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Preservice Teachers' Use of Lesson Study in Teaching Nature of Science

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ACCEPTANCE

This dissertation, PRESERVICE TEACHERS' USE OF LESSON STUDY IN TEACHING NATURE OF SCIENCE, by AMY VIRGINIA MCDOWELL, was prepared under the direction of the candidate's Dissertation Advisory Committee. It is accepted by the committee members in partial fulfillment of the requirements for the degree Doctor of Philosophy in the College of Education, Georgia State University.

The Dissertation Advisory Committee and the student's Department Chair, as representatives of the faculty, certify that this dissertation has met all standards of excellence and scholarship as determined by the faculty. The Dean of the College of Education concurs.

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ABSTRACT

PRESERVICE TEACHERS' USE OF LESSON STUDY IN TEACHING NATURE OF SCIENCE
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The purpose of this study was to explore preservice teachers' lived experiences in a lesson study focused on teaching and learning nature of science (NOS). The body of knowledge about shifting pre- and in-service novice NOS understandings is substantial. The focus of science education research is now exploring ways to move these informed NOS understandings into classroom practice (Abd-El-Khalick & Lederman, 2000b).

The research questions guiding the study were (a) how do preservice teachers' understandings of NOS shift as a result of the lesson study experience?, and (b) how does the reflective practice that occurs in lesson study influence preservice teachers' transition of NOS tenets into classroom practice? The participants in this study represented a sample of graduate preservice teachers, who were part of a middle and secondary science teaching alternative certification program in a southeastern university. In the first summer semester of this certification program, the participants were immersed in reform based science instruction; a section of which included NOS teachings (INTASC, 2002). In the following semester, participants were placed in a practicum setting; where the exploration of the preservice teachers' teaching of NOS was supported through the modified lesson study framework.

Data sources included the Views on Nature of Science – Form B (VNOS-b), interviews, and lesson study portfolios. Analysis of NOS understandings was guided by instruments found in literature associated with the VNOS-b (Lederman et al., 2002) and reflection (Ward & McCotter, 2004). Results showed successful transfer of NOS into

classroom practice using the modified lesson study framework, with less success in the deepening of participants' NOS understandings. Of particular significance was that results indicated a deepening of NOS pedagogical content knowledge for those participants functioning at higher levels of reflection. The study's results' contributes to two knowledge bases. First it provides insight to how lesson study can be used in the United States in alterative teacher preparation programs. Second, it contributes to what is understood about how to support the transition of NOS understandings into classroom practice.

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ABBREVIATIONS

INTASC	Interstate New Teacher Assessment and Support Consortium
NOS	Nature of Science
NRC	National Research Council
NSES	*National Science Education Standards*
NSTA	National Science Teachers Association
VNOS	Views on Nature of Science

CHAPTER 1

INTRODUCTION

For the United States, "Science For All Americans: Project 2061," details an approach to reform in education, specifically in science, mathematics, and technology (American Association for the Advancement of Science (AAAS), 1993). This seminal reform document informs national standards and benchmarks for literacy, such as the National Science Education Standards (NSES) for K-12 (NRC, 1996), the National Board for Professional Teaching Standards (NBPTS, 1996) and the National Science Teachers Association (NSTA) Standards for Science Teacher Preparation (NSTA, 2003). At different levels of education, these standards and benchmarks set minimum cognitive abilities and behavioral expectancies as they relate to the teaching and learning of science content, the nature of science, and the processes of science. Meeting these minimum standards would ideally lead to a scientifically literate nation of citizens, where the "knowledge of the nature of science can enable individuals to make more informed decisions with respect to scientifically based issues" and provide a "defense against unquestioning acceptance of pseudoscience and of reported research" (NSTA, 2003, p. 14). Furthermore, an outpouring of literature published after the 1999 Third International Mathematics and Science Study (TIMMS) brought to the public's attention a declining trend in standardized math and science scores among students in the United States in comparison to students of other countries, especially Japan (Stigler, Gozales, Kwanaka, Knoll, & Serrano, 1999). While this standardized approach to education is not one that most philosophers of science education would advocate, it is undeniable that the results of these assessments combined with growing energy needs and economic decline, have redirected political agendas in the arena of science education. In *The Teaching Gap* (Stigler & Hiebert, 1999), detailed analysis was provided from the 1999 Video Study of TIMSS. In a portion of *The Teaching Gap*, Stigler and Hiebert (1999) emphasize Japanese reflective teaching practices aimed at improving student learning; practices rendered in stark contrast to those of the United States.

This dissertation study draws from both results of the 1999 Video Study of TIMMS analyzed in *The Teaching Gap* and NSTA (2003) standards to explore a framework for teacher preparation consistent with the reform needs in science education as it relates to integrating nature of science (NOS) understandings into the classroom, using reform-based reflective practices. NSTA (2003) states that science teacher candidates must demonstrate competency and preparedness in teaching nature of science concepts, outlining three gateways of performance required. Consistently, NSTA (2003) addresses the need for future science teachers to plan and implement curriculum consistent with NSES:

> Teacher candidates should engage in planning and implementing lessons and units of instruction early and often, and should be responsible for demonstrating such planning throughout the programs. With little experience in teaching, candidates may find such planning difficult and time-consuming. There is a tendency among novices to fall back upon activities for their own sake, rather than deliberately plan a lesson or a unit with concern for how it might be made more effective…Candidates can be asked to formally assess the internal consistency of their plans using program criteria and may create a reflective narrative to explain that assessment. (p. 24)

Rendered in stark contrast to the United States' reflective practices in teacher training, Japanese practices commonly include what is known as lesson study. The success of Japanese schools has inspired several school systems and teams of educators in the United States to work toward improvement of teaching in a more systemic manner modeling that of Japan's Lesson Study (Fernandez & Yoshida, 2004; Fernandez, Cannon & Chokshi, 2003; Lewis, 2002a; Lewis, Perry & Hurd, 2004; Watanabe, 2002). Through lesson study, Stigler and Hiebert (1999) asserted that Japan has more successfully made the shift in professional development recommended by the National Research Council (1996) than has the United States itself. Stigler and Hiebert (1999) are not alone in the assertion. For example, Lewis and Tsuchida (1997) report "grassroots, teacher-initiated study circles and publicly supported study groups dot Japan's educational landscape" with an estimated 10 to 50 percent of elementary teachers as members of Japan's research groups (p. 319). The framework from which Japanese lesson study operates actually coincides with many recommendations, including those outlined earlier in the NSTA (2003) Standards for Teacher Preparation.

NSTA (2003) emphasizes the need for preservice teachers to actively reflect on ways for improving student learning. For example, standard ten (NSTA, 2003) emphasizes the need for future science teachers to continuously reflect on their practices, "striving continuously to grow and change" (NSTA, 2003, p. 30). NSTA (2003) recommends active engagement in reflection, using resources such as other students, colleagues, and supervisors and collaborating within this community of experts continuously demonstrating a commitment to science teaching through "examination of one's own teaching, experimentation with new approaches, and the sharing of insights with other teachers" (p. 31). NSTA (2003) standards for teacher preparation also advocate for future educators to demonstrate competencies in content knowledge, planning skills, success in engaging their students in relevant science issues, and inquiry into effective science teaching strategies (NSTA, 2003, p. 1). Standard two (NSTA,

2003) emphasizes three competencies science teachers must possess and demonstrate as it relates to current understandings of nature of science (NOS). These criteria include a contemporary understanding of science as an epistemology and discipline, and successfully engaging students in NOS studies (NSTA, 2003, p. 16). While the requirement to demonstrate effective NOS instruction in the classroom might seem simplistic, its successful transition poses a problem for many preservice teachers in teacher training programs (Abd-El-Khalick & Lederman, 2000b; Lederman, 1992).

Purpose of the Study

The research in this dissertation study explored preservice teachers' use of lesson study as they transitioned in teaching nature of science (NOS) curriculum outlined in the National Science Education Standards for K-12 (NRC, 1996). Lesson study has experienced long term success in Japan's education system as a means for professional growth and reflection; thereby prompting members of the United States research community to begin exploring its features for possible use in the United States. Lewis, Perry, and Murata (2006) anticipate a lack of success with lesson study in the United States as long as the knowledge base of the research community is structured around two seminal pieces of literature (Fernandez & Yoshida, 2004; Lewis, 2002b). This research contributes to literature in its exploration of the lesson study experiences of graduate level preservice science teachers' as they focus on ways to transition NOS curriculum into their classroom practice. The potential this holds in adding significant data to the knowledge base of how science teacher preparation programs can both promote NOS curriculum and foster the development of reflective practitioners is unparalleled. Hiebert, Morris, Berk, and Jansen (2007) argue for teacher preparation programs which prepare preservice teachers “to learn from teaching when they enter the profession” (p. 49). In the argument presented, Hiebert et al. (2007) call for teacher preparation programs to provide opportunities for preservice teachers to learn how to analyze teaching in terms of student learning. The researchers hypothesize that this can be accomplished by developing knowledge, skills, and dispositions which would contribute to the preservice teacher’s ability to study and improve teaching over time. Abd-El-Khalick and Lederman (2000b) call for research efforts in science education which seek to identify or isolate factors which “constrain or facilitate the translation of teachers’ conceptions of NOS into classroom practice” (p. 696). Inspired by the reviewed literature, this research study seeks to explore how preservice teachers experience lesson study as a reflective, analytical process for transitioning their teaching and learning of NOS content strands.

Research Questions

1. How do preservice teachers’ understandings of NOS shift as a result of the lesson study experience?
2. How does the reflective practice that occurs in lesson study influence preservice teachers’ transition of nature of science tenets into classroom practice?

Significance of the Study

When preservice teachers enter science teacher preparation programs as graduate students seeking to earn alternative certification, they have often been taught a body of existing scientific knowledge through lecture and validation labs. Unfortunately, the stark reality is that these former experiences in science classrooms account for preservice teachers' background of what science teaching should be like, or pedagogical content knowledge (Boyer, 1987; Dunkin & Barnes, 1986; Parsons, 1997). This understanding of how science works and its resulting body of knowledge is inconsistent with how science education researchers currently view the inclusion of NOS in classroom practice (McComas, Clough, and Almazroa, 1998). Additionally, science education researchers have long held beliefs that teachers' views of NOS are directly related to its integration in the classroom (Lederman, 1992). Therein lies a contradiction of epistemologies between contemporary NOS tenets promoted in teacher training programs and that of the preservice teachers' personal backgrounds (Lederman, Gess-Newsome & Latz, 1994). This means students former experiences in science classrooms are traditionally characterized by lecture and validation labs, which is pedagogy typically minimized in current science teacher training programs. Long held assumptions in science education research as to the relationship between these beliefs and teaching actions drives research of NOS in teacher training programs (Abd-El-Khalick & Lederman, 2000b; Lederman, 1999; McComas, 1998).

After a review of relevant research, McComas et al. (1998) attest to the influence of understanding NOS on teachers' actions, stating, "teachers consider the nature of what they perceive their discipline to be and those views are translated in ways they themselves may find surprising" (p. 19). King's (1991) research illustrates this point. King (1991) interviewed thirteen preservice teachers in a science curriculum and instruction course, after their student teaching experiences, to explore the preservice teachers' teaching and learning goals. King (1991) anticipated that this exploration would provide an opportunity to assess what sort of deficiencies in preservice teachers' backgrounds existed in order to suggest corrections. In one of the interviews a participant came to understand the disparity between how she was taught and her own teaching style. The participant stated,

> I learned science as a collection of facts, with no knowledge of how those facts came to be facts, or why those facts are considered facts. When I talk about teaching my students to think critically, I guess what I mean is that they have that historical and philosophical knowledge so that they understand and appreciate the hows and whys. I wonder how I'll be able to teach this way, given my shallow knowledge of science. The only thing I feel prepared to do now is to teach my students the facts I learned. (King, 1991, p. 139)

King reports that the preservice teachers in his study frequently complained about how difficult it was to incorporate inquiry, discovery, and critical thought into their teaching. Differences in ideas of the philosophy and sociology of how science works and the scientific knowledge that comes out of science work, reflects one of the issues faced in the strife to promote the inclusion of NOS tenets among preservice science teachers' experiences.

One significant line of inquiry in science education research has centered on ways for improving preservice teachers' understandings of NOS. As a result, a tremendous body of literature informs and continues to contribute to NOS curriculum in teacher preparation programs (McComas et al., 1998). As NOS curriculum has been researched, it has successfully provided evidence for ways to improve NOS understandings for preservice teachers. Described in detail of Chapter Two are four streamlined approaches to integrating NOS in teacher training repeatedly reported in the literature as improving NOS understandings (McComas et al., 1998). These approaches include NOS in methods courses, NOS in science content classes, authentic experiences "doing" science, and formal courses in NOS (McComas et al., 1998). However, the success of these improved NOS understandings at the preservice level transferring into classroom practice, has been inconsistently reported (e.g., Abd-El-Khalick, Bell, & Lederman, 1998; Bell, Lederman, & Abd-El-Khalick, 2000; Black, 2003; Schwartz & Lederman, 2002). Clough (1997) argues that even while some preservice teachers have had the aforementioned experiences with NOS, there is additional need to provide support in learning how to integrate contemporary NOS understandings when teaching science content. Clough (1997) states that while preservice teachers might have informed NOS understandings, they do not "possess strategies to incorporate it into instruction" (p. 197). The lack of transition of informed NOS understandings into classroom practice from preservice through the first several years of full time teaching poses an issue (Bell et al., 2000; Bentley & Fleury, 1998; Clough, 1997; Nott & Wellington, 1998).

Guidelines serving as a resource for NOS instruction and expectations in teacher training programs, such as those expressed by Interstate New Teacher Assessment and Support Consortium (INTASC), outline the needs for teachers to "understand the central concepts, tools of inquiry, application and structure of science" in various science content areas including NOS (INTASC, 2002, p. 10). INTASC (2002) standards, and NSTA (2003) performance standards for teacher preparation, recommend explicit, reflective instruction and first-hand experience in relation to contemporary views of NOS for preservice teachers. Abd-El-Khalick and Lederman (2000b) additionally argue the need for preservice teachers to be provided a conceptual framework within the context of content, activities, sociology of science, etc. through means of explicit, reflective instruction. Barring that the preservice teacher has an informed understanding of NOS, the authors argue that the reflective experiences associated with the use of various NOS activities would promote pedagogical content knowledge and the integration of NOS in classroom practices.

