, H. (1991). *Narrative understanding in the study of teaching*. Paper presented at the annual meeting of American Educational Research Association, Chicago.
- McGoey, J., & Ross, J. (1999). Guest editorial: Research, practice, and teacher internship. *Journal of Researcher in Science Teaching*, 36(2), 117-120.
- McGonigal, J. (1999). How learning to become a teacher-researcher prepared an educator to do science inquiry with elementary grade students. *Research in Science Education*, 29(1), 5-23.
- McLaughlin, M. W., & Zarrow, J. (2001). Teachers engaged in evidence-based reform: Trajectories of teachers' inquiry, analysis, and action. In A. Lieberman & L. Miller (Eds.), *Teachers caught in the action: Professional development that matters* (pp. 79-101). New York, NY: Teachers College Press.
- Merriam, S. (1998). *Qualitative research and case study applications in education*. San Francisco: Jossey-Bass.
- Minchew, C., Bryan, L. A., Deaton, B. E., Recesso, A., & Hay, K. (2004). *Teacher as reflective practitioner: Using video case tools to promote teacher inquiry*. Paper presented at the annual meeting of the National Association Research in Science Teaching, Vancouver, Canada.
- Morris, A. K. (2006). Assessing pre-service teachers' skills for analyzing teaching. *Journal of Mathematics Teacher Education*, 9(5), 471-505.
- Myers, C. B., & Simpson, D. J. (1998). *Re-creating schools: Places where everyone learns and likes it*. Thousand Oaks, CA: Corwin Press, Inc.

- National Board for Professional Teaching Standards (NBPTS) (2002). *What teachers should know and be able to do*. Retrieved July 4, 2007 from http://www.nbpts.org/UserFiles/File/what_teachers.pdf
- National Center for Education Statistics. (1999). *Teacher Quality: a report on the preparation and qualifications of public school teachers*.
- National Research Council (NRC). (1996). *National science education standards*. Washington, D. C.: National Academy Press.
- National Research Council (NRC). (2007). *Taking Science to School: Learning and Teaching Science in Grade K-8*. Washington, D. C.: National Academy Press.
- <http://books.nap.edu/openbook.php?isbn=0309102057>
- Nussbaum, J. & Novak, J. D. (1976). An assessment of children's concepts of the earth utilizing structured interviews. *Science Education*, 60, 535-550.
- Osborne, R., & Freyburg, P. (1985). *Learning in science: The implications of children's science*. Birkenhead, Auckland: Heinemann.
- Pajares, M. F. (1992). Teachers' beliefs and educational research: Cleaning up a messy construct. *Review of Educational Research*, 62, 307-332.
- Park, S., & Oliver, J. S. (2008). Revisiting the conceptualization of pedagogical content knowledge (PCK): PCK as a conceptual tool to understand teachers as professionals. *Research in Science Education*, 38(3), 261-284.
- Patton, M. Q. (2002). *Qualitative research and evaluation methods*. (3rd Ed.). Thousand Oak, CA: Sage.
- Phelan, A. M. (2005). A fall from (someone else's) certainty: Recovering practical wisdom in teacher education. *Canadian Journal of Education*, 28(3), 339-358.

- Pine, K., Messer, D., & St. John, K. (2001). Children's misconceptions in primary science: A survey of teachers' view. *Research in Science and Technological Education, 19*, 79-96.
- Pinnegar, S. E. (1989). Teachers' knowledge of students and classrooms. *Dissertation Abstracts Internationals, 51*(01), 0142A (UMI no. 9014676).
- Polkinghorne, D. E. (1995). Narrative configuration in qualitative analysis. *International Journal of Qualitative Studies in Education, 8*(1), 5-23.
- Posner, G. J., & Gertzog, W. A. (1982). The clinical interview and the measurement of conceptual change. *Science Education, 66*, 195-209.
- Prawat, R. S. (1992). Teachers' beliefs about teaching and learning: A constructivist perspective. *American Journal of Education, 100*(3), 354-395.
- Putnam, R., & Borko, H. (2000). What do new views of knowledge and thinking have to say about research on teacher learning? *Educational Researcher, 29*(1), 4-15.
- Recesso, A., Hannafin, M., Wang, F., Deaton, B., Rich, P., & Shepherd, C. (in press). Direct evidence and the continuous evolution of teacher practice.
- Rich, P., & Hannafin, M. (in press).
- Richardson, V. (1990). Significant and worthwhile change in teaching practice. *Educational Researcher, 19*(7), 10-18.
- Richardson, V. (1994). Conducting research on practice. *Educational Researcher, 23*(5), 5-10.
- Rodgers, C. R. (2002). Seeing student learning: Teacher change and the role of reflection. [Electronic version]. *Harvard Educational Review, 72*(2), 230-253. Retrieved July 8, 2007 from <http://ejournals.ebsco.com.proxy-remote.galib.uga.edu:2048/RemoteSiteWithInstructions.asp?JournalID=102010&RemoteURL=http%3A%2F%2Fwww%2Eedreview%2Eorg%2Fwelcome%2Ehtm>

- Rosebery, A. S., & Puttick, G. M. (1998). Teacher professional development as situated sense-making: A case study in science education. *Science Education*, 82, 649-677.
- Rosebery, A. S., & Warren, E. (Eds.). (1998). *Boats, balloons, and classroom video: Science teaching as inquiry*. Portsmouth, NH: Heinemann.
- Roth, K. J. (2007). Science teachers as researchers. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 1205-1259). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.
- Roth, K. J. & Chen, C. (2007). *Teacher learning from videocases of science teaching: A conceptual framework*. Paper presented at the annual meeting of the National Association Research in Science Teaching, New Orleans, LA.
- Rutherford, F. J. & Ahlgren, A. (1990). *Science for all Americans*. New York: Oxford University press.
- Schön, D. A. (1983). *The reflective practitioner*. New York: Basic Books.
- Schwille, K., Givvin, K. B., & Chen, C. (2007). *The use of videocases in pre-service teacher education: The VISTA project*. Paper presented at the annual meeting of the National Association Research in Science Teaching, New Orleans, LA.
- Seago, N. (2004). Using video as an object of inquiry for mathematics teaching and learning. In J. Brophy (Ed.), *Advances in research on teaching, Vol. 10: Using video in teacher education* (pp. 259-286). New York: Elsevier JAI.
- Seidman, I. (1998). *Interviewing as qualitative research: A guide for researchers in education and the social sciences* (2nd ed.). New York: Teachers College Press.

- Sherin, M. G. (2004). New perspectives on the role of video in teacher education. In J. Brophy (Ed.), *Using video in teacher education: Advances in research on teaching* (Vol. 10, pp. 1-27). London, UK: Elsevier Ltd.
- Sherin, M. G., & Han, S. Y. (2004). Teacher learning in the context of a video club. *Teaching and Teacher Education*, 20, 163-183.
- Sherin, M. G., & van Es, E. A. (2002). Using video to support teachers' ability to interpret classroom interactions. *Proceedings of the Thirteenth Annual Meeting of the Society for Information Technology and Teacher Education* (pp. 2532-2536). Norfolk, VA: Association for the Advancement of Computing in Education. Retrieved February 8, 2006, from http://www.aace.org/conf/site/pt3/paper_3008_1031.pdf.
- Sherin, M. G., & van Es, E. A. (2005). Using video to support teachers ability to notice classroom interactions. *Journal of Technology and Teacher Education*, 13(3), 475-491.
- Shuell, T. J. (1996). Teaching and learning in a classroom context. In D. C. Berliner & R. C. Calfee (Eds.), *Handbook of educational psychology* (pp. 726-764). New York: Simon & Schuster Macmillan.
- Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, 15(2), 4-14.
- Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review*, 57, 1-22.
- Shulman, L. S. (2002). Forgive and remember: The challenges and opportunities of learning from experience. *Learning the next generation of new teachers symposium proceedings*. New Teacher Centre at the University of California (pp. 59-66). Santa Cruz.

- Shymansky, J. A., Yore, L. D., & Anderson, J. O. (2004). Impact of a school district's science reform effort on the achievement and attitudes of third- and fourth- grade students. *Journal of Research on Science Teaching*, 41(8), 771-790.
- Smith, D. C., & Neale, D. C. (1989). The construction of subject matter knowledge in primary science teaching. *Teaching and Teacher Education*, 5(1), 1-20.
- Smithenry, D. W., & Gallabher-Bolos, J. A. (2008). *Video Cases of Whole-Class Inquiry*. Paper presented at the annual meeting of Association for Science Teacher Education, St. Louis, Missouri.
- Soutuerland, S. A., & Gess-Newsome, J. (1999). Pre-service teachers' views of inclusive science teaching as shaped by images of teaching, learning, and knowledge. *Science Education*, 83, 131-150.
- Sowder, J. T. (2007). The mathematical education and development of teachers. In F. Lester (Ed.), *Second handbook of research on mathematics teaching and learning* (pp. 157-223). NCTM.
- Sparks-Langer, G. M., & Colton, A. B. (1991). Synthesis of research on teachers' reflective thinking. *Educational Leadership*, 48(6), 37-44.
- Sparks-Langer, G. M., Simmons, J. M., & Pasch, M., Colton, A., & Starko, A. (1990). Reflective pedagogical thinking: How can we promote it and measure it? *Journal of Teacher Education*, 41(4), 23-32.
- Spillane, J. P., & Zeuli, J. S. (1999). Reform and teaching: Exploring patterns of practice in the context of national and state mathematics reforms. *Educational Evaluation and Policy Analysis*, 21, 1-27.