However, the transition of NOS into classroom practice transcends this assumption with a growing body of research to support the complexity of this issue (Abd-El-Khalick et al., 1998; Bell et al., 2000; Black, 2003; Schwartz & Lederman, 2002). While preservice teachers' conception is a variable to consider, well documented are the myriad difficulties for preservice teachers in understanding and integrating NOS into classroom practice. Factors shown to impact this implementation include the isolation of NOS outside of any authentic science experience, time constraints, management issues, subject matter knowledge, institutional constraints, NOS content knowledge, NOS beliefs, and level of comfort associated with integrating NOS (Abd-El-Khalick et al., 1998; Bell et al., 2000; Lederman & Zeidler, 2001; Smith & Scharmann, 1999). Early research, which highlights the difficulties preservice teachers' experience in transitioning NOS into classroom practice, brings to the forefront the significance of this study. As lesson study encompasses each of these issues, it provides a reflective framework for opening discussion about teaching NOS and student learning, as well as, a supportive environment for redirecting preservice teachers' attention to the intended cognitive outcomes.

Lesson Study

According to Lewis (2002a), Stigler and Hiebert (1999), and Yoshida (1999), several essential features characterize Japanese Lesson Study: curriculum goals, lesson development, and reflection. Japanese teachers participating in lesson study begin by purposefully choosing a broad, long-term goal that is compelling across grade levels.

Examples of these goals might be: “To develop instruction that ensures students’ basic academic abilities, fosters their individuality, and meets their individual needs” (Lewis, 2002b). The curriculum goals of Japanese Lesson Study are reflected in the top of Figure 1. As illustrated in the second part of the visual, the participating teachers then develop a research lesson. The research lesson typically targets a particular weakness, a difficult topic for the teachers, or a subject that has recently changed. When planning the research lesson, the participating teachers work collaboratively for several sessions using a myriad of resources to integrate the common goal into an instructional plan.

After the research lesson is developed, the participating teachers then turn their attention to how students react to the delivery of the instructional plan. In Figure 1, this is referred to as conducting research. In Japan, teachers are seen as researchers, especially as they participate in lesson study. As a result, when the lesson study group observes the lesson taught by one of the members, the ultimate focus is student learning and development. Observations during the research lesson typically center on student engagement, student conversations, and overall disposition during the lesson. Analogous to a participant observer, teachers involved in the research lesson, observe the students throughout the delivery of the lesson, take notes on student reactions to the research lesson, and make every attempt to see instruction through the students’ eyes (Lewis, 2002b). In the reflective dialogue that follows, the participating teacher who delivered the lesson shares his/her perspective of the students’ specific reactions during the lesson (e.g. involvement, disposition, responsiveness, demeanor, etc.). Other participants in the lesson study group add to this discussion by sharing observations and making suggestions that might promote improvement of student learning goals in the research lesson. This

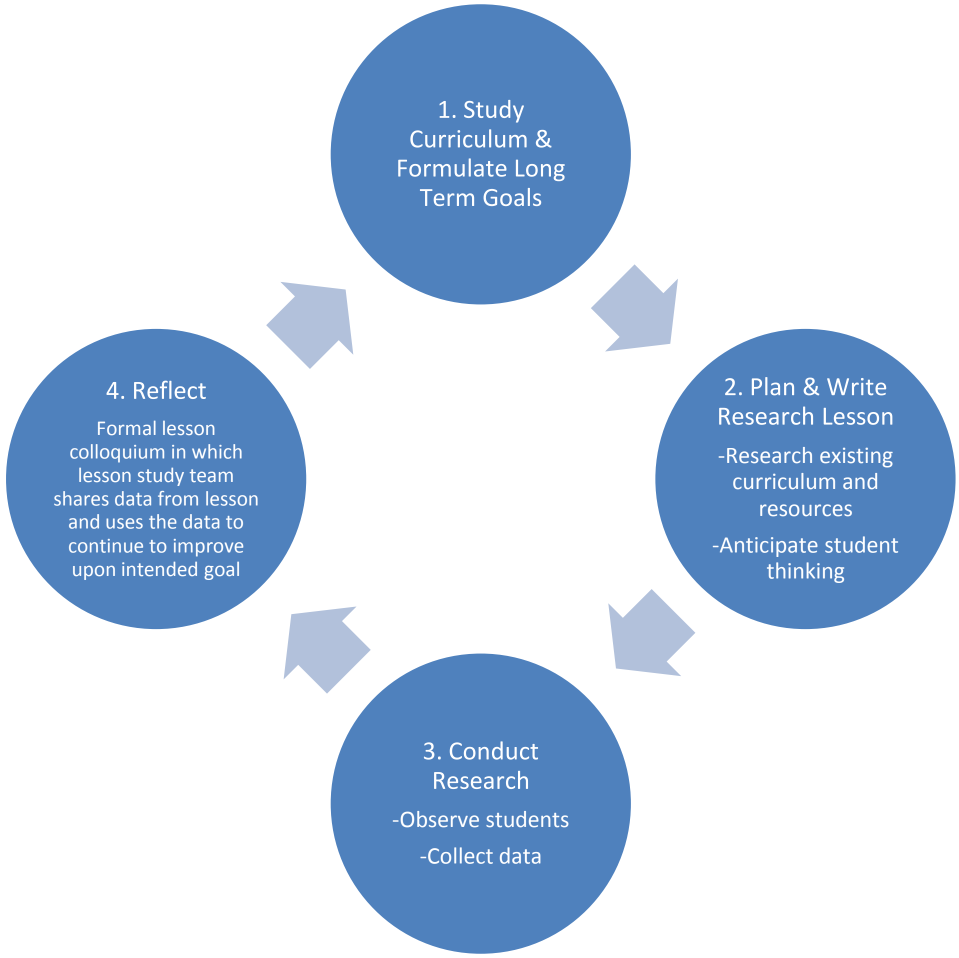

Figure 1. Visual representation of Japan's lesson study cycle. Reprinted from Lewis, Perry, Murata, 2006, p. 4.

feature of Japanese Lesson Study is represented in the fourth portion of Figure 1, which as indicated, then leads to a continuation of the cycle.

This continuation exists when the lesson study group re-visits the instructional plan to make modifications based on reflections, observations, and suggestions from the first delivery of the research lesson. The modified research lesson will often be re-delivered and others outside the lesson study group are invited to observe. In the final draft, the research lesson is published as a teaching resource, accessible for others to use.

Collectively, these features of Japanese Lesson Study work to form a culture of teaching focused on improving student learning by improving instruction. This proposed research serves to describe the specific reflective experiences of preservice teachers participating in a modified version of Japanese Lesson Study in a secondary science teacher preparation program in the United States. This modified version is described in further detail within the methods chapter.

Theoretical Framework

Models of teaching and learning NOS using explicit, reflective, activity based approaches have been moderately successful in the transition to reform based practices (Abd-El-Khalick et al., 1998; Bell et al., 2000). Research providing evidence of successful transitions typically reflect a constructivist approach to teaching, where learning is an active, reflective, socially mediated process (Clough, 1998; Schwartz & Lederman, 2002). Generically described, a constructivist approach to teaching operates with the understanding that a learner comes to understand their current way of knowing, and then engages in a series of activities whereby a new or different way of understanding emerges. Lawson (1995) describes how humans construct knowledge in the following way.

> Order imposed by the human mind is always a created thing. That creation is found to be true or false by testing through behavior. The mind creates from sensory data and then imagines the creation to be true to allow the generation of an expectation, which is then tested in the external world. If the expectation is met, the creation is retained. If not, the creation must be replaced. (Lawson, 1995, p. 2)

Constructivism incorporates a wide array of principles, all of which emulate science practice: (1) people construct meaning about new experiences from prior experiences, (2) new knowledge is situated, and (3) learning is socially mediated by language (Jarvis, Holford, & Griffin, 2003). Experiences where competing ideas are evaluated, compared, and reconstructed in relation to NOS tenets have played a significant role in teacher training programs (e.g. Hammrich & Blouch, 1998).

In consideration of the participants who were asked to participate in this study, constructivist based theories of the adult learner will now be expounded upon. Andragogy, a term coined by Malcolm Knowles, is the study of adult learning. Knowles makes the assumption that an individual who reaches the stage of adulthood is a self directed learner, in the sense that he/she is motivated to learn in order to be able to effectively handle future situations. Consistently, Elias, Merriam, and Caffarella (1991) assert an adult's self motivation and direction toward growth as an educator is best accomplished through discovery, experience, collaboration, and interaction with peers. Andragogy suggests that effective adult learning environments also involve the adult in planning learning experiences, the creation of personal objectives and goals, and both self and peer reflection (Knowles, 1980). In addition, adult learners are motivated to learn if they are told why they are learning the information and can see its benefits. According to Knowles, for an adult learner, his/her experiences act as a resource that are constantly being used to construct new understandings. Understanding in these ways is a continuous process of restructuring prior ideas and constructing new ideas.

Lesson study echoes aspects of constructivism and andragogy. For example, the lesson study framework supports reflection on pedagogy and evidence based decision making aimed to impact student learning. Inquiry into one's own teaching in this way supports personal autonomy; in that it promotes the preservice teachers' taking responsibility for their own learning. Additionally, Japanese Lesson Study creates new knowledge for the preservice teachers. One way in which this new knowledge is generated is in the transactions within the lesson study team and the practicum experience itself. This environment is important for developing insights into professional situations that are critical for developing practice and informing future practice.

It is also the agreement of many in science education that reflection on these experiences is critical to the success of adult transformative learning. Maudsley and Scrivens (2000) connect theories of inquiry into one's own teaching arguing, "reflective practice unites discussion of critical thinking with experiential learning" (p. 539). Harrison, Lawson, and Wortley (2005) explain that reflection is embedded within the process of sense making because it "involves a process in which evidence from our practice may be examined and explored, in which personal theories may be found adequate, or not, and in which alternative understandings may be formulated" (p. 422). Freire (1972) asserts that an unmasking of reality should be followed by critical intervention in order to transform it. In addition, for Friere (1970), thought and action are indissoluble aspects of a praxis where "mere reflection is nothing but verbalism…and there is not transformation without action" (p. 61). Friere believes in the liberating potential of education, especially when critical analysis of an experience is coupled with action. Similarly, Harrison et al. (2005) assert "insights (into professional situations) are important for developing practice but only if they can lead to further action" (p. 423). Harrision et al. (2005) further explain that critical reflection on practice involves a challenge to existing thoughts, therefore implying change.

The reflective processes of lesson study meets each of these criteria, providing time and opportunity for preservice teachers to experience planning and teaching for specific NOS tenets in a cyclical manner that promotes both personal and others' NOS understandings. Furthermore, expounding upon the second criteria above, Rodgers (2002) synthesizes the work of Dewey (1933, 1944) to include six phases which mirror scientific processes. These phases include (a) an experience, (b) interpretation of the experience, (c) identifying the problem or question that emerges out of the experience, (d) generating an explanation for the problem or question, (e) ramifying the explanation into a hypothesis, and (f) experiment with the hypothesis. Features of lesson study can be categorized into each of these phases.

Within the andragogical constructivist framework of lesson study, meaning making is socially and collaboratively constructed with others and in self reflection. Examining how meanings are derived and actions taken based on these meanings theoretically underpins symbolic interactionism. "The meaning people give to their experience and their process of interpretation are essential and constitutive, not accidental or secondary to what the experience is." (Bogdan & Biklen, 2007) Symbolic interactionism holds true to the idea that meanings are always up for negotiation and subject to peer pressure, again emulating scientific practice. Necessary for the success of peer and self reflection, is a language that promotes action or reaction to the particular area of professional growth being sought. The meanings derived from these experiences further promote the social constructivist goal of social transformation in addition to the type of meaning making sought in human constructivism. The transformation of informed NOS tenets conjoined with the integration of these understandings into classroom practice, potentially transforms a nation of scientifically literate citizens.

Independent, social, and human constructivism represents merely three of the constructivist branches of teaching and learning. This is by no means comprehensive of constructivist branches but definitely envelopes the whole of constructivism that was illuminated in this study. Lesson study as a medium for reflection about teaching and learning NOS tenets holds true to the main tenet of constructivism that knowledge is constructed by the individual in an active process of interaction within particular contexts. Particular contexts in this case further mimic (social) constructivism in that the framework of lesson study demands collaborative support and preservice teacher construction of knowledge, as opposed to the more traditional method of transmitting knowledge. The preservice teachers were required to socially negotiate meaning, representing both symbolic interactionism and human constructivism, through self and peer reflection within the instructional environment where lesson study was used to situate their learning. The shared knowledge that evolved from this exploration was indeed deemed personally relevant, representing individual constructivism. While not part of the focus of this study, this shared knowledge will quite possibly impact further social interactions the participants have with other communities of learners. This would further represent social constructivism.

This active process of socially constructing new meanings of what it is teach and learn NOS, required that the preservice teachers were engaged in meaning making with a team of others. This allowed the opportunity to examine the processes of lesson study and the dialogue supported within its framework. Particular attention was given to the dialogue between team members in order to explore how levels of reflection may have related to how pedagogical content knowledge was acquired. There was real potential for the lesson study framework to promote the professional growth of all involved. Since preservice teachers cite other classroom concerns to take precedence in their thoughts and reflections, specifically as it relates to reflecting on how to integrate NOS curriculum, symbolic interactionism also allowed the opportunity to examine if this is negated through the lesson study process. Symbolic interactionism also allows an opportunity to examine if lesson study supported the development of pedagogical content knowledge associated with meaning making of inquiry teaching practices of NOS curriculum. If this development of knowledge or skills associated with teaching NOS were acquired during the lesson study, then there was an authentic opportunity to examine how this resulted in a negotiation of perspectives and possibly changed the future practices of the preservice teachers.

Overview of Methodology

This dissertation study was explored through qualitative research methodology, particularly a single case study of multiple lesson study teams. The inquiry itself called for an exploration which would illuminate the experiences of preservice teachers teaching nature of science (NOS) curriculum. This case study sought to gain understanding as to "how" preservice teachers teach and learn about NOS through lesson study, a contemporary phenomenon, within the context of their practicum experiences. Yin (2006) presents each of these criteria, posing of a "how" question(s), contemporary phenomenon, and real-life context, as necessary components for case study to be an appropriate choice of research methods. Within this case study it was further intended to explore reflective practices in general and the transferability of explicit NOS teaching as a result of participating in lesson study. This need for general understanding about a program, e.g. lesson study, further supports the use of case study methods for this study (Stake, 1995; Yin, 2006).

Yin (2006) asserts that a quality case study design includes five elements: questions, propositions, units of analysis, sources of evidence linked to the propositions, and strategies for data analysis. In this dissertation study, the research questions broadly inquire into how lesson study experiences impact the transition of NOS curriculum for preservice teachers. Based from the theoretical framework, propositions imply that the explicit, reflective NOS experiences conjoined with the lesson study experiences will foster the teaching and learning of NOS for the preservice teachers. Units of analysis in this study were the preservice teachers that comprised the lesson study teams. Complete lesson study teams ideally consisted of a minimum of one to three preservice teachers, cooperating teachers within the K-12 public school, and the university supervising teacher. Sources of data linking the propositions to data analysis include open-ended questionnaires, interviews, researcher provided reflection frameworks (e.g. web based forum for open discussion, lesson study overview), field notes, and a reflective portfolio that included the research lesson along with other related artifacts which are a product of participating in lesson study. Analysis of these qualitative data sources were guided by the work of Lederman, Abd-El-Khalick, Bell, and Schwartz (2002) and Ward and McCotter (2004). Realizing the overview provided here warrants further explanation; details of each aspect of this research design are further expounded upon in chapter three.

Summary

Science educators are charged with the responsibility of generating students who have informed understandings of the nature of science (NOS). In order for science educators to teach NOS, it is necessary that they themselves have an informed understanding. Additionally, recognizing the (a) dynamic nature of the scientific enterprise and (b) diverse experiences and levels of understanding among their students also requires science educators to continuously reflect upon and improve upon their teaching of NOS. One way to foster both the teaching and learning of NOS and the development of a reflective practitioner is to actively engage in the related experiences and practices. The purpose of this dissertation study was to explore the impact of lesson study, a reform-based reflective framework, on preservice teachers' experiences in teaching NOS. To accomplish this, participants' initial understandings of NOS were first assessed. Then, the preservice teachers participated in a series of explicit, reflective NOS activities (Clough, 1998; Lederman et al., 1998). NOS understandings were re-assessed at the conclusion of these activities. In the following semester, the reflective framework of lesson study was introduced during the fall practicum experience. Preservice teachers engaged in a modified version of an actual lesson study process, at which times, multiple sources of data were collected to inform the research questions. At the conclusion of this experience, preservice teachers were requested to complete a final assessment of their NOS understandings and submit a portfolio reflective of their lesson study experiences. Through the combination of these experiences, I believed informed understandings of contemporary NOS would prevail. I also believed that participating in this modified lesson study framework would provide these preservice teachers with a deepened understanding of the performance needs of a quality science educator, specifically pedagogical content knowledge associated with teaching NOS.

CHAPTER 2

REVIEW OF THE LITERATURE

Introduction

For more than a decade, priorities in current science teacher preparation have focused reform movements toward constructivist theories of learning that emphasize critical thinking, evidence based decision making, and ultimately transformative learning experiences (National Science Teachers Association [NSTA], 2003; National Research Council [NRC], 1996). In this chapter, a historical overview of transition occurring in science teacher preparation programs will first be provided. Within this overview, review of competing views of nature of science (NOS) will be outlined, followed by a summary of the consensus view of NOS curriculum in both K-12 and teacher education. This section of the literature review includes a summary of the literature on this consensus view of appropriate NOS curriculum as it pertains to the myriad approaches to training science educators. Finally, at the core of the study is a review of the literature pertinent to Japanese Lesson Study. Lesson study serves as the context within which this study will be guided, therefore warranting the need for specific emphasis on how research indicates it correlates to current recommendations in science teacher training education.

Transitions in Science Teacher Preparation Curriculum

With the publication of the National Science Education Standards (NSES) in 1996, reform was set in motion to create a scientifically literate nation of high school graduates (NRC, 1996). Science literacy is defined by the NSES as the ability to critically analyze data, its source(s) and processes, express informed positions on scientific concepts, and evaluate evidence based arguments for the larger purpose of participating in society. (NRC, 1996, p. 22) Several years earlier, the American Association for the Advancement of Science (AAAS, 1993) published Benchmarks for Scientific Literacy, pushing for increased scientific literacy among high school graduates as defined by specific skill sets and a core of scientific understanding. Hurd (1998) contends the roots of scientific literacy defined by these pragmatic means dates back in the United States to the presidency of Thomas Jefferson. However, its importance was not realized until Sputnik, the first successful satellite to orbit Earth, was launched by the Soviet Union. In the United States, the post Sputnik era prompted significant government funding for research and curriculum reform in science education. With this shift to a new priority came willingness by politicians to consider reform which would ultimately lead to the United State regaining the competitive edge over other nations in the areas of science and technology. While the needs of the today's nation have changed, political motivation to work toward progress in science has not subsided over the decades. Current focus in science education as stated in the American Recovery and Reinvestment Bill of 2009 targets improvements in science education for the transformation of the economy and for additional funding for research in areas directly related to science (e.g. clean energy, stem cell research, and healthcare).

Beliefs among progressive educators describe evolving ideas and practices that aim to make schools more effective and efficient agencies of a democratic society. Early supporters of progressive education emphasized a child-centered curriculum, social re-constuctionism, and participating citizens (Schugurensky, 2002). Some progressive educators also believed curriculum should be based on cooperative social skills, critical thinking, and democratic behaviors (Rippa, 1997). Under these principles, learning outcomes needed to be challenged, verified, and reconstructed in the search for a possible truth. John Dewey, a philosopher who influenced this progressive line of thinking in the United States spent his life working diligently to experiment with these ideals of progressive education (Urban & Wagoner, 1999).

Although there are numerous differences of style and emphasis among pedagogical progressives, most share the conviction that democracy means active participation by all citizens in social, political and economic decisions which affect their lives. For historians, the 1890s began what is referred to as the Progressive era, a time of myriad reforms in reaction to industrialization and related economic and social problems (Urban & Wagoner, 1999). It experienced some ebbs and flows of mainstream pedagogical practice through specific movements, such as the School Gardening Movement (Kohlstedt, 2008). The education of engaged citizens within this era emphasized diversity among abilities, interests, ideas, needs, and cultural identity as well as the development of socially competent citizens. These beliefs were upheld by pedagogy emphasizing curriculum relevant to the students and a student centered approach to learning. Yet, in spite of such movements, traditional practice of teacher centered education held steadfast at work. In addition, while the Soviet satellite launch some fifty years later reignited political interest in science education, progressive ideals of relevant curriculum and student centered pedagogy had long been abandoned by most in public education. For those working in schools, emphasis at this time was on classroom control, obedience, and a structured, imposed curriculum (Urban & Wagoner, 1999).

Constructivism in Reform Curriculum

As is often the case with new paradigms, the importance and attention given to Dewey's work did not come until much later, but it continues to inspire many political and educational theorists (Urban & Wagoner, 1999). The influence of Dewey's principles is evidenced in all of education, but for the purposes of this dissertation, specific science education reform documents will be highlighted fromK-12 with the National Science Education Standards (NRC, 1996) and in teacher training with the Interstate New Teacher Assessment and Support Consortium (INTASC) model core standards for science teaching.

John Dewey's philosophy and educational theory emphasizes the experiences of everyday life. Dewey describes three characteristics of the relationship which he believed to exist between knowing and doing.

> The first is the obvious one that all experimentation involves *overt* doing, the making of definite changes in the environment or in our relation to it. The second is that experiment is not a random activity but is directed by ideas which have to meet the conditions set by the need of the problem inducing the active inquiry. The third and concluding feature, in which the other two receive their full measure of meaning, is that the outcome of the directed activity is the construction of a new empirical situation in which objects are differently related to one another, and such that *consequences* of directed operations form the objects that have the property of being *known*. (Dewey, 1938, p. 70)

In contrast to traditional practices, Dewey conceptualizes teaching and learning that begins and ends with the student and society at the core of its goals. Dewey believed that for educational growth to take place, students must continually reorganize and reformulate past experiences in light of new experiences. Dewey also believed students' experiences in school should combine the past and present, so as to provide a background for better understanding future experiences. Dewey hypothesizes, "If we see that knowing is not the act of an outside spectator but of a participator inside the natural and social scene, then the true object of knowledge resides in the consequences of directed action" (Dewey, 1938, p. 157). Dewey's early writings stressed the importance of a functioning relationship between learning activities and student experiences outside the classroom, as well as the nature of the learning process.

In one powerful example of how Dewey's philosophies on experiential learning has influenced science reform, "Project 2061: Benchmarks for Science Literacy," describes science teaching as a weaving of the philosophy and sociology of science and the acquisition of scientific knowledge (AAAS, 1993). Specifically stating,

> . . . the emphasis should overwhelmingly be on gaining experience with the natural and social phenomena and on enjoying science…By gaining lots of experience doing science, becoming more sophisticated in conducting investigations, and explaining their findings, students will accumulate a set of concrete experiences on which they can draw to reflect on the process. (AAAS, 1993, p. 4)

Dewey's theory of learning contextualizes learning situations, emphasizing that students both construct knowledge from prior and lived experiences, continuously moving around a continuum to expand conceptual understanding.

Dewey held to these principles, elaborating and detailing these ideas as he continued to prosper and gain respect in the field (Dewey, 1938). In relation to teacher training, Dewey maintains his philosophies of experiential learning writing of "practical deliberation" where educators systematically learn to resolve issues in teaching practices. Dewey (1933) explains that reflective practice is a meaning making process where understanding evolves in the space moving from one experience to another. Reflection remains on a continuum of learning, in that it is an ever expanding relationship between what is thought to be known and a new experience. It is a systematic way of thinking, communal, and requires a disposition which values personal and intellectual growth.

Rodgers (2002) writes extensively on the undeniable "cry for accomplishment in systemic, reflective thinking" while simultaneously arguing that what is meant by reflection and thinking is often delineated too quickly. Rodgers (2002) emphasizes that reflection is often reduced to standards and vague definitions, it lacks a common language, and it is difficult to research as a result of an unclear sense of what it means. Rodgers (2002) sought to clarify what is meant by reflection and thinking from Dewey's works. Dewey (1933) writes of reflection as a complex, rigorous enterprise that takes time. Rodgers (2002) in acknowledging the difficulty associated with making sense of Dewey's style of writing, attempts to characterize Dewey's concepts of reflection in four criteria. These criteria include:

> 1. Reflection is a meaning-making process that moves a learner from one experience into the next with deeper understanding of its relationships with and connections to other experiences and ideas. It is the thread that makes continuity of learning possible, and ensures the progress of the individual and, ultimately, society. It is a means to essentially moral ends.
> 2. Reflection is a systemic, rigorous, disciplined way of thinking, with its roots in scientific inquiry.
> 3. Reflection needs to happen in community, in interaction with others.
> 4. Reflection requires attitudes that value the personal and intellectual growth of oneself and of others. (Rodgers, 2002, p. 845)

Reflective practice in science education has earned attention as national science education reform documents have begun to discuss the development of a reflective practitioner. For example, both INTASC (2002) and NSTA (2003) state that science teacher preparation programs should provide opportunities for preservice teachers to learn and use various tools for self-reflection. For this dissertation study, the need for preservice teachers' "practical deliberation" about NOS tenets is of utmost importance. Reflective of the outlined principles of learning and reflection, the core of this proposed research is a practicum teaching experience using a reflective framework. This study has been designed in order to begin understanding the potential for both transforming preservice teachers' contemporary understandings of NOS and the development of relevant pedagogical content knowledge. An overview of literature examining past and present curriculum definitions of NOS follows. This historical account of the literature aims to lead into a discussion on NOS curriculum in teacher training programs. By reviewing this line of literature, insight to the issues of transitioning NOS curriculum faced by preservice teachers is gained.

Nature of Science

Views on Nature of Science

Project 2061 (AAAS, 1993) describes the scientific enterprise as an activity for understanding how the world works. Project 2061 (AAAS, 1993) advocates for students to understand the relevance of science as it relates to their future adult lives in a democracy where "they will be in a position to influence what public support will be provided for basic and applied science…and should be able to understand discussions of science issues in the news" (p. 14). Each of these components described in Project 2061 (AAAS, 1993) collectively define what is commonly referred to as scientific literacy. Ten years prior to Project 2061, the 1983 report, *A Nation at Risk: An Imperative for Educational Reform* brought to public attention the importance of students being capable of informed decision making about currently relevant, personal and social issues (National Commission on Excellence in Education [NCEE], 1983). With this call to action comes a need for those responsible for educating students to understand aspects of nature of science (NOS), ways of knowing and doing in relation to science, as it continues to be a main feature of today's times (AAAS, 1993).

Nature of science refers to science as a way of knowing, an epistemology, or those values and beliefs necessary for the development of scientific knowledge (Lederman, 1992; Lederman & Zeidler, 1987). Abd-El-Khalick and Lederman (2000a) assert that "no consensus presently exists among philosophers of science, historians of science, scientists, and science educators on a specific definition for NOS, " but that this should not be disconcerting given the "multifaceted, complex, and dynamic nature of the scientific endeavor" (p. 666). In summarizing the changes of science education's conception of NOS over the last 100 years, Abd-El-Khalick and Lederman (2000a) recount that the scientific community has moved from the early 1900s where NOS was equivalent to "the scientific method" through the 1960s with emphasis on process skills such as inferring, observing, and designing experiments; into the twenty first century where a growing body of psychological and sociological factors began to influence the defining characteristics of NOS. As early as 1982, the National Science Teachers Association (NSTA) asserted that socially mitigated inquiry based methods played a central role in NOS, as well as an understanding of the tentative nature of scientific knowledge.

Understanding NOS in this way and how it influences students, teacher training, and professional development continues to have relevance in current lines of research and science curriculum (Abd-El-Khalick & Lederman, 2000a; Bybee, 1997; DeBoer, 1991; Rudolph, 2000). While there is some disagreement in science education research as to what constitutes NOS (Abd-El-Khalick & Lederman, 2000a; Duschl, 1990), aspects of NOS such as those outlined by McComas (2004) are generally accepted. These generally accepted tenets ultimately define the scope of NOS included within science standards for educators and students. Understanding of the agreed upon NOS tenets by students and adults alike, is nationally supported in reform documents as they each assert that this informed understanding is crucial to a scientifically literate nation capable of participating in a democratic society (AAAS, 1993; NRC, 1996; NSTA, 2003).

According to McComas (2004), core NOS tenets deemed necessary for scientific literacy include the following: (a) Scientific data is reviewable by peers and justifies conclusions. (b) Commonalities exist in the production of knowledge, but there is no single scientific method by which science knowledge progresses. (c) Scientific knowledge is tentative. (d) Laws are generalizations or patterns of nature. Theories are explanations for how laws hold up. (e) Science is creative. (f) Science can be subjective. (g) Science works within a larger historical, cultural, and social enterprise. (h) Science and technology are not synonyms, but they do impact each other. (i)Science has limits. Benchmarks for Science Literacy for K-12 (AAAS, 1993), NSES for K-12 (NRC, 1996), INTASC (2002), and NSTA (2003) all place standards for science educators and K-12 students to demonstrate an understanding of these NOS tenets through various inquiry-based methods. What is most unfortunate is that both K-12 students and science educators do not consistently show retention of these more informed views (Abd-El-Khalick & Akerson, 2004; Duschl, 1990; Lederman, 1992, 1995, 2007).