- Sprinthall, N. A., Reiman, A. J., & Thies-Sprinthall, L. (1996). Teacher professional development. In J. Sikula, T. J. Buttery, & E. Guyton (Eds.), *Handbook of research on teacher education* (2nd ed., pp. 666-703). New York, NY: Association of Teacher Educators.
- Stein, M. K., Simith, M. S., Henningsen, M. A., & Silver, E. A. (2000). *Implementing standards-based mathematics instruction: A casebook for professional development*. New York, NY: Teachers College Press.
- Stokes, L. (2001). Lessons from an inquiring school: Forms of inquiry and conditions for teacher learning. In A. Lieberman & L. Miller (Eds.), *Teachers caught in the action: Professional development that matters* (pp. 141-158). New York, NY: Teachers College Press.
- Strauss, A., & Corbin, J. (1990). *Basic of qualitative research: Grounded theory procedures and techniques*. (2nd Ed.). Newbury Park, CA: Sage.
- Tabachnick, B. P., & Zeichner, K. M. (1999). Ideas and action: Action research and the development of conceptual change teaching of science. *Science Education*, 83, 309-322.
- Valli, L. (1992a). *Reflective teacher education: Case and critique*. Albany, NY: State University of New York Press.
- Valli, L. (1992b). Introduction. In L. Valli (Ed.), *Reflective teacher education: Case and critiques* (pp. xi-xxv). Albany, NY: State University of New York Press.
- Valli, L. (1993). Reflective teacher education programs: An analysis of case studies. In J. Calderhead & P. Gates (Eds.), *Conceptualizing reflection in teacher development* (pp. 11-22). London: The Falmer Press.
- Van Eekelen, I. M., Vermunt, J. D., & Boshuizen, H. P. A. (2006). Exploring teachers' will to learn. *Teaching and Teacher Education*, 22(4), 408-423.

- van Es, E. A., & Sherin, M. G. (2002). Learning to notice: Scaffolding new teachers' interpretations of classroom interactions. *Journal of Technology and Teacher Education*, 10(4), 571-596.
- van Es, E. A., & Sherin, M. G. (2008). Mathematics teachers' "learning to notice" in the context of a video club. *Teaching and Teacher Education*, 24(2), 244-276.
- van Zee, E. H. (2000). Ways of fostering teachers' inquiries into science learning and teaching. In J. Minstrell & E. H. van Zee (Eds.), *Inquiring into inquiry learning and teaching in science* (pp. 100-119). American Association for the Advancement of Science.
- Wang, J., & Hartley, K. (2003). Video technology as a support for teacher education reform. *Journal of Technology and Teacher Education*, 11(1), 105-138.
- Ward, J., & McCotter, S. (2004). Reflection as a visible outcome for pre-service teachers. *Teaching and Teacher Education*, 20, 246-257.
- Weinbaum, A., Allen, D., Blythe, T., Simon, K., Seidel, S., & Rubin, C. (2004). *Teaching as inquiry: Asking hard questions to improve practice and student achievement*. New York, NY: Teachers College Press.
- Wideen, M., Mayer-Smith, J., & Moon, B. (1998). A critical analysis of the research on learning to teach: Making the case for an ecological perspective on inquiry. *Review of Educational Research*, 68(2), 130-178.
- Wilson, S. M., & Berne, J. (1999). Teacher learning and the acquisition of professional knowledge: An examination of research on contemporary professional development. In Iran-Nejad, A., & Pearson, P. D. (Eds.), *Review of Research in Education*. Vol. 24. (pp. 173-209).

- Wilson, S. M., Shulman, L. S., & Richert, E. R. (1987). '150 different ways' of knowing: Representations of knowledge in teaching. In J. Calderhead (Ed.), *Exploring teachers' thinking* (pp. 104-124). New York: Taylor and Francis.
- Wong, E. D. (1995). Challenges confronting the researcher/teacher: Conflicts of purpose and conduct. *Educational Researchers*, 24(3), 22-28.
- Yerrick, R., Ross, D., & Molebash, P. (2005). Too close for comfort: Real-time science teaching reflections via digital video editing. *Journal of Science Teacher Education*, 16, 351-375.
- Zeichner, K. (1986). Preparing reflective teachers: An overview of instructional strategies which have been employed in pre-service teacher education. *International Journal of Educational Research*, II, 565-575.
- Zeichner, K. M., & Noffke, S. E. (2001). Practitioner research. In V. Richardson (Ed.), *Handbook of research on teaching* (4th ed., pp. 298-330). Washington, DC: American Educational Research Association.

APPENDICES

Appendix A

Questionnaire for Participant Selection

Questionnaire: Teacher Inquiry Project

Ms. Youngjin Song

Dr. J. Steve Oliver

Please respond to the items in this survey if you are interested in participating in this research project. This survey will be used to understand the specific nature of your interest. The only purpose of the survey is to obtain possible research participants, and it will not be used for any other purposes.

1. What subject matter (e.g., biology chemistry, physics, etc.) are you teaching this semester? Please specify the level (e.g., AP, CP, Honors, Gifted) and grade.

2. Have you ever had any opportunity to use video in order to closely inquire into your own teaching practices or your students' learning? If so, could you briefly explain your experience?

3. Suppose you have an opportunity to investigate your science classroom by using *The Video Analysis Tool* (VAT). Do you have any particular aspect of your teaching into which you would like to inquire deeply? What is that aspect?

4. What might be potential benefits that result from the experience of inquiring into your own instructional practices and the learning your students?

If you are interested in participating in the inquiry project, please leave your contact information below. I appreciate you taking the time to respond to the survey.

Name _____

Email address: _____

Phone (Cell / Home / Work) number: _____

Appendix B

Consent Form for Teachers

Evidence Based Decision Support

I, _____, agree to participate in the research study titled “Evidence Based Decision Support.” This research is being conducted by Drs. Arthur Recesso and Michael Hannafin (University of Georgia, Learning & Performance Support Laboratory, 542-3157). I understand that my participation is voluntary. I can stop taking part without giving any reason, and without penalty. I can ask to have all of the information about me returned to me, removed from the research records, or destroyed.

The reason for this study is to investigate teacher practices. This research may provide evidence on areas of strength and need in teacher education programs and teaching in general, helping to better teacher development across the continuum of teaching experience.

I may benefit from this study by becoming aware of ways in which both I and developing teachers deal with teaching issues in the classroom, including teaching methods, management and effective use of technology.

If volunteer to take part in this study, I may be asked to do the following things:

- 1) If there is a pre-service teacher also participating in this research, or an in-service teacher or colleague I am observing:
 - a. Allow the pre-service or in-service teacher to conduct self-directed research of his/her teaching practices in my classroom.
 - b. Record individual planning and follow-up conferences between myself and the teacher I am assisting.
- 2) Allow the researchers to record my open and public discussions, comments, and answering of questions when they are part of the class.
- 3) Allow the researchers to video- and tape-record my teaching up to ten times.
- 4) Be personally interviewed up to the times, which each interview lasting roughly one hour.
- 5) Provide artifacts of teaching and learning. These may include but are not limited to: lesson plans, personal reflections, teacher notes, student work samples, notes from mentor and cooperating teachers, and teacher observation forms.
 - a. In the case of providing student artifacts, I will first remove all identifying information.
- 6) Allow the teacher education course instructor(s) (named above) to view, comment on and give feedback regarding the aforementioned recorded experience(s) to either myself or the pre-service or in-service teachers.

I will not receive any monetary compensation for participation in this study. Any compensation I receive is in the form of perceived benefit from possible feedback and insight gained by reviewing the said recordings.

Information collected will be stored in a secure, locked location. Dissemination of information will be restricted to educators participating in professional learning experiences.

The investigator will answer and further questions about the research, now or during the course of the project (542-4010).

I understand that I am agreeing by my signing this form to take part in this research project and understand that I will receive a signed copy of this consent from for my records.

Name of Researcher: Arthur Recesso	Signature:	Date:
Telephone: (706) 542-4010		
Email: arecesso@uga.edu		
Name of Subject:	Signature:	Date:

For questions of problems about your rights as a research participants please call or write: The Chairperson, Institution Review Board, University of Georgia, 612 Boyd Graduate Studies Research Center, Athens, Georgia 30602-7411; Telephone (706) 542-3199; E-Mail Address IRB@uga.edu

Appendix C

Parental Consent Form

I agree to allow my child, _____, to take part in a research study titled, “Evidence Based Decision Support”, which is being conducted by Drs. Arthur Recesso and Michael Hannafin (University of Georgia, Learning & Performance Support Laboratory, 542-3157) under the direction _____ from _____ (phone: _____). The focus of this study is my child’s teacher (or student teacher). I understand that my child may be videotaped in the process. I do not have to allow my child to be in this study if I do not want to. My child can stop taking part at any time without giving any reason, and without penalty. I can ask to have the information related to my child returned to me, removed from the research records, or destroyed.

- The purpose of this study is to collect evidence on the actual teaching practice of teachers. The researchers are interested in teachers modeling practices that have been modeled / taught to them in their studies.
- The research does not focus on students, student learning, or student activities. My child is a participant in a teacher’s class who is interested in improving their instructional practices. My child will have no active role or expectation in this research. My child’s grade will not be impacted in any way. My child’s activity or performance will not be evaluated by the teacher or researchers in any way.
- The research is not expected to cause any harm or discomfort. My child can quit at any time. My child’s grade will not be affected if my child decides to stop taking part.
- Any information collected about my child will be held confidential unless otherwise required by law. All data will be kept in a secured location. Videos may be viewed by researchers and teachers for improvement of instructional practices. Student identities will be protected by assigning pseudonyms to school systems, school buildings, all teachers, student teachers, grade level, and course name. When possible, video will be filmed from the back of the room and directly on the teacher so only a rear profile (back of head) of a limited number of students will be seen.
- The researcher will answer any questions about the research, now or during the course of the project, and can be reached by telephone at: 706-542-4010. I may also contact the professor supervising the research, from _____ (phone: _____).
- I understand the study procedures described above. My questions have been answered to my satisfaction, and I agree to allow my child to take part in this study. I have been given a copy of this form to keep.

Name of Parent or Guardian
(please print)

Signature

Date

Name of lead researcher
Dr. Arthur Recesso
(706) 542-3157

Signature

Date

Please sign both copies, keep one and return one to the researchers.

Additional questions or problems regarding your child’s rights as a research participant should be addressed to The Chairperson, Institutional Review Board, University of Georgia, 612 Boyd Graduate Studies Research Center, Athens, Georgia 30602-7411; Telephone (706) 542-3199; E-Mail Address IRB@uga.edu

Appendix D

Worksheets used in the SpinachCo Project

SpinachCo Project Information

SpinachCo Position: We are looking to hire a scientific community that can prove that it is able to effectively and efficiently solve our technical research problems. You can prove your community's worth by solving the problem outlined below and giving a 20-minute maximum presentation to our company representative on the assigned deadline. We will supply one of our company's chemists to act as a consultant while you perform your experiments. She/he will only help when asked a question. She/he may not be able to answer all questions, but she/he will try.