Misconceptions surrounding NOS tenets are an important aspect of research (Abell & Smith, 1992; Akerson, Abd-El-Khalick, & Lederman, 2000; Koulaidis &

Ogborn, 1988; Lederman, 1992). Akerson, Buzzelli, and Donnelly (2008) have reported that many elementary teachers misinterpret the term "nature of science" to mean something to do with nature rather than "the essence of science itself" (p. 748). Furthermore, among students of all ages inaccurate perceptions of science and scientists have been described in much research (Fort & Varney, 1989; Mead & Metraux, 1957; Newton & Newton, 1992). Several examples include the belief in universal step by step process for conducting science work (Lederman, 1992), the belief that science can be proven correct (Aguirre, Haggerty, & Linder, 1990), and theories can become laws with enough evidence (Abd-El-Khalick & BouJaoude, 1997). Gallagher (1991) claims the knowledge base of scientific knowledge for the public comes from two primary sources, the school and media. Boylan (1992) also suggests that these perceptions represent students' knowledge of public stereotype constructed through a sundry mediums; ranging from television, museums, news paper articles, conversations with family, movies, the Internet, and so on. Akerson et al. (2000) assert that preservice teachers learning science content through traditional courses from a range of college departments lacking in any systemic reform of science teaching will continue to be highly likely to hold naïve views of NOS. As these conceptions typically reflect an inaccurate view of science, curriculum reform works to change these conceptions in teacher training programs.

NOS Instruction in Teacher Training Programs

The need for informed understandings of NOS among preservice teachers has been advocated since the late 1960s (Lederman, 1992). Lederman (1992) asserts, "if teaching is viewed as a purposeful and conscious act, a teacher must possess an adequate knowledge of what he/she is attempting to communicate" (p. 339). In a review of guidelines pertinent to the realm of preservice teachers transitioning with reform, NSES (1996) standards of professional development, INTASC (1992) standards for beginning teachers, and NSTA (2003) performance standards for teacher preparation, all recommend explicit instruction and first-hand experience with contemporary views of the NOS. Abd-El-Khalick and Lederman (2000b) contend that in order for science teacher education to promote adequate contemporary conceptions of NOS, utilizing elements from history and philosophy of science, and/or direct explicit, reflective instruction within science based activities is more effective than alternative approaches. Abd-El-Khalick and Lederman (2000b) also state, “Irrespective of the specific approach used, explicitness and reflection should be made focal to any attempt geared toward improving science teachers’ conceptions of NOS” (p. 695). Abd-El-Khalick and Lederman support this assertion with an exhaustive literature review on teachers’ retained or changed views of NOS which indicated “relative ineffectiveness”; further asserting the need for NOS to be a pervasive theme throughout science teacher preparation, as the duration of treatments among the teacher participants in the reviewed literature was extremely brief. Similarly, McComas et al. (1998) describe four NOS instructional approaches based on where the instruction occurred. This context is identified as either in science methods course, science content courses, self contained NOS courses, or authentic science experiences. McComas et al. (1998) additionally argue that in order for NOS understandings to be retained, NOS concepts must be a part of instruction across these contexts rather than as isolated instructional situations.

In “Avoiding De-Natured Science,” Lederman and Abd-El-Khalick (1998) provide hands-on strategies for providing experiences with NOS tenets for students and preservice or in-service teachers. Lederman and Abd-El-Khalick (1998) present these activities for use in either science methods or science content courses. However, Lederman and Abd-El-Khalick (1998) argue that when using the activities, “by not requiring specialized scientific knowledge, the activities free the learner from having to struggle with complex scientific concepts as they try to internalize certain aspects of the NOS” (p. 84). These activities are grouped into three categories relative to the NOS tenet being addressed. These groups include (a) observation, inference, creativity, and tentativeness, (b) subjectivity and social and cultural context in science, and (c) black-box activities. Specific examples of activities can be found in Appendix A, as some were included within the context of this study.

Akerson et al. (2000) sought to understand meanings ascribed to NOS aspects using an explicit, reflective, activity based approach of NOS instruction among 50 preservice teachers. An NOS questionnaire and interviews elicited that a majority of the participants held naïve views of targeted NOS aspects at the onset of the study. The purposeful selection and implementation of generic NOS activities (found in Lederman and Abd-El-Khalick, 1998; Appendix A), followed by whole class discussion highlighting the targeted NOS aspects, and both structured and unstructured reflective opportunities aimed to engage the participants in NOS concepts as well as elicit understandings of NOS. Akerson et al. (2000) concluded that participants made substantial gains in some of the targeted NOS concepts, such as the tentative NOS and distinctions between observation and inference. However, Akerson et. al (2000) extensively discussed the lesser gains in social and cultural NOS aspects, as well as, inconsistencies among the post treatment views as some of the participants continued to hold inadequate, or naïve, views of the targeted NOS aspects. Akerson et al. (2000) contend that these results show the "tenacity with which learners hold on to their own views" (p. 313). Several years later, Akerson et al. (2008) report that varying degrees of success with an explicit reflective approach to NOS in science methods course deemed a need for further exploration of how the characteristics of preservice teachers' might impact views of NOS.

Akerson, Morrison, and McDuffie (2006) express the uncertainty in science education research on whether conceptual changes of NOS are retained by preservice teachers once course work is completed. In an effort to gain understanding to how targeted aspects of NOS changed for preservice teachers, as well as, whether new understandings were retained over the initial year of coursework, Akerson et al. (2006) used Perry's scheme (1999) to investigate the cognitive developmental reasons of 17 participants for retaining aspects of NOS. Preservice teachers were engaged in explicit, reflective instruction of NOS, which included such tasks as reading pedagogically oriented articles, explorations of targeted NOS aspects (also from Lederman & Abd-El-Khalick, 1998), interviewing to elicit NOS understandings followed by the implementation of self written performance tasks, and weekly reflections. Data analysis indicated substantial improvements in the preservice teachers' understandings of the targeted aspects of NOS, but did not indicate that these new conceptions were retained by the end of course work. Interestingly students which exhibited characteristics at higher levels on Perry's scheme tended to retain their views of certain targeted NOS aspects, while students at lesser levels tended to revert to earlier understandings of NOS. Akerson et al. (2006) indicate that the data collected provides evidence to support the assertion that students at level 5 on Perry's scheme are able to retain informed views of the nature of science and are most likely at a meta-cognitive level that allows for the acceptance of ambiguity and tentativeness.

Akerson et al. (2008) explored fourteen preservice teachers' views of NOS, intellectual development, and cultural values as a result of explicit, reflective NOS instruction in an early childhood methods science methods course. Akerson et al. (2008) assert that "differences in values could inhibit preservice teachers' willingness to plan and implement lessons addressing NOS or that touch upon specific values" (p. 768). Akerson et al. (2008) also sought to find additional pedagogical practices that might increase preservice teachers NOS understandings. Akerson et al. (2000) suggest that a meta-cognitive approach, where by making science teachers aware of their naïve understandings of NOS might facilitate change in perspectives more consistent with contemporary ideals. Therefore in this particular study, the researchers shared with the preservice teachers their initial NOS understandings and then asked the participants to reflect on the similarities and differences in their initial NOS views and the suggested views in reform based curriculum documents. Modeled after Clough (2006), instruction was then targeted using de-contextualized NOS instruction, meaning the use of activities aimed at engaging students to think about NOS tenets. For example, the use of pictorial gestalt switches to help students understand the relevance of prior knowledge on observations (Clough & Olson, 2004). This was then followed by contextualized NOS instruction in science content, meaning the application of an informed NOS understanding when modifying a cookbook lab or illustrating how science works in historical and contemporary examples connected to fundamental science ideas (Clough &

Olson, 2004). The use of this type NOS instruction moved along a continuum during the course. Additional meta-cognitive activities used as part of the methods course required the preservice teachers track changes in their NOS views, conduct and reflect upon peer interviews, and design lessons to address student misconceptions' presented in classroom-based scenarios. From analysis of surveys, related documents, video, and interviews, Akerson et al. (2008) drew multiple conclusions about culture, intellect, and NOS understandings. Generally, all participants improved their understanding of NOS, but interestingly apparent disconnects between personal values and values held for science emerged from the data. Akerson et al. (2008) suggest that these differences in values could inhibit preservice teachers' willingness to plan and implement NOS. Furthermore, the need to explore longitudinal impact of meta-cognitive activities on the retention of the preservice teachers' improved NOS views became evident.

For example, to investigate changes in preservice teachers' NOS understandings in a science methods course, Seung, Bryan, and Butler (2009) developed an instructional module using three different instructional approaches. The researchers engaged ten participants in four NOS activities over the course of two semesters. These activities were labeled as explicit in nature; explicit, not context-based using a cube activity from Lederman and Abd-El-Khalick (1998); explicit, context based; and explicit, case-based (Seung et al., 2009, p. 162). From questionnaires and interviews, data analysis indicated significant differences in NOS understandings from pre- to post- intervention. However, the study was not designed to determine if the improved NOS understandings transcended into the preservice teachers' teaching practices later in the student teaching experience or beyond. An examination of literature that addresses this transfer of informed NOS understandings into classroom practice follows.

Preservice Teachers' Transfer of NOS in Classroom Practice

Research conducted in the context of methods courses and professional development programs using both preservice and in-service teachers' understandings of NOS have provided insight as to the impact of NOS understandings on classroom practice (e.g. Akerson & Hanuscin, 2007 and Southerland, Johnston, & Sowell, 2006). Plourde (2002) believes a cohesive concreting between NOS pedagogy and NOS understandings provides confidence for preservice teachers when they begin their student teaching. Segall (2001) contends that the overarching goal in science methods classes is to ensure easy transfer of these NOS tenets into practice.

Abd-El-Khalick, Bell, and Lederman (1998) collected data from fourteen preservice science teachers in order to determine if the preservice teachers made explicit plans to teach NOS and if so, the outcome of such plans. Furthermore, the researchers' sought to use the collected data, e.g. lesson plans, classroom videotapes, portfolios, observation notes, and follow up interviews, to identify any variables which prevented the transition of NOS into the preservice teachers' classroom practice. In data analysis, Abd-El-Khalick et al. (1998) found that while the participants expressed justifications and claims for teaching NOS, there was "rare evidence of planning to teach the NOS" (p. 426) and "discrepancy between the participants' assertions and their teaching" (p. 427). In discussion of the constraints that mediated the teaching of NOS, Abd-El-Khalick et al. (1998) presented several variables expressed by the preservice teachers; e.g. NOS learning outcome less significant than other learning outcomes, preoccupation with classroom management and routine chores, discomfort with their own understandings of NOS, lack of resources and experiences, and lack of time to plan instruction (p. 428).

Based on the results of this investigation (Abd-El-Khalick et al., 1998), Bell et al. (2000) collaborated again to not only identify mediating factors of preservice teachers' conceptions of NOS into instructional planning and classroom practice, but also assess the influence of separating teaching NOS content and pedagogy on the preservice teachers' instructional decisions and actual classroom practice (Bell et al., 2000). In this study, preservice teachers were exposed to a minimum of a dozen NOS activities and additional instruction on how to teach NOS using the same type of explicit, reflective, activity-based approach that was used in the course was re-emphasized as appropriate pedagogy for the secondary science students the preservice teachers would be teaching. Additional encouragement to consider NOS as a cognitive instructional outcome was also highlighted in this intervention. Data collection on eleven participants as they worked through the courses and internship included open ended questionnaires, lesson plans, observation notes, classroom videos, portfolios, and interviews. From interviews, lesson plans, and video tapes, Bell et al. (2000) saw an increase in the number of preservice teachers that attempted to teach NOS purposively, as well as an increase in preservice teachers that considered NOS an important cognitive learning outcome. In addition, 9 of the 11 preservice teachers in this study indicated that they had successfully addressed NOS in their instruction and the subsequent analysis of lesson plans, portfolios, and field notes substantiated explicit NOS instruction in their classroom practice. This is notably unlike the former study where a discrepancy existed between how the preservice teachers perceived teaching NOS and the lack of evidence to substantiate this in their actual classroom practice. Yet, while this group of preservice teachers was remarkably more successful in implementing NOS into classroom practice, many of the constraints were comparable to those in the first study. Pressure to cover content, lack of time, lack of confidence in ability to teach NOS, and overall feelings of being overwhelmed by the internship were all constraints expressed by the preservice teachers (Bell et al., 2000, p. 576). Of greater significance though is how this study informs science teacher training programs. Bell et al. (2000) found that the intervention deployed in this study was effective in facilitating the transition of NOS into classroom practice, hypothesizing that this was due to the concrete context of NOS pedagogy provided.

In a longitudinal study, Schwartz and Lederman (2002) investigated two preservice teachers' learning and teaching of NOS as they progressed through teacher training and into their first year of full time teaching. Data was gathered on their NOS understandings and instructional attempts through reflective questionnaires, interviews, lesson plans, and observations. While both participants integrated NOS and were considered success stories, the varying degrees of the participants' backgrounds again highlight the aforementioned contributing factors to implementing NOS curriculum. While the two preservice teachers developed pedagogical content knowledge of NOS which successfully transitioned through their first year of teaching, Schwartz and Lederman (2002) attribute the extent of success in these NOS teaching efforts to the "experiences, discussions, reflections, successes, and even failures" of the participants' backgrounds (p. 234). Schwartz and Lederman (2002) further assert that the identification of mediating factors such as this need to begin to inform teacher education programs as they develop a knowledge base for supporting NOS teaching at the preservice level (p. 206).

In Akerson and Buzzelli (2007) where intellectual levels were found to be a mediating factor that influenced the NOS understandings among preservice teachers, a follow up study was conducted with four preservice teachers to determine if intellectual levels also influenced the actual teaching of NOS. In Akerson and Buzzelli (2010) all four participants held adequate or informed views on NOS with varying degrees of intellectual levels categorized using the Perry (1970) scheme. As these participants were working through their teaching internship, classroom teaching was videotaped, lesson plans were collected, and field notes written along with first hand observations. Akerson and Buzzelli (2010) additionally used questionnaires and interviews to analyze NOS understandings, intellectual levels, and stages of concerns. In discussion, Akerson and Buzzelli (2010) assert that the support of the cooperating teacher was the most vital to the teaching of NOS for their participants. In addition, Akerson and Buzzelli (2010) found that "preservice teachers required a combination of the cooperation teacher understanding NOS and how to teach it, as well as supporting the preservice teacher in planning and adapting the science curriculum to emphasize NOS" (p. 228).

Preservice Teachers' Reflection about NOS Understandings

The presentation of competing ideas to be evaluated, compared, and reconstructed in relation to NOS tenets plays a significant role in science teacher training programs (Lawson, 1995). For example, Smith and Scharmann (2006) designed an instructional model for teaching NOS to preservice teachers over a three year stint of preparing preservice teachers for teaching science. While the researcher's purpose was to analyze the degree to which conceptual change occurred among the preservice teachers, it is the researcher’s outline of assumptions for the context of their study that is most enlightening and pertinent to this discussion. Smith and Scharmann (2006) based this instructional approach for preservice teachers on assumptions and claims drawn from literature. Some of these assumptions included: (1) focus on NOS concepts agreed upon within national standards documents, (2) methods courses should promote NOS understanding, (3) explicit instruction is likely to be most effective, (4) active engagement with NOS issues that requires preservice teachers reflect on current positions and their own understandings is likely to be most effective, and (5) conceptual change methodology is likely to be effective. It is these types of assumptions about NOS instruction in teacher training programs that are repeatedly found in the literature and pertinent to this discussion. This constructivist approach to teaching requires preservice teachers experience learning as an active, reflective process (INTASC, 2002 and NSTA, 2003). As it relates to NOS, this implies a preservice teacher comes to understand their current way of knowing NOS, and then engage in a series of activities whereby a new or different way of understanding emerges. It is the role of reflection that is of particular interest in this portion of the literature review.

Reflection of NOS understandings by preservice teachers’ has been guided through assorted mediums. McComas (1996) cites various explicit, reflective contexts within teacher preparation have included such things as reflective journal writing, science-embedded activities, concept mapping, and analysis of critical teaching incidents. Nichols, Tippins, and Wieseman (1997) outline reflective “tools for the toolkit” which provide preservice teachers with opportunities to self direct their conceptual changes, negotiate understandings, and resolve personal issues related to teaching and learning. Teacher preparation courses provide a time for introducing mediums of reflection to preservice teachers which promote the continued learning from and enhancing of teaching practices. The use of portfolios, journals, classroom case narratives, learning maps, and metaphors are but a few of the mediums integrated by science education researchers. Abd-El-Khalick and Lederman (2000b) assert that past research indicates the following assumptions can be made as it relates to reflection on NOS:

> . . . prospective teachers should be given opportunities to discuss and reflect on the various aspects of NOS within the various contexts of teacher education. For instance, prospective teachers could be asked to design lessons that aim to promote understandings of NOS in microteaching courses. They could be asked to design an instructional unit on NOS in curriculum courses. They could be assigned the task of designing alternative methods to assess students' understandings of NOS in evaluation and assessment classes, and so on. The idea is to get prospective teachers to reflect on and think about the various dimensions related to teaching about NOS in context specific situations such as planning and assessment (see for example, Lederman et al. 1999). (p. 695)

Explicit, reflective approaches in teaching NOS are specific in the planning for, explicit language used during, and assessing of particular tenets within the characteristics of NOS (Lederman, 1999).

Carey and Stauss (1968, 1970) conducted two seminal investigations to assess preservice teachers' understandings of nature of science before and after methods courses where nature of science was a theme throughout the courses. The preservice teachers were introduced to NOS through lectures, discussions, articles, etc. Then in classroom discussion preservice teachers were consistently required to reflect on whether the topics or activities were consistent with contemporary nature of science views. These investigations showed significant gains in the preservice teachers' understandings of nature of science. During this time, the conjunction of explicitness and reflection of NOS understandings was just beginning to be explored in science teacher training programs.

Abd-El-Khalick and Lederman (2000b) in an exhaustive literature review of the evolution of NOS, attests that Shapiro's (1996) interpretive case study of elementary preservice teachers was most important because of its continued emphasis on reflection and explicitness of NOS tenets. Shapiro (1996) reported on a preservice elementary teacher using a case study which emerged from a larger research project on participants' independent studies into the nature of scientific investigations. It was in this case study where evidence from journals, a repertory grid (researcher generated tool), and interviews guided the reflections of the participants toward enhanced NOS understandings. It is from this research that the inclusion of guided reflections began to become an assumed part of necessary NOS instruction (e.g. Schwartz & Lederman, 2002; Schwartz, Lederman, & Crawford, 2002; Schwartz, Lederman, & Khishfe, 2002; Smith & Scharmann, 2006).

For example, Schwartz, Lederman, and Crawford (2002) examined preservice secondary science teachers' understandings of NOS during a science research course. Preservice teachers were immersed in the context of science research while also participating in seminars and journal assignments. The participants' NOS views were assessed using the Views of Nature of Science questionnaire (VNOS-c) with post course analysis indicating substantial gains in NOS understandings. From multiple seminar transcripts, interviews, and journals, the researchers concluded that guided reflection of the research experiences had the greatest impact on NOS understandings, further asserting that the preservice teachers' who took on a reflective stance were more successful in moving toward informed NOS conceptions.

Additional evidence to the impact of reflection mediums are highlighted in Matkins and Bell (2007) investigation into the impact of reflective, explicit NOS instruction within global climate change issues on preservice teachers' understanding of NOS, science content relating to global climate change, and decision making. Matkins and Bell (2007) designed the course such that the preservice teachers' prior knowledge of NOS was first elicited, followed by the 'mystery tube' activity (Lederman & Abd-El-Khalick, 1998) and other opportunities for connecting specific NOS tenets to global climate change content. During the course, preservice teachers reflected on their NOS understandings through questionnaires, assignments, and journals. Significant growth in the preservice teachers' understanding of contemporary tenets of NOS and the science content of global climate change were reported by Matkins and Bell (2007) and attributed to the explicit, reflective approach pursued in the course.

Reflection on Integrating NOS in Classroom Practice

Literature on reflective practice as it relates to the practice of integrating NOS in classroom teaching is sparsely mentioned. Reasons for this are unknown, but seemingly worth investigating as the theoretical framework underpinning this dissertation study put reflection at the forefront of a possible enduring approach to ensuring the transfer of NOS in classroom practice. In Abd-El-Khalick, Bell, and Lederman (1998) data sources used in a search for explicit references of NOS in classroom practice included instructional plans, video, portfolios, and weekly clinical observation. It was only in post interviews where preservice teachers reflected upon both their plans to teach NOS and the way in which these plans were reportedly carried out. Of the fourteen preservice teachers participating in the study, only three actually included NOS in lesson plans. The lack of attention to reflection during the classroom teaching experience could account for the discrepancy between how the preservice teachers reported their plans of teaching NOS in post interviews and the actual evidence of implementing such plans. In addition, perceived limitations associated with teaching NOS for the preservice teachers included the value of NOS learning outcomes as less significant than other cognitive outcomes, concerns with classroom management and other daily teaching responsibilities, and a lack of confidence in their own understandings of NOS which inhibited their own delivery. Arguably, the participants might have been more successful in their transfer of teaching NOS had reflection been present during the teaching experience, rather than just at the conclusion.

In Schwartz and Lederman (2002), two participants were encouraged to reflect in writings and explicit discussions throughout the teaching experience. Schwartz and Lederman (2002) credit these reflections with aiding one of the participants in "developing his views of NOS pedagogy. The result of these reflections was an enhanced level of NOS understanding and the view that learning about NOS was not a natural outcome of conducting scientific investigations or learning science content" (Schwartz & Lederman, 2002, p. 229). Schwartz and Lederman (2002) additionally write the following of the role reflection played in the participants teaching of NOS:

> They both gained insight into NOS as the "nature of the beast". That is, they both came to recognize NOS as inherent to all science subject matter they had been taught and were trying to teach. Rich was able to recognize and use this insight during his teaching by reflecting on his own science experiences. When Laura stepped back from her focus on teaching NOS and reflected on *what* it was she was trying to teach, she also achieved this

> deeper level of understanding. Perhaps it was her trying to "fit" NOS to various science subjects that led to her revelation. For Rich and Laura reflection on science in general and reflection on how their own NOS knowledge fit within that context were essential for their progression in NOS learning and, in turn, teaching. (Schwartz & Lederman, 2002, p. 230)

Schwartz and Lederman's (2002) attention to reflection in this study is an exception, rather than rule, in the literature reviewed. Discussion of reflective practices as it relates to the integration of NOS in classroom practice is absent. The importance of the reflection that occurs in these experiences is often downplayed, highlighted as a strategy or a medium, which is exactly at the heart of fears of philosophers such as Dewey (1933, 1944). Rodgers (2002) argues that reflection is "not an end in itself but a tool or vehicle used in the transformation of raw experience into meaning-filled theory that is grounded in experience" that is a "forward-moving spiral from practice to theory" and includes precise steps (p. 864). Lesson study maintains a high level of rigor and relevance consistent with these principles of reflection. Seeking to contribute to the literature by exploring preservice teachers' experiences reflecting upon the teaching of NOS tenets using lesson study will provide unprecedented data about reflection. The significance of this study hinges on the collaborative reflective experiences of the preservice teachers as reflection is guided through the inquiry based, spiraling process of lesson study. The importance of lesson study as it relates to the context of this dissertation study merits a literature review of how it has informed other disciplines follows.

Lesson Study

Jugyou Kenkyuu translates to Lesson Study, the approach to professional growth accredited for the steady improvement of elementary education in Japan. *Jugyou kenkyuu* is an umbrella term for a host of instructional improvement strategies with the shared feature of a group of teachers observing live classroom lessons while collecting and analyzing data on teaching and learning (Lewis, Perry, & Murata, 2006). While the features of Japanese Lesson Study and its significance to this dissertation study were highlighted in chapter one, there is a definite need to more completely present the related literature. Since the ethnographic accounts of lesson study were brought to public audience in 1999, Lewis, Perry, and Murata (2006) cite over 335 schools where lesson study has emerged in the United States. However, in the United States, results of its effectiveness in making improvements are inconsistent in both teacher and student learning, and "the fact that to date discussions of what lesson study has to offer teachers have remained speculative, anecdotal, or based on evidence from Japan" further require the need for a discussion on the current research base (Fernandez & Cannon, 2005; Lewis & Tsuchida, 1997; Stigler & Hiebert, 1999). A review of seminal research follows.

Lesson Study in the United States

The first example of United States public lesson study can be found in Paterson, New Jersey at a pre-kindergarten through grade 8 public school serving a high poverty population of students. In compiling the lesson study team, Fernandez, Cannon, and Chokshi (2003) recruited a dozen Japanese teachers from nearby Connecticut to serve as coaches for the 16 teachers and administrators at this urban public school. In an exploration of the potential of lesson study during this United States-Japan lesson study collaboration, Fernandez et al. (2003) collected artifacts such as lesson plans produced by the United States teachers, videotaped and took field notes of all meetings and research lessons, as well as, interviewed members of the team at various points. From this data, Fernandez et al. (2003) then described aspects of professional development in the United

States preventing lesson study from working in the same way as it does in Japan. In the evidence presented from this particular lesson study cycle, Fernandez et al. (2003) highlight the United States teachers' failure to develop critical "lens", such as the researcher, student, or curriculum developer lens, while participating in the lesson study cycle. For example, the United States teachers were continuously encouraged to rely on evidence to support the process and decisions made within. This is what would be considered a researcher lens. Yet, when the teachers' responsibilities were to observe the lesson for evidence of the established goal, the participants instead helped the instructor pass out and collect materials or helped with classroom management, rather than adopting a stance that allowed them to fully concentrate on collecting classroom data. Perhaps more importantly lack of research lens "tainted the validity of their teaching experiment" (Fernandez et al., 2003, p. 175). In order for the ideals and successes of Japanese Lesson Study to be evidenced in the United States, Fernandez et al. (2003) emphasize the need for particular lens to be present and a natural part of the disposition of those participating in lesson study.

Research in Paterson, New Jersey extended from 1999 to 2002 to include more than 30 teachers. Using the same data sources as above, Fernandez and Cannon (2005) later explored whether lesson study provided a team of two second-, one third-, and one fifth- grade teachers at this school with opportunities to develop pedagogical content knowledge and/or to learn how to reason mathematically when unexpected events in actual classroom teaching unfold. A second purpose of Fernandez and Cannon's (2005) exploration was to assess whether the teachers had sufficient subject matter knowledge to make participating in lesson study a worthwhile endeavor (p.268). In the presentation of data, Fernandez and Cannon (2005) provide evidence to substantiate the claim that lesson study does in fact provide an entry point for improving pedagogical content knowledge.

> Specifically, as these teachers tried to determine exactly what sharing equally problem to use in their problem they inevitably found themselves talking about: (a) the ways children think about mathematics when faced with various sharing equally situations, (b) the challenges this thinking implies for students' understanding of fractions and teachers' attempts to teach this content, and (c) how best to address such challenges. (Fernandez & Cannon, 2005, p. 273)

Fernandez and Cannon make the case for how lesson study opened the door for educative discussions among the lesson study team; specifically asserting,

> Not only can lesson study provide an incentive for teachers to develop their understanding of content but it can also serve as a vehicle for teachers to learn about content in a way that directly feeds into their own understanding of how best to teach this content, and vice versa, thus engendering an ongoing cycle of learning. (p. 282)

In one such example, the Illinois Department of Education provided financial support to initiate lesson study among elementary math teachers. This resulted in a multiple case study bringing out the potential of improving the teaching of math at the forefront of discussion for two teacher groups (Puchner & Taylor, 2006, p. 923). Puchner and Taylor (2006) closely aligned the professional development of 17 area teachers with the approach of Japanese Lesson Study, resulting in the process taking six months and reinforcing the notion that changes in teaching practices are gradual but necessary in order to allow teachers time to inquire and reflect together (Lewis, 2002a; Puchner & Taylor, 2006; Stigler & Hiebert, 1999). Both of which are desired outcomes advocated by reform documents (AAAS, 1993; NRC, 1996; NSTA, 2003). Puchner and Taylor (2006) found that the lesson study process had a positive long term impact on the participating teachers' efficacy and collaborative efforts, ultimately resulting in the students' increased learning and a change in the teachers' professional practices.

Funding from the National Science Foundation (NSF) through "Lesson Study Communities Project in Secondary Mathematics" in Massachusetts made significant attempts to broaden the knowledge base of what is understood about lesson study in the United States. In this two year project, the research team sought to provide insight to the applicability of lesson study in the United States, specifically to answer "How" questions, e.g. "How does lesson study serve as a form of professional development? And, how does lesson study meet the particular needs of secondary mathematics teachers?" After attempts to conduct the project coordinator and thorough scrutiny of the web based resource page, final presentation of the data was not provided by the researchers. However, links to data collected provide some insight to how the participants viewed the lesson study process and the manner in which the lesson study framework was upheld. For example, in reflection of observing students during lesson study, one participant wrote, "I got to see a side of students that you miss when teaching. I think this was insightful…" In another quote, a participant reflected on the collaborative feature of lesson study stating, "Every time we meet I come away with a few more new ideas. I'm a veteran teacher and the new teachers feel they learn so much from me, but I also am learning so much from them." (http://www2.edc.org/lessonstudy/lessonstudy/-thoughtsbyparts.asp, retrieved March 8, 2009). Additional data from this two year study was provided in a 2008 presentation before the National Council of Supervisors of Mathematics. Gorman and Nikula (2008) presented insightful data as to the leadership roles and needs that emerged from these lesson study experiences. Gorman and Nikula (2008) also provided an outline of fundamentals for the success of lesson study, e.g.

teacher driven inquiry based learning model, all participants need to come as active learners, a primary goal of lesson study is to build a sustainable learning community.