SpinachCo Technical Problem: SpinachCo wants to put spinach in vending machines around the world. Since a lack of iron can cause fatigue, we feel that businesses and schools will want to use our spinach vending machines to increase worker productivity. To determine the specifications of the machine and the feasibility of this health conscious initiative, we need to know:

1. What variables affect the amount of iron in spinach?
2. How do each of the variables listed in #1 affect the amount of iron in spinach?
3. What conditions should we set for the vending machines to obtain the maximum amount of iron in spinach?
4. Are these conditions reliable enough to give the maximum amount of iron possible in the spinach? Provide enough data to support your claim.

Your Quality Presentation: Due to the representative's limited time, your community's presentation of results will be limited to a maximum of twenty minutes on _____ (at the end of your class period). Your presentation will start at exactly _____. Your presentation needs to concisely answer the four questions outlined above (thing about "effective communication" when preparing). On this date, please provide a hard copy of your community's presentation. Your community will be competing against _____ other companies for our future business.

SpinachCo Rubric

Part I Community Grade (100 points)

- _____ Scientific Community (50 points)
 - _____ Safety (25) (OSHA violation)
 - _____ All class members participate, have pre-lab done BEFORE entering lab, and keep lab book up-to-date as lab progresses-no paper can be taken to lab station-lab procedure is at table already (25)
- _____ Presentation (50 points)
 - _____ What variables affect the amount of iron in spinach?
 - _____ How do each of the variables listed in #1 affect the amount of iron in spinach?
 - _____ What conditions should we set for the vending machines to obtain the maximum amount of iron in spinach?
 - _____ Are these conditions reliable enough to give the maximum amount of iron possible in the spinach? Provide enough data to support your claim
 - _____ Time limits/presentation skills

Part II Individual Grade (100 points)

- _____ Lab Book (50 points) - title, safety, brainstorming ideas, list major parts of experiment and tell how their experiment does these; data table, any parts on the log book guidelines that you use
- _____ Lab Assessment (50 points)

Journal Reflection

Answer the following questions. Your answers should be complete and show that you have spent time thinking about them. Answer the questions **on NOTEBOOK PAPER**.

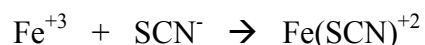
- What do you think went well?
- What would you change for next time?
- What content questions do you have about the activity?
- What role did you play in this activity?
- How did you feel about your role in this activity?

Testing Foods for Iron

Qualitatively and Quantitatively

Iron is an essential mineral for humans. At one time parents in Eastern Europe nations inserted iron nails into apples which they later gave their children to eat. A small amount of iron reacts and dissolves with the acids in the apple. Today, iron is often added to products. The labels “reduced iron” or “100% iron”, mean that iron fillings are added to the products. The iron reacts with stomach acid to produce iron (II), Fe^{+2} and iron (III), Fe^{+3} , ions. The iron (II) ion is more easily absorbed from the intestine than iron (III). Thus, iron (II) sulfate is most commonly used to treat iron deficiency and anemia.

Iron is found in foods such as broccoli, spinach, raisins, parsley, kidney beans, and cauliflower. In this experiment, the iron in one of these foods will be converted to iron (III) ions. These ions will be reacted with the colorless thiocyanate ion, SCN^- , to produce iron (III) thiocyanate ions which have a red color. The darker the red color, the more iron that is contained in the food.



Part 1

Pre-lab Questions:

1. Define filtrate
2. Differentiate between element, ion, and compound.
3. Describe how to turn on a Bunsen burner.
4. What are several safety considerations when using a Bunsen burner?

Procedure:

1. Measure and record the mass of a clean, dry crucible. Add about 5g of a finely chopped sample of the food to be tested and determine its mass to the hundredths place.
2. Heat the sample over a Bunsen burner. (Caution: long hair and loose sleeves MUST be tied back). Continue heating with a hot flame until the sample has been reduced to a grey ash. The heating process will cause some smells and smoke. Avoid breathing the fumes. No splashing should occur.
3. After the sample has cooled, add 10.00cm^3 of 2.0M HCl (Handle with care. Burns can occur) to dissolve the iron present in the ash. Stir gently for about 5 minutes. Filter the mixture into a small beaker. Collect the filtrate.
4. Mix 5.00 cm^3 of the filtrate with 5.00 cm^3 of 1.5 M KSCN in a test tube. Mix well. Compare your test tube with other lab groups.

Post-lab Questions:

1. Label the following as element, ion, or compound:
 a. Fe^{+3} b. Fe c. $\text{Fe}(\text{SCN})^{2+}$ d. FeSO_4
2. Is this experiment qualitative or quantitative? Explain.
3. List one physical and one chemical change in this lab.
4. Which is more concentrated, the HCl or the KSCN solution? Explain.
5. List the foods tested from most iron content to least iron content.

Part 2

Use a spectrophotometer to determine the concentration of iron in food. A spectrophotometer can be used to determine the concentration of dilute, colored solutions. The spectrophotometer passes light through a sample and measures how much light is transmitted. The more deeply colored a solution, the less light transmitted or, in other words, the more light absorbed. When a sample of a solution is put in a cuvet (the special test tube a spectrophotometer needs) and inserted into the spectrophotometer, the spec. reads the amount of light that is absorbed by the solution. The more absorption, the more concentrated the solution. A graph can be made to show the amount of iron in the food tested.

Procedure:

1. Repeat Part 1 except in step 4, mix reactants in a small beaker then fill the cuvet $\frac{3}{4}$ full.
2. Place the cuvet in the spectrophotometer and read the absorbance of the solution soon after mixing. The color changes significantly within 15-30 minutes.

Calculations:

1. Using the graph provided, determine the mg of iron in your sample.
2. Determine the mass (in milligrams) of iron per gram of food used.
3. Using the provided table, determine your percent error.
4. According to your results, what mass of the vegetable analyzed would you have to consume to get your daily requirement of iron?

Post-lab Questions:

1. Suggest reasons why the accepted values for the amount of iron in the analyzed foods sometimes differ in different reference resources.
2. Why is it possible to use a spectrophotometer in this lab?
3. Why does your body need iron?

<u>Sample</u>	<u>Iron Supplied by Foods</u> <u>CRC value mg Fe/g of food</u>
Broccoli	8.6×10^{-3}
Frozen green peas	1.6×10^{-2}
Almonds	3.6×10^{-2}
Cabbage	0.6×10^{-2}
Pinto beans (cooked)	3.0×10^{-2}
Spinach	2.7×10^{-2}
Frozen black eyed peas	1.3×10^{-2}
Raisins	2.1×10^{-2}

Appendix E

Worksheets used in the Carter Center Nigerian Trip Project

Carter Center Nigerian Trip Project

The Jimmy Carter Center in Atlanta is responsible for leading a program to eradicate the guinea worm. An excerpt from our web site http://cartercenter.org/health/guinea_worm/index.html is:

Guinea worm disease is a parasitic disease that rarely makes headlines but is so painful and debilitating that its effects reach far beyond a single victim, crippling agricultural production and reducing school attendance. A child suffers and is unable to attend school, work, or play. A parent suffers and is unable to harvest crops or care for younger children. Commonly called the "fiery serpent," dracunculiasis — the medical term for Guinea worm disease — has been around for centuries, but The Carter Center is leading a worldwide effort to eradicate the disease.

We are planning a trip in one month to travel to Nigeria and set up a water treatment center that will serve as a model for other countries that have a problem with the guinea worm. This treatment center will also serve as a model for providing clear, safe, drinking water for the people in these regions.

We are looking for a scientific community to design an affordable water treatment process that will protect people from the guinea worm and provide them with clear, colorless water that has few dissolved ions in it. We are most interested in communities that perform high quality work and who explore all options. We are providing each community with 2L of water from Nigeria. Here is that we will be looking for in your power point presentation:

Part I Community Grade (100 points)

Presentation (70 points)

_____ Water Quality (20 points)

- _____ Show evidence of the water before and after your treatment options (5 pts)
- _____ Show and discuss the final water (clarity, color, odor, conductivity) (10 pts)
- _____ Show calculation of % of water recovered from process that you end up using (start with 100.0 ml – perform set of tests that you recommend – how many ml of water did you purify from 100.0 ml water that you started with – keep this water so show) (5 pts)

_____ Methodology (40 points)

- _____ Data / discussion of options of water treatment that you investigated but did NOT decide to use for the Nigerian water treatment plant (5 pts)
- _____ Data / discussion of options of water treatment that you investigated and DID decide to use for the Nigerian water treatment plant (5pts)
- _____ Include a list of each process that you think we should use, rationale for each, and list of materials that we will need to transport to Nigeria (30 pts)
- _____ Give special attention to the method of water treatment that will remove guinea worm (5pts)

_____ Length should be 10-20 minutes (not considered if above or below this time limit)

_____ Use professional presentation skills (5 pts)

_____ Give me some “WOW” information / presentation (5 pts)

Work environment (30 points)

- _____ Safety-OSHA rules followed (15 pts)
- _____ All members of community always on task and EVERYONE have lab notebook up-to-date (15 pts)
 - _____ Have ready BEFORE anyone goes to lab: title, safety highlighted in yellow, research notes that you make, brainstorming ideas (list every idea that your classmates discuss), data table ready for data
 - _____ Calculation of % water recovered
 - _____ Conclusion: Final chart showing a) what processes that you recommend for the Jimmy Carter Center to take to Nigeria, b) rationale for each, c) list of materials needed for each process.

Part II Individual Grade – Lab Assessment (100 points)**Nigerian Water Plant Post Presentation Questions****Water Quality-Clarity, Color:**

- What did you do to achieve a high level of clarity in your water?
- How can you measure clarity?
- What did you do to achieve colorless water?
- How can you measure color?

Water Quality- Dissolved Ions

- Where do dissolved ions in water come from?
- What type of dissolved ions would you expect to find in water?
- What about water from Nigeria?
- Is it harmful to have high levels of dissolved ions in the water? Why or why not?
- How would you remove those ions?
- Do we even have to remove the ions?
- Is distillation a practical method for Nigeria? Why or why not?
- How does distillation remove the ions?

Water Quality – Guinea Worm

- Why is the guinea worm a problem?
- What method did you come up with to remove the guinea worm in the drinking water?
- Is this method practical for remote regions?
- What other methods are currently being used by the Carter Center to remove the guinea worm in drinking water?
- Why might these methods be better/worse than yours?

Water Quality – Oil

- It appears as though there is oil in the water, is that normal?
- What method did you come up with to remove the oil in the water?

Feasibility of Treatment Process

- What materials would be needed for your treatment plant?
- Are these materials expensive?
- Is your treatment process cost effective?
- Is the treatment process practical for a person living in Nigeria? Why or why not?
- Is boiling an effective method for treating water?
- Is boiling water used in the United States?

Carter Center Nigeria Project Reflections

I. In a successful class or career position, a person has to be innovative and thorough and prepared before attending a planning session. How well did you prepare yourself for this project? See how quickly you can answer the content questions below and the research question.

A. Matching-each letter may be used more than once

- | | |
|---|--------------------|
| <input type="checkbox"/> removes colloidal particles | A. screening |
| <input type="checkbox"/> grease and scum are skimmed off | B. chlorination |
| <input type="checkbox"/> neutralizes acidic water | C. flocculation |
| <input type="checkbox"/> remove suspended particles | D. sand filtration |
| <input type="checkbox"/> remove odors | E. aeration |
| <input type="checkbox"/> remove large objects | F. pH adjustment |
| <input type="checkbox"/> prevent tooth decay | G. fluoridation |
| <input type="checkbox"/> aluminum sulfate, calcium hydroxide | H. settling |
| <input type="checkbox"/> what you need to do after flocculation (2 letters) | |

B. What did **you** research for this project?

II. Which of the following comments are helpful to the success of the class? Put a check in each blank that is helpful.

- ☐ That is a stupid idea.
- ☐ Your water is awesome.
- ☐ Do something productive.
- ☐ Did you know that Rico from Hannah Montana is going to come to RSHS?
- ☐ We need a way to collect steam.
- ☐ I am going to wait to copy the data table when **they** are finished with it.
- ☐ They haven't told us what to do yet.
- ☐ I am not copying another data table down.
- ☐ When are we doing the power point?
- ☐ Can and I be responsible for the "wow" points?
- ☐ Join us in planning the power point.
- ☐ How many trials should we use – remember last time we lost points for this.
- ☐ How would you do that?

III. Proud moments

- A. What are you most proud of that your class did?
- B. What are most proud of that you did?

III. Improvements

- A. What could the class improve on next time?
- B. What could you improve on next time?

IV. Leadership-A good leader empowers everyone to be apart of the effort and listens to all ideas.

- A. How did you contribute with leadership?
- B. Did anyone surprise you with their contributions? Who do you think would be a good class manager and why? (Just a note: All the class managers for all the classes did an incredible job- each one had various strengths that were obvious- this question is just exploring other people in the class who might also have leadership potential)

V. Time management – If you would have had more time, what would you have done-be specific.

Carter Center Nigerian Water Lab Post-lab Questions

1. What were the 5 major goals of the lab?
2. What is meant by clarity (clearness)? How do you measure it? Through what process can you achieve it?
3. What is meant by being colorless? How do you measure it? Through what process can you achieve it?
4. What is the most practical way to kill the guinea worm?
5. What are dissolved ions? Where do you think they come from? How do you measure them? Through what process can you change the amount of dissolved ions in water?
6. Now, design a process that best achieves the 5 major goals of the lab.
7. Now what measurements do you need to include in a data table that reflects your answers to 1-6.
8. What type of matter do you want to end up with after your final process (homogeneous, heterogeneous, solution, element, compound)?
9. Read the facts about Guinea Worms below. How do you think the Carter Center has been doing in its efforts to eradicate the Guinea worm?
10. Read the Article of TDS in Nigeria. Do you think TDS is a major problem in Nigerian water?

Facts about Guinea Worm

1950's	50 million estimated cases in Africa and Asia
Late 1980s	Eradication program started by Carter Center and supported by many
1999	96,000 cases reported world wide and only in 13 countries in Africa
2004	16,000 cases (7,266 in Nigeria-mainly very remote villages)
2006	25,517 cases (20,582 cases in Sudan – civil war interfering with eradication program); only 16 in Nigeria
2007	32 cases in Nigeria reported so far
2009	Expected date for total eradication

Article on TDS in Nigeria

Inter-relationship between major ions, total dissolved solids and conductivity in some E. Ekpenyong

[Abstract]

Major ions, total dissolved solids (T.D.S.), conductivity and their inter-relationships were investigated in eight fish ponds located in Ile-Ife, Nigeria. Chloride concentrations were the least of all the measured. Sulphate and magnesium concentrations were highest in station 7 while other parameters (potassium, chloride, calcium, alkalinity, conductivity and total dissolved solids (T.D.S.) were highest in station 6. The ponds belong to class 1 of the African waters since they all have electrical conductance of less than 600 s cm⁻¹. Highest conductivity values were recorded between March and May and thereafter values dropped gradually until the end of the investigation in August. Very high positive correlations existed between the summation of the total cations and anions, suggesting a direct relationship between the measured ions. Similarly, high and positive correlations existed between the total ions and electrical conductance and between total dissolved solids (T.D.S.) and conductivity of the pond waters, also suggesting that increase in total ions still results in the increasing level of total dissolved solids (T.D.S.) and electrical conductance. These inter-relationships are used to explain the contributive role of each ion to the total dissolved solids (T.D.S.) and conductivity levels of a tropical fish pond.

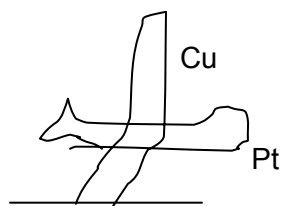
Global Journal of Pure and Applied Sciences Volume , No 1 January (2001) pp. 29-32

Appendix F

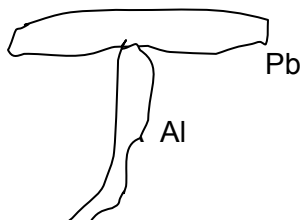
Worksheets used in the Moley Avogadro's Statues Project

Moley Avogadro's Statues Project

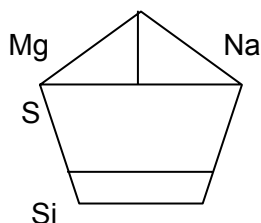
Objective: The City of Atlanta is hiring you to determine which statue design should go in Centennial Park. Moley Avogadro designed all 5 statues below. Your job is to find the BEST statue by studying all properties (research and lab testing-must test at least one quantitative physical property and 1 qualitative or quantitative chemical test + 3 other tests-see rubric) of the substances used in creating the statues and to make a written recommendation based (in lab book) and a power point on scientific data on your choice.

Moley's Different Statues**Statue Component Volumes****Statue #1 –**

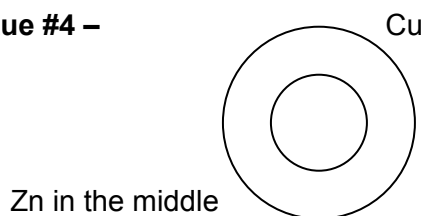
750,000 cm³ Cu
750,000 cm³ Pt

Statue #2 –

750,000 cm³ Pb
750,000 cm³ Al

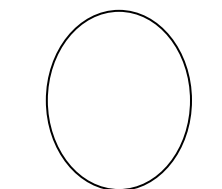
Statue #3 –

750,000 cm³ S
250,000 cm³ Mg
250,000 cm³ Na
250,000 cm³ Si

Statue #4 –

1,000,000 cm³ Cu
500,000 cm³ Zn

Statue #5 – 100,000 Post 1982 pennies in the shape of a water droplet sitting on a platform to make people aware of the water issues in Atlanta.



Assignment: Research as much as you can about each substance (include the type of substance, location on periodic table, physical properties, chemical properties, uses, etc...). Test as much of these properties as you can in lab – design a data table and get approval before going to lab from the lab consultant. Consider the environment that statue will be subjected to and environmental concerns that these substances might pose to the environment. Your final task will be to choose one of these statues (you can suggest modifications in the materials used -as long as they don't change the look of the statue and as long as you have data to support your changes- but not in the design in order to keep in mind the feelings of the artist). Start by reading your text (pre Moley Assignment)– p. 28, 55-63, 158, 200, 250, 277-8, 287-288, 300-301, 610, 847-849- to get some ideas. See also: ChemCom – p. 120-121. Also complete the Researched Properties Table (last page of this handout). : Items 1-4 and 5i must be completed by all students prior to the Moley Statue lab dates.

Lab Book Set Up (see attached rubric)

1. Title
2. Safety -Wear goggles and apron. Wash hands after lab. (Add to this as needed)
3. Objective
4. Pre-lab notes (answer questions from handout)
5. Data Tables
 - i. **Researched Properties Table (see rubric)**
 - ii. **5 Lab Data Tables – data table for each test you perform:**
 - 1 quantitative physical property that you test
 - 1 quantitative or qualitative chemical property that you test
 - 3 other properties that you test
6. Procedure (5 – one for each test)-Must be approved before doing.
7. Drawing of the statue that you decide is the best one with any modifications of elements included.
8. Conclusion – Which statue are you picking and give reasons why this would be a good or bad choice.

Note: Items 1-4 and 5i must be completed by all students prior to the Moley Statue lab dates.

Presentation and Power Point (see attached rubric)

You are competing to become the company chosen to build the statue in Centennial Park. In your presentation, you should include:

- Power point
- The major points that you want to make to convince the City of Atlanta that you are the best people for the job
- Persuasive, convincing presentation based on physical and chemical properties, aesthetic considerations, environmental considerations, cost factors, etc... (these must be listed on a slide)
- Your 3 coolest discoveries that your group made throughout the course of this lab
- Everyone talks
- Chemical equations – balanced-should represent chemical tests that you did in lab or reactions that you researched

LAB AREA INCLUDING SINK MUST BE THOROUGHLY CLEANED AFTER THE CONCLUSION OF THE LAB! All nonreacted metals should be dried and returned to original containers. Any reacted elements should be disposed of in the garbage can.

Moley's Statue Pre-Lab Assignment

- Complete questions 1-26.
- Setup lab book and copy and complete the "Researched Properties Table" (back of this paper)
- These must be done BEFORE starting Moley Statue Lab

Density (p.28)

1. What is the formula for density?
2. How could you find the density of a key?
3. Suppose a sample of aluminum is placed in a 25 mL graduated cylinder containing 10.5 mL of water. The level of the water rises to 13.5 mL. What is the mass of the aluminum sample?