While not considered research, additional documentation of lesson study in the United States can also be found in less formal arenas. For example, in spring of 2001, *The Northwest Teacher*, a publication of the Northwest Eisenhower Regional Consortium (NERC) for Mathematics and Science, devoted the edition to presenting information about lesson study. Through their collaboration with the Mid-Atlantic Consortium and other United States pioneers of lesson study such as Hurd in Lewis et al. (2006), Stepanek (2001) reflects on the Bellevue, Washington school district's first experiences with lesson study. As the description of middle school math teachers participating in a lesson study on linear relationships is relived through the article, "Creating Happy Memories," teachers describe the collaboration involved in developing the research lesson and the resulting ah-hah moments in teaching where they began to understand why students struggled with the concept (Weeks, 2001). Rather than repeating the past by "plugging through" the concept, the lesson study team chose this concept to be the focus of their research as it allowed an opportunity to explore different instructional strategies, be more creative in teaching, address misconceptions, and break down ideas into smaller chunks. One participant stated that she is now "more in tune with each student's understanding," admitting that while her own knowledge of mathematics deepened it was her students that were the direct beneficiaries (Weeks, 2001, p. 6).

The Northwest Teacher continued to support the teachers' professional development in lesson study. Two years later, *The Northwest Teacher* highlighted the efforts of additional school systems using lesson study in their professional development.

The editors provided updates on the teams from Bellevue, and spotlighted novice lesson study teams that had been developed within the last two years. One novice lesson study team from Oregon included sixth grade math teachers from North Marion Middles School. The lesson study team worked more than six weeks developing the research lesson, then opened their classrooms to a large audience of teachers and administrators from around the northwest. The audience came to find out more about lesson study and observe the research lesson; all while the lesson study team was delving into the minute details of teaching mathematics. It was lesson study in its most ideal sense. The newly, clearly stated vision of *The Northwest Teacher* evidenced the positive impact and potential of lesson study in the professional lives of those involved:

> Our vision is that *Northwest Teacher* will serve as a tool for professional development by actively engaging readers and by speaking to them as imaginative problem solvers, thoughtful inquirers, and lifelong learners. The stories that follow were selected to inspire teachers to reflect on and talk about their own experiences and beliefs….*Northwest Teacher* can serve as a starting point for group dialogue about issues in mathematics and science teaching, as well as for independent reading and personal reflection. (NERC, 2003, p. 1)

In Highlands School in western United States, Lewis, Perry, Hurd, and O’Connell (2006) began a lesson study team with kindergarten through grade five teachers. The success of the school’s first lesson study cycles during the 2000-2001 school year prompted the remainder of the faculty to participate in subsequent lesson study cycles within the next two years. Lesson study teams at Highlands have allowed teachers to “make sense of and bring to life new mandates, new ideas, and new curricula” (Lewis et al., 2006, p. 272). Lesson study is in its sixth year at Highlands and represents a systemic approach to professional growth reflective of the time necessary for lesson study to evolve in a way that more accurately embodies its full potential. At its inception in

Highlands, lesson study teams were focused on maintaining the features of lesson study and the development of plans. This shifted significantly toward a focus on essential philosophical principles of lesson study, such as "increasing teachers' opportunities to learn from one another, from practice, and from the curriculum" (Lewis et al., 2006, p. 274). Lewis et al. (2006) emphasize the importance of such evolution, asserting that "A shift of this kind is noteworthy because reforms often fail when their surface features are implemented in recipe-like fashion, without sufficient attention paid to the underlying rationale" (p. 274). Additional evidence to support the positive impact of lesson study on Highlands is found in the statistically significantly improvements in student achievement scores on state mathematics achievement tests. While a causal relationship cannot be made between achievement results and lesson study, it is the primary difference between Highlands and the practices of other schools in the district being studied.

Publications such as these illustrate the link between lesson study and its potential impact on both reflective practices and the development of pedagogical content knowledge. Simultaneously, the anecdotes illustrate a reform based approach to reflective teaching practices. What is unfortunate is that they do little to contribute to the literature. Based on these personal accounts presented in a narrative way, lesson study provided the context for which these teachers were able to learn how to collaborate, focus on student learning, improve pedagogical content knowledge, hold educative discussions, etc. There is a real need for rigorous examination into these professional development models. Lewis et al. (2006) express concerns of the fate of lesson study as faddish, proposing three lines of research needed in order for lesson study "to avoid the fate of so many other once promising reforms that were discarded before being fully understood or well implemented" (p. 3). These lines of inquiry include development of a research base, explication of innovative mechanisms, and iterative cycles of improvement research (Lewis et al., 2006).

Lesson Study in Teacher Training

In one published study conducted at the University of Georgia with preservice math teachers, Parks (2008) sought to contribute descriptions of preservice teachers' lesson study. With 27 preservice teachers in a graduate level math methods course, Parks (2008) viewed the structure Japanese Lesson Study provided "as a way to connect teaching in elementary classrooms to knowledge, skills, and dispositions that I was trying to develop" through the course (p. 1203). Parks (2008) provided the preservice teachers with a choice of four research goals related to equity and social justice. The preservice teachers then worked collaboratively over several days to create instructional plans designed to meet specific needs of the student population. During the time provided for the preservice teachers to practice teaching in the elementary schools, the delivery of the research lesson was followed by a debriefing at the school and additional time during the methods course to analyze the collected data. Each lesson study team completed their experience with a presentation and final report reflecting on what was learned about mathematics, children, and teaching. Parks (2008) describes the context of this research as more "lesson study like" than ideally representing the framework of Japanese Lesson Study (p. 1204). In analysis, Parks (2008) concludes that this variation to lesson study did support the preservice teachers' development of a mathematical and equity lens.

Summary

It is the purpose of this study to explore the potential of lesson study at the preservice level of middle and secondary science educators. The literature presented indicates a gap in our understanding of both lesson study and the transition of informed NOS understandings into classroom practice. The anxiety for preservice teachers in the United States associated with practice teaching tends to initially focus on logistical challenges, such as classroom management (Abd-El-Khalick, Bell, & Lederman, 1998; Bell, Lederman, & Abd-El-Khalick, 2000a; Lederman & Zeidler, 2001; Lederman, Gess-Newsome, & Latz, 1994; Smith & Scharmann, 1999). Anxiety associated with concerns such as these pose a challenge for preservice teachers to “plan and teach lessons that allow them to learn about content or teaching practices” as emphasized within the essential features of lesson study (Parks, 2008). While the potential challenges associated with the use of lesson study as part of teacher training is not to be ignored, a more complete understanding of reflective models that promote the transfer of NOS into classroom practice is a worthwhile endeavor.

CHAPTER 3

METHODOLOGY

Introduction

The research explored preservice teachers' integration of nature of science (NOS) curriculum in a lesson study, a reflective professional growth framework borrowed from one of Japan's frequent and successful approaches toward professional development (Lewis, 2002a). Researchers in education continue to examine the potential use of lesson study in the United States (Watanabe, 2002). Implementing lesson study as it is used in Japan is met with multiple obstacles due to social and cultural differences, infrastructure of education systems, etc. (see Watanabe, 2002). The importance of modifying Japanese Lesson Study to work within the United States has been asserted, in addition to, being recognized that the success of lesson study is contingent upon a thorough understanding (Chokshi & Fernandez, 2004; Fernandez, Cannon, & Chokshi, 2003; Lewis, 2002a; Lewis, Perry, & Hurd, 2004; Masami and Arani, 2005; Watanabe, 2002). In this dissertation study modifications to Japan's Lesson Study was guided by the standards established within the university's teacher preparation program which were consistent with national reforms (e.g. the Interstate New Teacher Assessment and Support Consortium [INTASC] model core standards for science teaching) aimed to graduate reflective practitioners with informed views on the NOS. The research questions themselves included, "How do preservice teachers' understanding of NOS shift as a result of the lesson study experience?", and "How does this reflective practice that occurs in lesson study influence preservice teachers' transition of nature of science tenets into classroom practice?"

As is evident from the research questions, the nature of the inquiry itself aimed to shed light on how the preservice teachers' experiences teaching NOS occurred within the reflective framework of lesson study. As the experiences of the preservice teachers' unfolded, case study methodology served to tell these experiences, while analysis of reflection was informed by Ward and McCotter (2004) and NOS understandings was informed by Lederman, Abd-El-Khalick, Bell, and Schwartz (2002). In this chapter the research methods employed to explore these lived experiences are expounded upon, both in the bodies of literature informing these methods and the prior experiences of the pilot case study.

Yin (2006) argues for the value of a pilot case study in working out particular data analysis issues, data collection efforts, and a more detailed research plan. In fall 2007, a pilot case study ensued to do just that. The primary research question associated with this pilot case study was to explore, "How do preservice teachers use lesson study to improve their teaching practices?" In this pilot case study it was hoped that much could be learned about the capacity of preservice teachers' to complete a lesson study and the ways that it could be used in future courses. Of particular importance to the pilot case study were ways preservice teachers improved their teaching of National Science Education Standards (NSES) relating to the NOS content strands (NRC, 1996).

Data collection for the pilot case study was situated in a graduate course focused on science pedagogy. Lederman's (1992) research on the understanding of students' and teachers' conceptions of NOS and core components of McComas' (1998) myths of science were the key research pieces driving the course requirements. Explicit NOS instruction was part of the teaching and learning during normal scheduled class meetings.

An additional component of the course was for all of the preservice teachers to participate in a Japanese Lesson Study. The framework of the Japanese Lesson Study requirements was explicitly outlined in the syllabus, with a follow up question-answer session about these requirements held during a normally scheduled class meeting. The course syllabus highlighted the placement of preservice teachers "with a team that consists of two interns and a cooperating teacher. Each intern was responsible for teaching inquiry based nature of science lessons, reflection, and assisting in recording evidence." These course requirements were guided through instruction during normally scheduled class meetings, and additional resources such as lesson plan formats and access to the university's supervising professor during posted office hours were also provided.

Data sources in this pilot case study were consistent with the course requirements. This included lesson study portfolios which encompassed and original, modified, and published research lesson, evidence of observations during deliveries, and final reflections. From all preservice teachers enrolled in the graduate course those who submitted complete portfolios were asked to participate in this pilot case study. Informed consent was provided by two of these five possible lesson study teams. The dynamics of the teachers in these particular groups represented contrasting degrees of experience in teaching; ranging from prior teaching experience at the pre-school level and graduate teaching apprenticeships to no teaching experience at all. These participant profiles provided an opportunity to explore many elements of the potential for lesson study in alternative teacher preparation programs.

Initial data analysis began by coding each participant's final reflections on the lesson study process. This analysis was not based on an instrument, but from categories that emerged as a result of the shared experiences provided in the participant's post reflections. Analysis of the reflections provided opportunity for the researchers to gain perspective on the attitude and over arching disposition toward lesson study, in addition to any value placed on the process. Categories for value ranged from low to high value and attitude toward lesson study was coded as a negative, neutral, or positive experience. Analysis continued with coding the "Observation and Reflection Guideline" found in Appendix C with the lesson study portfolio requirements, where participants' documented observations of the events occurring in their classrooms during the lesson study (Martin-Hansen, 2007). The participants' self generated observations were coded in relation to whether there was evidence of observing the teaching and learning of NOS, and whether there was any reflection about teaching NOS. Categories emerging in this participant generated document ranged from no analysis of NOS to clear analysis of NOS. In the middle of these dichotomy there was also analysis labeled, "mixed analysis," which meant that there was some analysis of NOS conjoined with other science content. Final data analysis ensued of the participant's digital recordings of their delivery of the instructional plans outlined in the submitted lesson study. This was used to check for consistency in the participant's observations, as well as, contribute to detailed descriptions more accurately representing the events as they unfolded for the participants. Details of this data analysis and the pilot case itself were later presented at the Association for Science Teachers in Education in January 2009 (McDowell & Martin-Hansen).

As mentioned, this pilot case served to inform the research plan for this dissertation project in several ways. During analysis, questions were raised as to how the participants' own NOS understandings may have impacted the outcomes. While coding of participants in the pilot case allowed for some perspective of NOS understandings and the transition into classroom practice, it did not allow for the rich, descriptive presentation characteristic of case studies. Thus, the need to include analysis of participants' NOS understandings by using established instruments such as the VNOS-b (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002) became evident. Furthermore, the pilot case highlighted a need for data which could explore how reflection was occurring during the lesson study. From this it was agreed that there needed to be additional avenues for reflection that could be analyzed by the researcher. This analysis would need to include a way to explore the sophistication of reflection in relation to how NOS curriculum was taught or NOS understandings may have changed. Lastly, the reliability of analysis was weak in this pilot case study. This was primarily due to the aforementioned design flaws, but also because the role of the researcher was too far removed. A closer relationship between the researcher and participants needed to be established for the dissertation. This would provide in-depth field notes that could establish trustworthiness in the research. The remainder of this chapter aims to explicate the research methodology for this dissertation study and the research which ensued as now informed by literature and the pilot case.

Research Methodology

The natural context of exploring graduate level preservice science teachers' reflective experiences in teaching and understanding NOS conjoined with multiple data sources lent itself to qualitative research design, specifically case study methods. Additionally, qualitative research was ideal for this line of inquiry because of the focus on experiences within the specific context of lesson study and the multiple realities that reside within each of the lesson study teams. Rationale and evidence to support this research method will now be expounded upon.

Merriam (1998) identifies three research traditions in education. The work of Carr and Kemmis (1986) and Merriam (1998) distinguish between positivistic, interpretive, and critical orientations of education research. Positivistic forms of research acquire knowledge through objective and quantifiable experimental research. Positivistic perspective is rooted in a stable, observable, and measurable reality (Merriam, 1998, p. 4). Interpretive orientations seek to understand lived experiences, recognizing that multiple realities are socially constructed. From interpretive research designs knowledge emerges inductively. The third form of education research, labeled critical, is an "ideological critique of power, privilege, and oppression" drawing from Marxist philosophy, critical theory, and/or feminist theory (Merriam, 1998, p. 4). Merriam (1998) states that determining the type of research to be conducted begins with an examination of one's own orientation about the "nature of reality" (p. 5). Once examined, the researcher is then to consider the research purpose and the knowledge to be produced.

Crotty (1998) describes " The nature of knowledge, its possibility, scope, and general basis…is concerned with providing a philosophical grounding for deciding what kinds of knowledge are possible and how we can ensure that they are both adequate and legitimate" (p. 8). Crotty (1998) further explains that one's way of knowing is "embedded in the theoretical perspective and thereby in the methodology" (p. 3). Interpretive orientations, such as this line of inquiry, naturally lend itself to a constructionist epistemological framework. Constructionism is characterized as "the view that all knowledge, and therefore all meaningful reality as such, is contingent upon human practices, being constructed in and out of interaction between human beings and their world, and developed and transmitted within an essentially social context" (Crotty, p. 42). Merriam (1998) provides the conceptual foundation for conducting qualitative research in education, defining its primary purpose as providing meaning in context.