Properties of Substances (p.55-63; p.277-8)

4. Pure substances are elements and compounds. Label the following as an element or compound:
 - a. mercury b. aluminum oxide c. aluminum
 - d. sodium hydrogen carbonate
5. Define physical property.
6. Define chemical property.
7. Classify the following as physical or chemical properties: color, density, reacts with water, melting point, flammable, does not react with acid, odor, taste, hardness, malleable, ductile, brittle
8. Define physical change.
9. Define chemical change.
10. Classify the following as a physical or chemical change: cutting paper, breaking crystal, crushing sulfur, rusting of iron, bending iron, leaves changing color, ice melting, methane burning, sugar dissolving
11. What are some ways to tell that a chemical change might have taken place?

Types of elements: metals, nonmetals, metalloids (p.155-158)

12. Describe the different types of elements (metals, nonmetals, metalloids), examples of each, and characteristics of each.
13. p. 200 Are any strategic materials found in only one location?

Acids (p.250)

14. Study p. 250-1 and do p. 250 18-22 Check your answers in the back.
15. Name the following: HF and H₂SO₃ and H₂SO₄
16. Which of the acids in #15 are oxyacids? How does this change the way they are named?

Single Replacement Reactions (p.287-8, 300-301)

17. Why does silver not react with Cu(NO₃)₂?
18. Would tin react with Cu(NO₃)₂? Would gold react with Cu(NO₃)₂?
19. Write the activity series from p. 288 in your lab book-VERY IMPORTANT.
20. If Mg reacts with Zn(NO₃)₂, would Zn react with Mg(NO₃)₂? Explain.
21. Will Cu react with HCl? Explain.

Environment: Acid Rain (p.610 Figure 19-11; p.847-9)

22. Describe the pH scale.
23. What causes acid rain?
24. What are the effects of acid rain?
25. Can acid rain be controlled?

26. Pennies –Post 1982 Explain what they are made out of-Research this.

Test #2 will cover all of the above, writing formulas, naming compounds, identifying types of reactions, balancing equations, writing balanced chemical equations from word equations, mole interactive stations, molar mass, molar conversions, % composition, hydrates, and empirical formulas.

Rubric for Lab books

Name _____ Per _____

_____ Title, Safety, Objective

_____ Pre-lab notes (answers to questions 1-25)

_____ **Researched Properties Table** (at least 5 properties, type of substance, and 2 uses for each substance)

_____ copper	1	2	3	4	5	_____	1	2
_____ platinum	1	2	3	4	5	_____	1	2
_____ lead	1	2	3	4	5	_____	1	2
_____ aluminum	1	2	3	4	5	_____	1	2
_____ magnesium	1	2	3	4	5	_____	1	2
_____ sodium	1	2	3	4	5	_____	1	2
_____ sulfur	1	2	3	4	5	_____	1	2
_____ silicon	1	2	3	4	5	_____	1	2
_____ zinc	1	2	3	4	5	_____	1	2

_____ **5 Lab Data Tables** for each test (all data with units included)

_____ Test 1 _____
 _____ Test 2 _____
 _____ Test 3 _____
 _____ Test 4 _____
 _____ Test 5 _____

_____ **Procedure** for each lab test listed above

_____ Test 1 Procedure
 _____ Test 2 Procedure
 _____ Test 3 Procedure
 _____ Test 4 Procedure
 _____ Test 5 Procedure

_____ **Element Chart** – List of 9 elements, would it be good for a statue choice, reasons.

_____ copper	_____ platinum
_____ lead	_____ aluminum
_____ magnesium	_____ sodium
_____ sulfur	_____ silicon
_____ zinc	

_____ **Impact Analysis-Address each of the items below.**

_____ Analysis of Current Material Cost for the statue that you have chosen.
 _____ Show calculations of cost for each element
 _____ Show calculation of cost for overall statue (what you are going to charge us)
 _____ Any Environmental concerns for all elements in all statues
 _____ Chemical reactions (at least 2 shown-balanced and explained)

_____ **Conclusion: Statue choice** clearly stated with major reasons(at least 3) given with data to support choice.

_____ Statue chosen is drawn in lab book with any modifications shown
 _____ Reason 1-
 _____ Reason 2-
 _____ Reason 3-

_____ Any modifications with detailed reasons for modifications

_____ **Answers to Moley Statue Post-lab questions**

Power Point/Presentation Rubric

Power point must be submitted to teacher folder (per teacher instructions). Do not submit your power point until you are sure it is ready – no corrections can be made once submitted. Power points must be submitted before presentation. Print a copy of the power point (Handout – 6 slides to a page; black and white).

_____ **Introduction**

- _____ Motivational introduction
- _____ Assignment acknowledged (why are you presenting today)

_____ **Element data** (researched and lab results) on all elements

- _____ Slides show all properties of elements (do NOT read these aloud)
- _____ Only highlighted, important data mentioned orally in presentation
- _____ Elements that are rated as good or bad choices for statue with reason(s) given

_____ **5 Lab tests**

- _____ Why did you do each test?
- _____ What did each test tell you?
- _____ How do the results of each test impact your statue choice?
- _____ How do your lab results compare with published values?

_____ **Environmental concerns** for all elements in all statues.

_____ **Chemical reactions** (at least 2 shown-balanced and explained)

_____ **Statue Choice**

- _____ Which statue do you choose?
- _____ Major reasons for picking this statue
- _____ Analysis of Current Material Cost for the statue that you have chosen.
 - _____ Show calculations using bridges of cost for each element
 - _____ Show calculation of cost for overall statue (what you are going to charge us)
- _____ Any modifications?
- _____ Major reason for not picking other 4 statues

_____ **Conclusion**

- _____ Briefly restate major ideas
- _____ Pull entire presentation together
- _____ End with final statement or selling point or gimmick to help us choose you

_____ **Why we are so clever!** List the 3 coolest discoveries that your class made throughout the course of this lab. These must be listed on a slide.

_____ **Presentation skills**

- _____ Each person must have a speaking part and understand entire presentation.
- _____ Slides are not to be read out loud.
- _____ Presentation must be able to be presented with absent team members.
- _____ Unique, pertinent information presented
- _____ Logical flow of ideas toward conclusion
- _____ Persuasive and convincing presentation

Moley Statue Post-Lab

1. If Na reacts violently with water, why can you eat table salt, NaCl? Can you use salt to test the properties of Na?
2. Label each test done as physical or chemical.

	Physical or chemical
Reacts with CO ₂	
Melting point	
Oxidation	
React with acid rain	
Density	
Malleability	
Color	
Dissolves in water	
Reacts with water	

3. Will nickel react with acid rain? Explain. What is acid rain?
4. In your research, did you find anything that would be better to use than metals?
5. In your Log Book Guidelines in the beginning of your book, it states that ALL Data (which means any measurement) must appear on the Data Table. Sketch a data table for finding the density of 20 shots of nickel. Would you use all 20?
6. What is the significance of observing luster? Should metals be shiny? If they're not, what does that tell you? Which metals were the least lustrous? The most? What does this tell you about them?
7. Does each metal only occur in one form (i.e. pellets, sheets, etc)? Would this affect any of your tests?
8. Conductivity and lightning? Reflect on this as a serious consideration.
9. Did you think about other metal statues that you've seen outside? Where have you seen these? What are they made of?
10. Are metals soluble in water? Is sulfur soluble in water? How do you know? Differentiate between dissolves and reacts.
11. Did you expect aluminum to react more than it did based on the activity series? Why don't you think it reacted as much as it should? Did any other metals surprise you in how they reacted? How could you make them react quicker/better?
12. Many of you looked up Mohr's Hardness for your different elements. What does this tell you? What is malleability? Are hardness and malleability the same? Do they tell you the same thing?

13. Compare metals, nonmetals, metalloids.

	Metals	Nonmetals	metalloids
Location on p.t.			
Examples			
Malleable			
Ductile			
Luster			
Reacts with acid			
Conducts heat and electricity			
Melting point			

14. Name the acids below:

- a. HI b. HClO_3 c. HClO_2

15. Write the balanced equation for the reactions below that will actually take place.

- lead + potassium chloride
- calcium + aluminum nitrate
- magnesium + platinum (IV) chloride
- aluminum + hydrochloric acid
- aluminum + water

16. Write balanced equations for the following.

- magnesium reacting with oxygen
- aluminum reacting with acid rain (sulfuric acid)
- sodium reacting with water

17. What are the most reactive metals on the periodic table? What is the trend in metal reactivity as you go down a group? What is the trend in metal reactivity as you go across a period?

Moley Statue Lab Assessment

For questions 1-8, label physical or chemical. (3 pts each)

1. silver tarnishes
2. gold is malleable
3. alcohol is flammable
4. copper has a density of 8.9 g/mL
5. magnesium melts at 650 C
6. baking a cake
7. copper is brownish
8. a substance bubbles and changes color when acid is added

Choose the BEST answer for each of the following. (3 pts each)

9. Acid rain has a pH below
 - a. 3.6
 - b. 5.6
 - c. 7
 - d. 8.6
10. A metal that lacks luster might
 - a. have an oxide coating
 - b. have an oxyacid coating
 - c. have reacted with a noble gas
 - d. be a nonmetal
11. A(n) _____ is a solid-solid solution composed of 2 metals or a metal and a nonmetal.

For questions 13-15, write metal or nonmetal (3 pts each)

13. malleable
14. conductive
15. high melting point

Short Answer (#16-17 are 15 points each; #18 is 25 points)

16. Some aluminum (density = 2.7 g/mL) has a mass of 21.4 g. When put in a graduated cylinder with 55.0 mL of water, the water rose to 61.6 mL. Calculate the density.
17. Which of the following reactions will occur? If they occur, then write a balanced equation for it.
 - a) silver + magnesium nitrate
 - b) tin + copper chloride
 - c) zinc + hydrochloric acid
- 18.

Substance	Density (g/mL)	Melting point(C)	malleable	Acid rain
A	4.1	890	no	reacts
B	12.4	125	yes	Does not react
C	2.7	30	yes	Does not react

You must pick one of the above substances for the top part of a statue. Tell which one you would pick (none are perfect) and justify why it is better than the other 2. Also, tell why it is less than perfect.

Mole Interactive Station Practice

How many hospitals would you need to hold a mole of tootsie rolls if 85,000 tootsie rolls could fit in 1 room of the hospital and there are 1,020 rooms in each hospital (Assume that all rooms can hold the same amount of tootsie rolls)? You must use a bridge to solve this problem.

Appendix G

Time Line of the Data Collection & Data Sources

Table G1

Data Collection with Dorothy

Date	Project / Context		Data Sources			
			Classroom observation	Audio record	Video record	Interview
9/21/2007	Afterschool meeting 1			√		
9/21/2007	Water unit		#1	√		
9/24/2007	Water unit		#2	√		
9/25/2007	Water unit		#3	√		
9/27/2007	Carter Center Nigerian Trip Project	Introduction	#4	√	√	#1 (Initial interview)
10/01/2007		Day1	#5	√	√	
10/02/2007		Day2	#6	√	√	#2 (Pre/post interview)
10/03/2007		Day3	#7	√	√ (V1, V2, V3)	
10/04/2007		Day4	#8	√	√ (V1, V2 V3, Presentation)	#3 (Pre/post interview)
10/05/2007		Reflection	#9	√	√	
10/09/2007		Post-Lab	#10	√	√	
10/04/2007	Afterschool meeting 2			√		
11/05/2007	Moley Avogadro's Statues Project	Introduction	#11	√	√	#4 (Pre/post interview)
11/07/2007		Day1	#12	√	√	#5 (Pre/post interview)
11/08/2007		Day2	#13	√	√	
11/09/2007		Day3	#14	√	√ (V1, V2, V3)	#6 (Pre/post interview)
11/12/2007		Day4	#15	√	√ (V1, V2, V3)	
11/13/2007		Day5	#16	√	√	
11/14/2007		Post-Lab	#17	√	√	
11/19/2007		Reflection	#18	√	√	
2/21/2008	Reflective interview through VAT			√		#7 (Reflective interview)
3/11/2008				√		#8 (Reflective interview)
3/20/2008				√		#9 (Reflective interview)
3/28/2008	Final interview			√		#10 (Final interview)

Table G2

Data Collection with Lisa

Date	Project / Context		Data Source & Indication			
			Classroom observation	Audio record	Video record	Interview
9/21/2007	Afterschool meeting 1			√		
9/25/2007	Water unit		#1	√		
9/27/2007	Water unit		#2	√		
9/28/2007	Carter Center Nigerian Trip Project	Introduction	#3	√	√	#1 (Initial interview)
10/01/2007		Day1	#4	√	√ (V1, V2)	
10/02/2007		Day2	#5	√	√ (V1, V2, V3)	
10/03/2007		Day3	#6	√	√ (V1, V2, V3, Advise)	#2 (Pre/post interview)
10/04/2007		Day4	#7	√	√ (Front, V1, V3, Presentation)	#3 (Pre/post interview)
10/05/2007		Reflection	#8	√	√	
10/09/2007		Post-Lab	#9	√	√	#4 (Pre/post interview)
10/04/2007	Afterschool meeting 2			√		
11/05/2007	Moley Avogadro's Statues Project	Introduction	#10	√	√	#5 (Pre/post interview)
11/07/2007		Day1	#11	√	√	#6 (Pre/post interview)
11/08/2007		Day2	#12	√	√ (V1, V2, V3)	#7 (Pre/post interview)
11/09/2007		Day3	#13	√	√ (V1, V2, V3)	#8 (Pre/post interview)
11/12/2007		Day4	#14	√	√	
11/13/2007		Day5	#15	√	√	#9 (Pre/post interview)
11/14/2007		Post-Lab	#16	√	√	
11/19/2007		Reflection	#17	√	√	
2/21/2008	Reflective interview through VAT			√		#10 (Reflective interview)
3/11/2008				√		#11 (Reflective interview)
3/19/2008				√		#12 (Reflective interview)
3/20/2008				√		#13 (Reflective interview)
3/28/2008	Final interview			√		#14 (Final interview)

Table G3

Data Collection with Cindy

Date	Project / Context		Data Source & Indication			
			Classroom observation	Audio record	Video record	Interview
9/21/2007	Afterschool meeting 1			√		
9/24/2007	Water unit		#1	√		
9/27/2007	Carter Center Nigerian Trip Project	Introduction	#2	√	√	#1 (Initial interview)
10/01/2007		Day1	#3	√	√	
10/02/2007		Day2	#4	√	√ (Back, Front)	#2 (Pre/post interview)
10/03/2007		Day3	#5	√	√ (V1, V2, V3)	#3 (Pre/post interview)
10/04/2007		Day4	#6	√	√	#4 (Pre/post interview)
10/05/2007		Reflection	#7	√	√	
10/09/2007		Post-Lab	#8	√	√	#5 (Pre/post interview)
10/04/2007	Afterschool meeting 2			√		
11/05/2007	Moley Avogadro's Statues Project	Introduction	#9	√	√	#6 (Pre/post interview)
11/06/2007		Day1	#10	√	√	#7 (Pre/post interview)
11/07/2007		Day2	#11	√	√ (V1, V2, V3)	
11/08/2007		Day3	#12	√	√	#8 (Pre/post interview)
11/09/2007		Day4	#13	√	√	#9 (Pre/post interview)
11/13/2007		Post-Lab	#14	√	√	
2/21/2008	Reflective interview through VAT			√		#10 (Reflective interview)
3/11/2008				√		#11 (Reflective interview)
3/20/2008				√		#12 (Reflective interview)
3/20/2008	Final interview			√		#13 (Final interview)

Appendix H

Interview Questions

Initial Interview

Background information:

- Tell me about influences on your decision to be a science teacher. (*When did you decide to become a science teacher? Why? If they do not have an answer, ask undergraduate education, a specific teacher or parental influence.*)
- Tell me about positive / negative experiences with regard to your own learning of science.
- Tell me about your science teaching experiences—years of teaching.
- Tell me about the classes (3rd, 5th, 7th period) you are teaching this semester. Tell me about the students in your classes.
- (*If they have not already said this*) What is your definition of student learning?
- How do you think your students learn science best?
- How do you differentiate between what students do and what students learn? (*How do you use instructional activities to aid student learning?*)
- What do you think makes science (chemistry) a difficult subject to learn for many students?
- How do you know when learning is occurring or has occurred in your classroom?
- Have you ever had any chance to use video in order to inquire into your own teaching practices and your students' learning?

Community Based Inquiry Lesson:

- Tell me about the CBIL. How did you come up with this idea?
- (*Use as expansion questions if not already answered*) What did you do in the summer workshop? Who developed all the materials for the activities?
- What is your purpose for using the CBIL? (*What do you intend for the students to learn from the CBIL? Why is it important for students to learn? if not already said*)
- What evidences are you looking for that your students are successful in achieving the learning goals?
- Tell me about the 1st project. Have you used this project before?
- What did you intend for the students to learn (about the concepts) from the 1st project? Why was it important for students to know (/learn) that?
- What aspect of your knowledge of students was most important in planning and implementing the lesson? (*If not already answered - What was difficult for students to understand about this concept? Were there any obvious misconceptions that students have related to this content?*)
- Did anything happen during the lesson that you had not anticipated?
- How did you assess your students' learning? What evidence did you use for assessment? How did you know whether or not students accomplished what you wanted them to get out of the lesson?
- Can you describe anything you would change about this lesson next time? What? Why?

Pre Interview

- Have you ever used this project before? If so, tell me about the previous episodes that you remember with regard to the project.
- What do you intend for the students to learn from this project? Why is it important for students to know that?
- What do students need to know before they start the project?
- What do students need to know and be able to do in the project today?
- What aspect of your knowledge of students influenced on planning the project?
- How could you monitor your students' learning while you are implementing the project?
- Where do you expect your students will be at the end of the project?

Post Interview

- How did the project go today?
- Could you tell me the most important / interesting moments from the perspective of students' learning science?
- Did anything happen during the project that you had not expected?
- What do you think the students got out of the project today?
- What signaled you that students were (not) learning science while they were involved in the project?
- Is there anything you would change about this project next time? What? Why?

Final Interview

About Community Based Inquiry Lesson:

1. How does your vision of teaching science and learning as inquiry match with the CBIL? (*Prompt: what do students need to know and be able to do?*)
2. To what degree does the CBIL match up to the overall goals of the courses in which you used it as an instructional strategy?
3. Please identify challenges that you faced when enacting the CBIL? Please identify successes that you felt resulted from using this instructional strategy?
4. (*If they do not discuss changes they would make when discussing challenges, ask*) What changes to this instructional strategy will you make before you use the CBIL again?

About student learning & teaching:

There were three CBILs used: Spinach Co., Nigerian Water, and Moley Statues.

1. How did you know whether or not students accomplished what you wanted them to get out of these lessons? (*Prompt: How did you become more aware of students' learning in terms of — content / thinking skills (reasoning) / inquiry skills / socials skills?*)
2. What were the most important signals (*prompt: evidence*) that your students were learning in the CBIL? (*Prompt: Could you see the development of students' ideas?*)
3. Could you explain your role as a facilitator, as compared to being an authority, within the CBIL?

About teacher inquiry using VAT:

1. How has inquiring into student learning informed your ideas about teaching science / inquiry? (*Prompt: Were there benefits from watching videos of your own classroom?*)
2. What could you consider the most effective teaching moment in the CBIL?
3. Do you see yourself doing this type of teacher inquiry project again in the future?