Some researchers are in agreement in characterizing qualitative research methodology (Bogdan & Biklen, 2007; Crotty, 1988; Merriam, 1998;). Bogdan & Biklen (2007) describe the "meaning" associated with qualitative research as essential to making sense of the participant's lives (p. 7). As outlined in Chapter 1, the theoretical framework of this dissertation project is rooted in philosophies of symbolic interactionism within a constructionist epistemology, both characteristics typical of qualitative research (Crotty, 1998; Merriam, 1998). In addition, the experiences of the lesson study teams is a subjective representation of what the participants chose to record in their observations and reflect upon. Yet, the direct observations of participants in the school setting, formal interviews, informal conversations in e-mail, phone, and around class times, and follow up member checking promoted interplay between the participants' lives and the researcher. This elicited richly descriptive comprehensive data and placed the researcher as the primary instrument in analysis (Merriam, 1998). During analysis, a picture was constructed "that takes shape as you collect and examine the parts" in an effort to accurately portray both the holistic lesson study experience and the preservice teachers individual constructions of teaching and learning NOS (Bogdan & Biklen, 2007).

Research Design

Historically case study methods are prevalent in education research, yet the available resources for researchers are scarce (Merriam, 1998). In the field of qualitative research, Merriam (1998) asserts that there is “little to no consensus on what constitutes as a case study or how this type of research is done” (p. 26). In general terms, Bogdan and Biklen (2007) define case study methods as “a detailed examination of one setting, or a single subject…” with “the general design of a case study best represented by a funnel” (p. 59). Several qualitative researchers are seminal in the field of case study research (Merriam, 1998; Stake, 1994; Yin, 2006) and cited regularly in introductory texts (e.g., Bogdan and Biklen, 2007). Specifically, Yin (2006) comprehensively presents case study methods, designs, and analysis as an empirical approach to “theory and logical inquiry” that provides novice researchers with a “cookbook on case studies” that can and have been used exclusively (xiv). Therefore, as a novice researcher the work of Yin (2006) was used to inform the research design of this dissertation.

Yin (2006) states the inquiry itself drives the research strategy. As an exploration of a phenomenon, the transitioning of NOS tenets into classroom practice within the context of lesson study, the use of qualitative case study is an appropriate strategy. Yin (2006) identifies that the scope of a case study aims to investigate contemporary phenomenon within its real-life context. In this dissertation the contemporary phenomenon to explore is the transition of NOS tenets within the real life context of lesson study. Yin (2006) asserts that case study is especially appropriate when boundaries between the phenomenon and context are indistinguishable in the real-life situations (p. 13). Similarly, Merriam (1998) states that case study research design is “employed to gain in-depth understanding of the situation and meaning for those involved. The interest is in process rather than outcomes, in context rather than a specific variable, in discovery rather than confirmation” (p. 19). The case study strategy used in this dissertation allows in-depth understanding of both the phenomenon of teaching and learning of NOS and the context of lesson study in alternative teacher preparation programs.

Concurrently, Yin (2006), Stake (1999), and Merriam (1998) argue the use of case study as a research strategy is appropriate when (1) the focus of the study is to answer “how” and “why” questions; (2) there is little to no control over the participant’s behavior; and (3) the context of the study is contemporary. In this line of inquiry, the exploration of reflection that occurs in lesson study and how it might influence the transfer of NOS tenets into classroom practice for preservice teachers meets the first criteria. The reality that once the preservice teachers’ enter the classroom, there is no control on whether the NOS tenet(s) is successfully integrated fulfills the second criteria. Finally, this study is very much contemporary in that both the transfer of NOS in classroom practice and the use of lesson study in science education has been deemed relevant and lacking by multiple key researchers in the respective fields.

Yin (2006) identifies components of research design for case studies that are especially important. These components are represented in this dissertation study and include the following: study’s questions, unit(s) of analysis, and criteria for interpreting the findings (Yin, 2006, p. 21). In determining the study’s questions, Yin (2006) suggests placing boundaries, such as time and place, on a case in order to prevent a topic that is too broad or with too many objectives. The research question, “How does this reflective practice that occurs in lesson study influence preservice teachers' transition of nature of science tenets into classroom practice?" placed boundaries on two elements. This question restricted the time preservice teachers' actions were studied to the twelve week practicum experience, but even more specifically to the time of the lesson study within that practicum experience. It also restricted what was being studied (unit of analysis) to the preservice teachers' reflections within the lesson study. In the second research question, "How do preservice teachers' understandings of NOS change as a result of the lesson study experience?," subsequent boundaries within the unit of analysis are established by looking only at the preservice teachers' NOS understandings. Within these boundaries of the case and unit of analysis, the line of inquiry warranted a collection of descriptive data.

Data Sources

Multiple data sources were used in this dissertation study. Yin(2006) overviews six common sources of evidence used in case studies, arguing that "no single source has a complete advantage over all the others…are highly complementary…and a good case study will therefore want to use as many sources as possible" (p. 85). The data in this dissertation will come from five sources: (1) Form B of the Views on Nature of Science (VNOS-b) (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002) questionnaire and interview responses, (2) web based group forum weekly reflections, (3) field notes, (4) Lesson Study portfolios, (5) and interviews after completing the lesson study process. These data sources will now be described.

VNOS -B Questionnaire with Follow-up Interviews

VNOS-B was developed by Abd-El-Khalick et al. (1998) to assess preservice science teachers' views of NOS and then create contextual situations for discussing these views. This questionnaire is found in Appendix D. In follow up interviews, Abd-El-Khalick et al. (1998) provided participants their questionnaire responses and asked them to provide explanations for responses and clarify meanings through specific examples. Abd-El-Khalick et al. (1998) used this strategy in order to gain construct validity within the instrument by allowing the participant "to clarify vague statements or seeming contradictions" in their response (p. 504). This instrument and strategy was then used in subsequent studies (Akerson & Abd-El-Khalick, 2000; Akerson et al., 2000; Bell et al., 2000) and the completed questionnaires and interview transcripts were then analyzed to support construct validity of the VNOS-b, with assessed aspects of NOS categorized as "more informed," "informed," or "novice" (p. 507).

In this dissertation study, participants were asked to complete the VNOS-b on three different occasions: at the beginning of the graduate program, after specific NOS instructional interventions, then again after conducting a lesson study. Participants began their graduate program in the summer of 2009 by completing the VNOS-b. These responses were then analyzed to determine specific instructional interventions which represented the most prevalent misconceptions among the entire group. At the end of this summer course, the participants were provided their original responses as a springboard for refining their responses, providing additional examples, or changing responses altogether. These instructions were made clear at the onset of the administration and participants were allowed to either write directly on their original responses, write new responses on a blank form, or type responses into a provided document consistent with the VNOS-b. While different in structure to the recommended interview (Lederman et al., 2002), this particular approach still allowed the researcher to gain insight to the participants' NOS understanding and promoted additional construct validity in the instrument itself, as well as, promoted self reflection of NOS understandings. An additional modification to the recommendations of Lederman et al. (2002a) occurred in the way that this second administration was structured. During the course of the summer, participants had expressed their frustration with hand writing responses, with several requesting the option to type responses, arguing it would likely promote greater depth in responses along with less fatigue. After consulting members of the dissertation committee, it was agreed that this modification would not compromise the instrument's validity and therefore was put in place. Once this second administration had been completed, more than half of the participants were asked to interview for follow up clarifications and elaboration about the changes in understanding NOS. An example interview transcription has been provided in Appendix E.

The final administration of the VNOS-b occurred at the end of the fall semester once the Lesson Study had been completed by all of the lesson study teams. The option to type was again provided, as well as, responses from the first and second administration. Follow up interviews after the final administration occurred at the same time when participants were interviewed about the lesson study process itself. This was in an effort to respect the participants time, minimizing the intrusion of their personal time.

As recommended in Lederman et al. (2002) participants in this dissertation study were administered the VNOS-b under controlled conditions with no time restrictions. For the first administration, the questions were printed on a single page to provide ample space for responses. In the second and third administration, participants were given copies of earlier responses, and then given the choice of typing their responses or writing new responses on printed questions. Follow up interviews were conducted with participants where there was a need to clarify any ambiguities and explore the participants' lines of thinking (Lederman et al., 2002, p. 511). These interviews were open ended in structure, guided simply by requesting each of the participants to read, explain, and elaborate on their responses. Specific questions about the participants' experiences and their way of thinking emerged during the interview and are also included in the transcriptions. This approach was modeled after Lederman et al. (2002) where respondents were asked to clarify any ambiguous responses, with the interview tailored to the particular participant based on their questionnaire responses. Yin (2006) also identifies the interview as a critical source of case study information because of the nature of the line of inquiry into human affairs (p. 92). Yin (2006) describes case study interviews as open-ended, allowing for the participants to "provide insight into a situation" (p. 92). Consistently, the NOS interviews conducted in this study ensured accuracy and valuable insight to the participants' perspective. Indeed, the human nature of this line of inquiry elicited much more than the participants' NOS understandings. As described in a later sub-section, the final interviews also served as a way of member checking to ensure that the participants' responses were aligned with the data analysis.

Web Based Group Forum

In the fall 2009 practicum experience, a web based group forum was established by the university supervising professors. In this group forum, participants were expected to share experiences, reflect, and respond to others' postings. A minimum number of postings were part of the course requirements. Participants' were required to post individual weekly reflections, as well as, respond to someone else's reflection. Content posted was dependent upon the participants' needs and experiences while in their practicum schools. Postings were monitored by the university supervising professors for appropriateness within a professional environment. Inclusion of participation in this group forum was considered a vital data source as it would provide insight into the participants' science teaching experiences in a non-obtrusive way. These insights would also contribute to the richness of the presentation of the data, allowing an opportunity to chronicle the participants' experiences in the fall practicum experience.

Lesson Study Portfolio

Data sources as it relates to the teaching of NOS and the experience of lesson study were culminated into what is referred to as a "Lesson Study Portfolio". The minimum requirements for the lesson study portfolio included evidence of the following: developing a research lesson through collaborative efforts, develop a data collection and/or observation tool that focuses on the teaching and learning of NOS, observe and teach the research lesson, modify the research lesson based on these observations, re-teach with the modifications in place, and reflect on the process once its completed. Details of these specific requirements can be found in Appendix C. Within this portfolio, the first source of reflective evidence was the inclusion of the original, modified, and final version of the research lesson that was created as a result of completing the lesson study cycle. Participants were encouraged to modify aspects of the research plan directly on the original plan; then submit all three versions in the portfolio. Second, participants were encouraged to use a data collection or observation tool that was appropriate for gaining better insight to the teaching and learning of the particular NOS tenets being taught within the research lesson. Guidelines for collecting data aimed at student learning of NOS were provided, as evidenced in Appendix C, but important to note is the unique approach that each lesson study team was encouraged to take in directing focus during the deliveries of the research lesson. It was intended for this data collection or observation tool to direct the participants' focus on the specific issues of teaching and learning NOS, which again, was unique for each lesson study team and dependent on the intended learning goals found in their research lessons. An example of a participant generated data collection tool is found in chapter four within the Lolash Middle School lesson study description. Last, final reflections in the portfolio were also part of the portfolio requirements. These final reflections were guided by Martin-Hansen (2007) and aimed to provide a springboard for thinking back to the entirety of the lesson study experience. All of these requirements were provided and discussed with participants at the start of the fall practicum experience, as conducting a lesson study during the practicum experience was a required part of the course.

Field Notes

Field notes were kept during the summer and fall semesters. These field notes were used in two ways. These field notes assisted in accurately describing the particular teaching strategies used to present NOS and lesson study. Second, these field notes allowed for accuracy in describing the lesson study experiences of the participants, particularly the events on the day of delivery. These field notes reflect the specific events and other interactions that occurred between me and participants. Some of these interactions occurred during and around class schedules, through e-mail, and in phone conversations. Furthermore, for some of the participants my interactions influenced the outcome of their experiences. While part of the benefit of my researcher role provides trustworthiness in the data, it also brings the issue of bias to the forefront of analysis and the effectiveness of the case. The ways in which these issues were minimized will be further explained in the presentation of data analysis and again in chapter five.

Final Interviews

The interview is crucial to a quality case study research design (Yin, 2006). In this study interviews served several purposes. As described in the VNOS-b description, the first set of interviews was to ensure that the meanings ascribed to responses in the VNOS-b were accurately represented and interpreted. This is explained in further detail in the data analysis section. A second round of interviews was also conducted at the end of the fall semester. These final interviews served multiple purposes. Each of these final interviews began by asking open ended questions about the provided analysis associated with the participants' NOS understandings. Each participant was given an opportunity to further elaborate on a particular tenet, ask questions, and confirm the accuracy in depicting their individual NOS understandings. This final interview was then followed by questions about the lesson study process itself. The protocol for questions is found in Appendix F, and illustrates the open ended nature of this portion of the final interview. This elicited the participants' ideas and thinking about lesson study and the participants overall experiences during the fall practicum as it related to conducting a lesson study. This allowed for rich, descriptive representations of the participants and their lived experiences in the lesson study experience.

As a critical component for understanding these lived experiences, it was additionally critical to explore how these lived experiences in a lesson study contributed to shared and individual perspectives about teaching and learning NOS. Therefore, these final interviews were conducted in small groups that represented each of the lesson study teams that were purposefully selected to participate in this dissertation. There were three lesson study teams purposefully selected based on criteria further expounded upon later in this chapter. These three interviews lasted approximately an hour and a half each. The interviews were conducted outside of class time, in a location chosen by the participants based on convenience. These final interviews were audio-taped, and later transcribed.

Structuring each of these data sources within the research strategy conjoined with my prolonged engagement with the participants led to an additional layering of rigor in the quality of this dissertation. Trust and rapport was established with the participants over the course of the two semesters. This provided means for gaining in-depth understanding of the participants and their lived experiences. This prolonged engagement additionally played a role in the accuracy of the data and the rich descriptions that contributed to the presentation of findings.

Participants and Setting

In the summer of 2009, a cohort of graduate students entered an alternative teaching certification program at a university in the southeastern United States. These graduate students were working toward a teaching certificate in middle and secondary broad field science and a Master's degree in education. University requirements for completing the alternative certification program follow the minimum standards of science teaching outlined in the Interstate New Teacher Assessment and Support Consortium (2002). The cohort began their alternative certification program in a six week summer session which consisted of two introductory courses in science teaching methods, EDSC 8600 (Introduction to Secondary Teaching) and 8550 (Principles of Science Teaching). Sessions strands within the summer courses highlighted instruction based on INTASC (2002) science standards on assessment, curriculum, pedagogy, and classroom management. Within the curriculum strand, specific attention was afforded to NOS tenets found in K-12 curriculum. These experiences were described in an earlier section. In the following semester, several course options were offered to the same cohort of graduate students. One of the mandated courses focused on theory and pedagogy in science education which coincided with a ten week practicum teaching experience in one of the surrounding metro middle schools. In was in this course where participants were introduced to lesson study through journal articles, modeling, and individual or small group assistance. These lesson study experiences were also described in an earlier section.