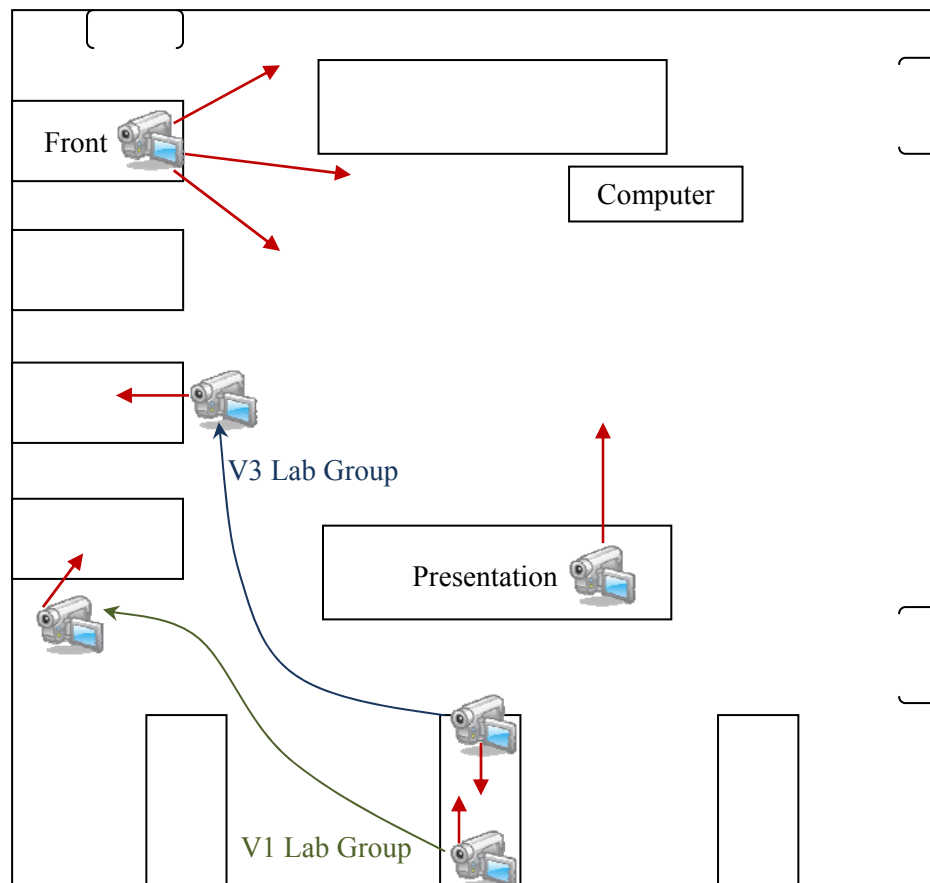
Appendix I

Sample of a Classroom Chart

Lisa's classroom

Date of observation: 10, 04, 2007

CBIL: Carter Center Nigerian Trip Project



Video data obtained:

- Front
- V1 Lab Group
- V3 Lab Group
- Presentation

Appendix J

Video Analysis & Reflective Interview Questions
— Carter Center Nigerian Trip Project —

Table J1

Video Analysis with Dorothy

09, 27, 2007 (36:16)		
Time	Description	Questions
16:25-20:21	TDS : Conductivity tester	Could you describe what happened in this moment? Why did you ask those questions? What did you intend for the students to know and to do?
22:43-27:48	Introduction of the Water project	Could you describe what happened in this moment? What did you intend for the students to know and to do?
27:56-31:04	Explanation of the grade / process	Could you describe what happened in this moment? Why did you explain the grade in detail?
32:16-35:09	Background information	Could you describe what happened in this moment? What did you intend for the students to learn?
10, 01, 2007 (53:36)		
Time	Description	Questions
04:09-04:50	Teacher role	What was your role as Ms. Lab assistant?
12:26-13:34	Classroom manager	What was the role of classroom managers?
13:55-15:45	Screening	What do you think about their ideas of screening?
16:24-17:20	Chlorination	What do you think about their discussion about chlorination? (There was a question about the amount of chlorine, but it was ignored. What do you think?)
19:19-21:00	Flocculation	What do you think the reason she did not understand crystals of alum will remove particles?
22:07-23:05	Settling	What do you think his idea?
23:40-24:20	Sand filter	What do you think her idea?
24:40-25:43	Filter paper	What do you think about their discussion about using a filter paper?
27:30-29:00	Post- Chlorination	What do you think about their idea of using water in this process? You did give amount of chlorine that they would use. Why?
30:00-32:25	Aeration	What do you think their ideas (boiling and distillation) which came from TV? What do you think her idea of blowing air by using a straw?
34:45-35:43	Several trials	She suggested testing different types of trials. What do you think?
36:55-38:07	Different sifters	She proposed to use different types of sifters. What do you think?
46:53-49:31	pH & Calcium oxide	What do you think about their ideas of pH?
10, 02, 2007 (49:17)		
Time	Description	Questions
0:01-00:30	Procedure:	What do you think about their 4 combinations?

	4 combinations	
6:38-7:48	Big filter	What do you think about his idea about using a one gig filter?
8:16-8:47	1st chart	What do you think about their first chart?
10:10-10:30	Communication	Based on this segment, what do you think about their communication skills? Do they communicate well?
16:25-17:35	Several tests	What do you think her idea?
19:40-20:30	Variables & trials	I will show couple of short clips, and then ask questions. If you want to make comments on those clips, you can do at any time. What could you know about your students' idea?
20:58-21:25		
22:35-23:35		
24:09-24:30	Color: spectrophotometer	What do you think about their idea? Where did this idea come from?
25:20-25:37	Odor	What do you think about his idea that only one person should smell odor?
28:00-28:15	hypothesis	What do you think about their ideas of hypothesis?
31:18-31:47	Measurement	I will show couple of short clips, and then ask questions. If you want to make comments on those clips, you can do any time. Why was it difficult for the students to decide when they would measure the amount of water?
33:15-33:41		
36:51-37:28		
38:13-39:10	final process	This is their final process. What do you think?
39:31-40:30	Contradictory data	What do you think about this conversation?
40:53-41:10	Data table	What do you think about these discussions and why is it important for them to create one data chart?
10, 03, 2007 / V1 Lab (40:33)		
Time	Description	Questions
2:15-2:23	IV/DV	The students did not mention independent variables and dependent variable. However, they wrote down at the beginning of the class. How did this idea come from?
5:59-7:10	Spray bottle	What did they do? Where did they get this idea?
8:00-8:40	Teacher	Why did you do this? (Calcium hydroxide)
9:06-9:14	Misconception	What do you think about the student's idea of "Calcium Carbon Hydroxide"?
14:14-14:23	Teacher	Why did you ask about using the graduate cylinder?
15:12-15:24	Teacher	You prepared all needed chemicals with labels and provided them to the students. Why did you do that? You mentioned the chemicals in the cup several times. Why did you do that?
16:14-16:23		
25:04-25:31		
10, 03, 2007 / V2 Lab (53:29)		
Time	Description	Questions
33:42-34:16	Flocculation	When you hear that what do you feel?
38:21-39:10	Settling	Do you have any intention to do the community-based inquiry lessons again?
43:43-44:43	Exciting	
47:30-47:40	Exciting	
46:35-47:00	Concerns about evaporation	What do you think about his idea about boiling and evaporation?
10, 03, 2007 / V3 Lab (36:25)		
Time	Description	Questions
8:28-8:40	Color & odor	One of the students asked about recording the color / odor of

		water, and the class manager’s answer was no. What do you think?
14:13-14:45	Flocculation	What do you think about Laura’s idea of using another beaker?
19:30-20:00	Boiling	What do you think about her question?
21:20-21:35	Boiling	What do you think about her idea of boiling?
29:53-30:18		
30:58-31:30		
10, 04, 2007 / V1 Lab (26:31)		
Time	Description	Questions
16:00-17:05	Teacher role	What was your role in this clip? Why did you answer like that?
23:30-25:40	Spectrophotometer	Could you describe what the students were doing in this moment?
10, 04, 2007 / V3 Lab (36:11)		
Time	Description	Questions
5:48-6:17	Distillation	Why did you introduce and explain the distillation process and the tool?
10:15-10:34	Distillation	Was there any reason you were giving more directions at this point?
12:10-13:00		
14:18-15:42		
25:17-26:00		
19:00-19:20	Spectrophotometer	What do you think about this moment?
23:35-23:45		
10, 04, 2007 / Presentation (16:07)		
Time	Description	Questions
6:33-6:48	Hypothesis	What do you think about their hypothesis?
6:49-7:38	IV / DV	What do you think?
10, 05, 2007 (25:45)		
Time	Description	Questions
5:59-6:20	Different sources	What do you think about her idea?
12:04-12:36	Clarity / color	Why did you ask those questions?
15:34-15:55	improvement	What’s your evidence?
10, 09, 2007 (55:34)		
Time	Description	Questions
2:41-2:56	Data table	Why did you to this?
5:30-6:56	Water left	What do you think about students’ idea?
13:29-14:47	Research	What did you expect for your students learn from research?
26:25-28:14	Tyndall effect	Did you plan this part before?
43:28-43:47	Questions	Why these two questions are important?
51:15-52:45	Other classes	There was kind of a competition between the classes. What was the purpose of doing that?

Table J2

Video Analysis with Lisa

09, 28, 2007 (16:55)		
Time	Description	Questions
1:03-5:03	Introduction of the Water project / TDS	Could you describe what happened in this moment? Why did you ask those questions? What did you intend for the students to know and to do?
5:39-8:30	Explanation of the activity	Could you describe what happened in this moment? What did you intend for the students to know and to do?
8:51-9:57	Review the last activity	Could you describe what happened in this moment? What do you think that your students learned from the Spinach Co activity?
10:51-12:10	Research	Could you describe what happened in this moment? What were the roles of students?
10, 01, 2007 / V1 (46:51)		
Time	Description	Questions
0:00-1:20	Teacher role	What was your role as Ms. Fluorine?
2:48-4:00	Job assignment	What do you think about the process of assigning jobs?
10, 01, 2007 / V2 (45:00)		
Time	Description	Questions
11:58-13:10	Lab process	What do you think about the question from Vicki (individual / series)?
15:50-17:08	Lab stations	How did the students resolve this issue?
23:05-24:40	Objective, hypothesis	What do you think about their ideas of objective and hypothesis?
28:33-31:30	Debate / sewage or water	Students debated on the test groups (e.g. sewage/water treatment). What do you think about their debate?
33:40-36:20	Independent variable	What do you think about their ideas of independent variable?
38:28-39:42	Procedure	What do you think of their conclusion about the procedure?
10, 02, 2007 / V1 Front (45:46)		
Time	Description	Questions
12:34-12:55	Naming chemicals	What could you know about your students' learning? (She pointed out the two chemicals, but could not name them.)
36:11-36:33		
10, 02, 2007 / V2 Conner (52:58)		
Time	Description	Questions
19:33-19:47	Chlorine debate	What do you think about their conclusion (no chlorine)?
31:44-32:27		
33:46-34:50		
41:25-42:40		
10, 02, 2007 / V3 Back (54:59)		
Time	Description	Questions
2:50-3:50	Writing procedures	Could you describe what happened in this moment?
7:40-8:00		What do you think?
30:05-31:30	Divide water	What do you think the way they divided water?
31:44-32:20	Suggest boil	What do you think her idea of boiling?
32:36-33:32	Chlorine	I will show three clips, and then ask questions. If you want to

36:18-37:00		make comments on those clips, you can do at any time. Why was
39:36-39:50		if a big issue that they would use chlorine?
44:40-45:20	Experiment skills	What could you know about your students' (experimental skills)?
47:11-47:55	Writing procedure	What do you think?
10, 03, 2007 / V1 Lab (48:07)		
Time	Description	Questions
3:00-3:43	Flocculation	What do you think about their discussion?
5:51-6:14	Naming chemicals	What could you know about your students' learning?
33:30-35:45	Distillation equipment	Why did you introduce and explain the distillation process and the tool?
36:45-37:10		
38:50-39:10	Distillation	Why did you ask that question?
10, 03, 2007 / V2 Lab (49:17)		
Time	Description	Questions
16:18-16:31	Oil remove	Where did this idea come from? What do you think?
18:00-19:04		
20:11-20:18		
23:13-23:25	Boiling	What could you notice the development of students' ideas?
28:10-28:55		
33:33-33:58		
24:20-25:12	Aeration	What do you think about using a spray bottle? Where did this idea come from?
29:15-30:00		
32:38-32:45		
10, 03, 2007 / V3 Lab (50:52)		
Time	Description	Questions
2:54-3:20	322 ml	What do you think?
6:34-7:45	Paper towel	What do you think about the whole idea of using paper towels?
9:34-10:45		
11:13-11:36		
12:52-13:05		
23:02-23:22	Aeration	What do you think about the debate about the purpose of aeration?
25:52-26:06		
26:33-27:34		
32:23-32:53		
29:50-30:32	Boiling	What do you think about their diverse ideas of boiling water?
37:43-38:28		
39:40-40:20		
38:44-39:00	TDS	What do you think about Vicki's idea?
10, 03, 2007 / Advise (13:55)		
Time	Description	Questions
6:10-6:50	Filtering	What do you think about students' ideas about sand filter?
9:34-10:22	Rationale	What do you think about students' ideas about using a paper towel?
10:33-11:08	Nylon filter	Discuss about using a nylon filter
10, 04, 2007 / Front (32:44)		
Time	Description	Questions
2:48-2:56	Classroom	Students were copying down the conclusion.
11:53-12:00		What could you notice in this moment?

3:43-3:50	Equipment	What could you know about your students' learning?
5:06-5:25		
24:32-25:10	% of water	What do you think?
10, 04, 2007 / V1 Lab (30:39)		
Time	Description	Questions
24:50-25:23	Conductivity tester	What do you think about their trial?
10, 04, 2007 / V3 Lab (19:03)		
Time	Description	Questions
0:00-0:40	TDS	What do you think?
1:25-1:45		
2:55-4:00		
14:27-14:55		
10, 04, 2007 / Presentation (16:11)		
Time	Description	Questions
4:43-5:04	Hypothesis	What do you think about their hypothesis?
5:37-5:41	Experimental design	Dependent variables / independent variables
5:43-6:01	Materials	Al sulfate => what do you think about their expression on the slide?
8:50-9:00	Choose mixed method	They chose the water + sewage group for filtering as the final trial. What could you know about their reason?
10:20-11:05	Rational	NO chlorine, NO aeration, NO sand filter => What do you think?
11:45-12:26	Conclusion	What do you think about their conclusion?
10, 05, 2007 (32:49)		
Time	Description	Questions
0:00-1:00	Spectrophotometer – color / clear	Why did you ask those questions? How did you notice students' misconceptions?
1:58-3:16		
3:25-4:36	Dissolved ions /	Why did you ask those questions?
5:01-6:24	Boil / distill	
18:07-20:40	Lab notebook	Why did you explain how to structure a lab notebook in detail?
10, 09, 2007 (52:47)		
Time	Description	Questions
7:21-8:35	Argumentation	What did you become more aware of students' learning in terms of social skills?
11:40-13:36	Research	What did you expect for your students learn from research?
13:40-19:52	Tyndall effect : clarity	Did you plan this part of lesson before? If so, how did you?
24:34-25:37	Conductivity probe	Why did you do that?
29:31-30:37	Filter paper	What could you learn about your students' idea?
34:41-34:53	Other classes	There was kind of a competition between the classes. What was the purpose of doing that?

Table J3

Video Analysis with Cindy

09, 28, 2007 (53:54)		
Time	Description	Questions
0:46-2:39	Review the Spinach Co	Could you describe what happened in this moment? Why did you ask those questions? What do you think that your students learned from the Spinach Co activity?
6:56-8:00	Introduction of the Water project	Could you describe what happened in this moment? What did you intend for the students to know and to do?
8:21-11:13	Explanation of the grade	Could you describe what happened in this moment? Why did you explain the grade in detail?
15:55-16:30	Wow!	Could you describe what happened in this moment? Why the “WOW” factor was important for you and your students?
19:44-22:07	Background information	Could you describe what happened in this moment? What did you intend for the students to learn?
38:29-39:55	Chemical and physical change	Could you describe what happened in this moment? What was difficult for students to understand about the concept of chemical and physical change?
44:15-46:10	Classification of matter	Could you describe what happened in this moment? What was difficult for students to understand about the classification of matter (pure substance, heterogeneous mixture, homogeneous mixture)?
10, 01, 2007 (46:05)		
Time	Description	Questions
2:47-3:24	Teacher role	What was your role as a teacher in this community based lesson?
4:10-5:20	Classroom manager	What was the role of classroom managers? What do you think the process of selecting classroom managers?
14:17-16:02	Hypothesis	What do you think about their ideas of hypothesis?
24:35-29:29	Classification of matter	Why did you ask these questions? (Pure substance, heterogeneous & homogeneous mixture)
28:22-32:07	Aeration	Physical change? Chemical change?
41:47-42:45	Conductivity test	Why did you introduce the conductivity tester?
10, 02, 2007 / Front (49:38)		
Time	Description	Questions
4:38-6:03	Filtering	Last time, the students discussed about 10 procedures in detail. But, today they jumped to the filtering process. What do you think?
24:00-25:58	Grouping	What could you know about your students (learning, ideas, and abilities)?
27:33-29:10	C filter	Why did you show Carbon? What do you think about his ideas that carbon is a form of gas?
10, 02, 2007 / Back (49:38)		
Time	Description	Questions
2:29-3:40	Bleach	What do you think about their ideas of using bleach?
4:33-5:21	Aeration	What do you think about their conclusion in relation to aeration?

5:23-5:32	Guinea worm	The classroom leaders asked questions about research. “Who did the research on something?” Then, the students presented their research findings. What do you think about these procedures? What could you learn about your students from this discussion?
6:40-07:03	Boiling	
7:13-7:50	Filtration	
7:54-8:00	Nigerian water	
8:46-8:52	Research	
9:44-10:09	Chorine	
10:10-10:18	Conductivity	
10:50-11:02	Sand filtration	
11:35-11:40	Guinea worm	
13:35-14:24	Chorine debate	Why it was issues for the students?
16:12-16:38	Filter	Why did you introduce the filter/screen equipments?
26:43-28:15	Amount of water	Why was it difficult for the students to decide the amount of water to test?
28:56-29:11		
29:29-32:22		
33:45-34:25	3 different groups (carbon, sand, coffee)	What do you think about her suggestion?
43:13-44:07		
46:36-48:26	Final process	What do you think about their conclusion?
10, 03, 2007 / V1 Lab (24:00)		
Time	Description	Questions
1:15-01:35	CM	Do they know what they would do?
12:20-13:12	Paper towel	Where did they get the idea of using a paper towel?
16:00-16:38		
20:34-20:40		
10, 03, 2007 / V2 Lab (35:42)		
Time	Description	Questions
1:00-2:00	Teacher role	What’s your role in this project?
2:34-2:46	CM	What’s the role of the classroom managers?
4:50-5:40	Paper towel	Where did they get the idea of using a paper towel?
7:00-7:05		
25:58-27:00	Paper towel + filter paper	
10, 03, 2007 / V3 Lab (1:38:27)		
Time	Description	Questions
12:46-13:15	CM	What’s the role of the classroom managers?
14:50-15:03	Teacher role	What’s your role in this project?
17:56-18:12	Filtering	Why didn’t filtration work?
26:09-26:55		
33:25-33:55	CM	What’s the role of the classroom managers? What do you think about students’ attitude?
44:43-45:40	Distillation	Why did you introduce the distillation equipment to the students?
45:50-46:05		
49:23-50:15		
54:40-56:00		
25:03-25:37		
10:32-10:51	Discussion procedure	What could you know about your student learning from the way they set up the final procedure?
11:37-12:25		
14:11-14:25		
14:50-15:00		

32:00-34:25		
10, 04, 2007 (52:53)		
Time	Description	Questions
1:39-1:59	Data Table	What do you think about their discussion or what they were doing?
4:24-4:35	DT: filter paper	
4:52-5:03	DT: color	
5:36-6:04	DT: chlorine	
6:52-6:59	DT: boiling	
7:05-7:12	DT: filter	
7:52-8:30	DT: Boil	
13:34-13:51	Predict the results	What do you think about the fact that the students were making up data?
14:15-14:27		
28:58-29:23	Conclusions	What do you think about their conclusions?
29:32-29:59		
33:56-34:16	Teacher role	What was your role as Ms. H ₂ O?
38:30-39:11	Presentation	What do you think about their rational?
45:45-46:39	Teacher questions	Why did you ask these questions? What do you think their ideas?
48:38-50:01		
10, 05, 2007 (25:22)		
Time	Description	Questions
1:58-3:32	Clarity / Color	Why did you ask those questions? How did you notice students' misconceptions?
14:09-14:31	Tyndall effect	Why did you ask about this concept?
16:01-17:33	Compounds	Why did you ask about this concept?
10, 09, 2007 (51:31)		
Time	Description	Questions
0:56-1:10	Other classes	What was the purpose of doing that?
3:43-4:31	Improvement	What's your evidence of students' improvement?
10:38-11:35	Passive	What could be more effective ways that motivate students?
11:36-12:03	Research	What did you expect for your students learn from doing research?
25:00-27:39	Colloids	Could you explain
29:44-30:37	Clarity / Color	Why is it important to know these concepts?
31:29-33:10	Tyndall effect	Did you plan this part of lesson before? If so, how did you?