Sixteen preservice teachers were enrolled in the fall semester theory and pedagogy course and placed at six different schools within the metro area. In this fall semester, prospective participants for this study were initially chosen purposefully based on provided consent and completion of all coursework from the summer NOS experience. Completion of the NOS coursework was determined by evidence of participation in each of the planned NOS experiences and two sets of responses to the

VNOS-b questionnaire. This data was copied and organized electronically. From the six possible lesson study teams that were established in this semester, three teams consisted of members that met both criteria for selection. In an effort to exhaust the data sources, all three teams were asked to participate in final interviews for purposeful inclusion in this dissertation. The description of the participants in the lesson study teams that follows includes those three teams of consenting preservice teachers that completed the summer and fall course criteria. For each participant, a detailed profile was created. In these profiles descriptions about past experiences relating to science education, initial teaching philosophies, and views on NOS at the onset of the fall semester are provided. Some data contributing to these profiles was not part of the data sources specifically chosen to assist in understanding the research questions. For example, all participants were separately working on electronic portfolios as part of their graduation requirements. Additionally, part of the summer course requirements was a daily reflection that was submitted on three different occasions during the summer semester. Components from each of these contribute to adequately describing these participants and their perspectives leading up to the time during the lesson study. Of additional importance are the participants' NOS understandings at the onset of the fall semester. This analysis has been included because the research question asks if there is a shift in NOS understanding after the lesson study experience. This could not be analyzed without first understanding the participants' views at the end of the summer course. The three lesson study teams described below represent the unit of analysis for this dissertation study (Yin, 2006). Participants in this dissertation are organized by their practicum placements within middle schools. The nature of the organization of the lesson study teams at the various middle schools has led to the organization of the descriptions below.

Lesson Study Team at Lolash Middle School

The lesson study team completing their practicum experience at Lolash Middle School included three preservice teachers: Brad, John, and Linda.

Brad. Brad is a single, white man in his early thirties. Brad decided to earn his undergraduate degree in physics at a university in the southeast after several years of working in the art and information technology community. He wrote that making the decision to become a teacher was a result of several influences.

> I have had professor after professor who has shared with me their passion for the subjects they teach. Whether it is the simple beauty of a mathematical proof, or the mind numbing awe that comes when you first begin to truly grasp the power released in the death throws of a star as it goes supernova. I want to pay my professors back for each and every one of those moments of understanding, wonder and inspiration, by sharing what they've given me with my own students. (electronic portfolio)

Brad’s more informed views on the NOS consistently emerged in his VNOS-b responses pertaining to the structure and nature of scientific theories and experiments. Brad wrote in great depth at the end of the summer semester about the importance of teaching theories. Brad explained,

> We teach theories for several reasons. First, some theories, even if imperfect, represent our best understanding of how the universe around us, or some small part of it, works. Second, we teach theories because they have predictive power. ….Third, we teach theories because they can often serve as ways to bridge gaps understanding. Here, again, outdated and invalidated models are often useful teaching tools. By showing where older theories break down, i.e. where they fail to work, we can often help students understand why different theories break down. Theories also can serve in the classroom as a tool to help organize knowledge. Finally, we teach theories because they can never be proven true. Bodies of supporting evidence can be accumulated, but it impossible to prove a theory, because it only takes a single piece of contradictory evidence to invalidate a theory… (Form B: Item 2)

In contrast, Brad's novice views on the empirical NOS consistently emerged in three VNOS-b responses where Brad writes of the objectivity of scientists and influences on data interpretation. Brad's consideration of the human endeavor of science itself, and the creativity or socio-cultural factors which might influence a scientist's perception or interpretation of data was void in each administration of the VNOS-b responses. From question four, Brad responded at the beginning of the summer course, "art is typically an interpretation of reality by the artist, while science is an effort to create an unbiased, objective description". In question five, Brad wrote, "Scientists often look at data and have no idea what it means. They have to be able to form ideas, based on their understanding of physical laws, as to what the data might describe." Then in question six, Brad wrote, "Scientific knowledge is something which is demonstrably true. Something which is measurable, repeatable, and can be objectively demonstrated." At the end of the summer course, Brad elected not to change or modify any of these responses; evidence that Brad's novice views on the empirical tenets of NOS.

As Brad reflected on the teaching approaches taken in the summer course that addressed the NOS concepts, he found most of the activities to be inappropriate for the age and experience of the class. Brad wrote after one of the NOS activities that he felt "talked down" to, and that he has had "professor after professor pounding the idea into my head for so long, that I'm not sure how I could not feel a little annoyed with lessons designed to help me understand the 'Nature of Science.'" (summer learning journal) In a follow up interview, Brad commented on this perception, stating that he now understood why the teaching approach was taken but thought that perhaps the rationale for teaching

NOS using the various research-based (e.g., Clough & Olson, 2004; Lederman & Abd-El-Khalick, 1998) approaches could be more clearly stated in the presentations.

From these first two semesters, Brad's desire to teach science had not waned. However, the complexity of teaching presented Brad with unexpected concerns. For Brad, some of these complexities included parents attending conferences, off task students, un motivated students, his role as a disciplinarian and how that impacted classroom management, and incomplete assignments. As an example, in one of Brad's on-line posts he wrote,

> I'm getting increasingly frustrated with parents who won't attend conferences, with the fact that I can't assign something as simple as looking something up online as homework, and yet when I ask, half the kids in class say they have plasma TV's at home. The last couple of days, I've been dealing with a student coming to school with burn marks, and I'm not sure if they're self inflicted or not, plus a student who's run away. I just don't get it….It's frustrating. Very, very frustrating. What keeps me going, though, is thinking about how big a difference teachers have made in my life. Some of the best memories I have of the first twenty years of my life at the direct result of things teachers did for me.

In leading up to the lesson study Brad had also mentioned that he was excited to see his peers teach. He felt like he would be able to learn from them in a way that he could not learn from his cooperating teacher.

John. John is a single, white man in his late twenties. As the oldest of four children, John recalls that his parents supported their science related interests when he was a child with frequent trips to zoos, interactive museums, books, etc. John realized his career related interests in the sciences as a high school student. When provided the opportunity to shadow professionals, he would often choose teachers, mechanical drafters, etc. John later earned an undergraduate degree in physics in the Great Lakes area of the United States. During this time in John's life he had also been an active member of the student government and worked in several capacities in order to financially support himself through school. Upon moving to the southeast, John worked as a pesticides field agent for a couple of years before deciding to earn a master's degree in science education. While John enjoyed the field work, limiting factors about the position led John to consider teaching. In addition, John's fiancé is a teacher in the southeastern area and served as a strong supporter for John while making the transition. As John reflects on his passion for science he recalls his own struggles in particular classes that may have led him to believe "that everyone should have an understanding of how they and their world work," later leading him to "becoming a science teacher." (electronic portfolio)

Based on VNOS-b responses, John's novice understanding of the NOS permeated at the onset of entering the graduate program. For example, John described the structure of an atom using ideas from Bohr and the electron cloud model, validating the answer with, "I don't know what specific evidence was used to create this view, but again it's the only one I've ever been taught." Then in describing the relationship between laws and theories, John provided examples of Newton's Laws of Motion as the basis for rocket science and also explained, "I was taught that once a theory was used as the basis for other theories or as a foundation for branches of a scientific field that it can be considered a Law." John wrote in parts of his daily reflection log about several of the NOS activities over the summer course, and how they provided John with an opportunity to grapple with his understandings of some of these NOS concepts. After the Tricky Tracks lesson, John wrote in his reflection log, "...it gave me a new perspective on how students might be viewing a situation". Interestingly though, John did not consider this as a rationale for how data can be interpreted differently by scientists. Then after reading the McComas (1998) article John wrote extensively about how astounded he was when being confronted by misconceptions that he too had held to true. For example John wrote, "The first myth, about the connection of hypothesis to theories to laws, was one that I admit I fell for. No one had ever taught me the definition of a law as stated by the article, and apparently by Newton in his *Principia*. I am fascinated that I did not know that." Later in the course as John was reflecting after a class activity about laws and theories, he wrote, "…we all need to be on the same page and using the same definitions…it is more than keeping and using proper vocabulary, but also truly understanding what those words mean. I had no idea about the difference between law and theory before this class, and would have stayed blissfully naïve…" As John finished the fall course, reflecting on his responses to the VNOS-b in the summer, his responses more consistently represented more informed views about the structure and function of theories and laws, the empirical NOS, and the tentative NOS. In a follow up interview, John stated that he had read over his VNOS analysis and felt "alright" about his understandings of NOS.

Upon beginning the summer course, John was admittedly anxious. John wrote in his daily reflection after the first day of class, "Speaking of freaking out, we have been assigned a topic to teach to a group of high school students tomorrow. I am honestly very nervous and on edge about it. I don't know how to teach, and I don't know what our instructors are looking for. I'm being pushed out of my comfort zone, which is OK, but right now my stomach is doing back flips." Prior to beginning this summer graduate course, John was a graduate teaching assistant in an algebra based introductory physics course where inquiry strategies were used to provide undergraduates with physics concepts. While this experience was valuable to John, he felt that he "walked into this class not knowing anything about teaching…" As John ended the summer course this perceived lack of understanding had been transformed. John wrote in his final course reflection that he is walking "out with a sense that I will know what I am doing when I get in front of a classroom….I also know where my weaknesses lie, and where I am uncomfortable content wise…A little push over the hill was all it was, and was all I needed." Early in the practicum experience John felt overwhelmed by the responsibilities of being a teacher. He wrote, "I was nervous to work directly with the students. After observing the students I didn't know if I would be able to manage the students or if I would have the patience to deal with them. I wanted to scream after observing a gifted class and the students were just too rowdy. But today, when I was up in front of the class, honestly everything felt so right. I enjoyed teaching those kids so much, and even when they were loud and hard to manage, I really felt so reassured in my choice of being a part of this program."

Linda. Linda is a single, white woman in her late twenties. Linda graduated from a southeastern research university in biology and German. While an undergraduate Linda gained experience in tutoring middle and high school student. During the fall semester Linda, "realized that my teaching philosophy is being morphed by having experience teaching!" (web based forum) As Linda gained more teaching experience she began to develop concrete plans for structuring her future classroom. Linda recognized a need for beginning the school year by presenting students with rules, procedures, and a behavior plan. In the final interview Linda was explaining that "having that balance among all the different theories" would be important. Linda mentioned that within constructivism this would mean using inquiry teaching strategies and determine students' zone of proximal development. "For instance, finding out what they know, picking a kid's brain, using methods that will allow them to tell me what they know first and then move them into what I want them to know using like culturally appropriate ways and you know…like developmentally appropriate ways for moving them into what I want them to know." (interview, January 4) From this perspective Linda stated she was most concerned about "creating an environment where students can reach their highest potential."

As Linda reflected on her responses to the VNOS-b questionnaire she wrote that the open-endedness of the questions was somewhat overwhelming. Linda found it difficult to condense her responses but still "express all of the information that I wanted to convey". Linda commented that she realized "a trend towards the end that we were writing about the way science is, not necessarily content itself. I think in general it is going to end up being weird to LEARN about TEACHING." As Linda continued to reflect daily on the course activities and outside readings she wrote about how exposure to new information or class activities would change or enrich how she understood science and how to teach. Linda perceived the outside readings to be more purposeful in providing direct information while class was better spent in discussion or in application through a collaborative activity. Linda's final responses to the VNOS-b support this claim, showing her understandings of the NOS aspects assessed more consistent with an informed view. One example of this is found in Linda's final responses about the nature of scientific theories and knowledge, "So because theories change, it might be thought at times, we could be teaching things that aren't true. This is not such a bad thing; however, because often theories serve as the best explanation that we have for what occurs around us."

As the fall semester was progressing, Linda explored teaching strategies that were proposed by the university. For example, after a class session about the use of wait time when questioning students Linda practiced this technique in her practicum placement. Linda wrote,

> I have noticed a few things when I tried this! The first is that the teacher and students are not used to this kind of structure…(and)…my mentor teacher does not use this in the classroom. So even if I'm teaching, if I wait for them to answer or expand on their answer, he jumps in and tells them the answer. And if a student gives a wrong answer, he immediately jumps in and tells them why they are wrong. It's kind of difficult to practice teaching inquiry in an environment that has been free from it for so long! (web based forum)

Additional concerns about unmotivated, failing students, keeping student conversations on topic, and fulfilling the expectations of both the supervisor professor and the mentor teacher were expressed concerns in Linda's web based forums. As the time for the lesson study was approaching, it was the blending of ideals from the university and the realities of life in the classroom that seemed to cause the greatest of Linda's concern. She wrote,

> …I have tried to compensate for when I'm being observed by showing how I ideally would have structured the lesson, had they not had prior information, but this is not working very well either….I find being a student teacher is very frustrating because I am submitting to the wishes of two different people, as well as my own, and it is impossible to please all the way around. (web based forum)

Lesson Study Participant at Deer Crossing Middle School

The lesson study team at Deer Crossing Middle School was quite unique in that it consisted of only one preservice teacher: Holly.

Holly. Holly is a single, white woman in her early twenties. Holly has lived in this southeastern metro area all of her life. Both of Holly's parents are involved in education. Holly's mom teaches music and her father recently retired from teaching middle school. Holly also has several friends that are currently working on teaching certificates or already teaching. When Holly was a sophomore as a biology student Holly worked in a doctor's office. Her time there had informed her later career choice in teaching science. Upon making the decision to become a science teacher, Holly entered the graduate program in this urban research university with the hope and anticipation of eventually teaching in the same area where she grew up and her family still resides.

Holly considered her understanding of science and how it works to be well informed, and had no doubts that she would be a quality teacher. Holly had been involved in science related activities for as long as she could remember. Aside from graduating with a biology degree, Holly considered other aspects of her life as contributing to her future success: she saw her parents as scientifically literate; she had participated in the science fair in middle and high school; and she had even helped her mom at the elementary school with their science fair projects. Holly found it surprising when her views on the nature of science (VNOS) were initially assessed using the VNOS-b, and many of her understandings of science and how science works were novice. Generally speaking, Holly saw science as a rigid, linear process that held knowledge to strict facts. At the beginning of the summer course Holly wrote of the function of scientific laws and theories and creativity in science when developing methods to follow and presenting results. Holly wrote, "all scientific laws were at some point theories", and the definite structure of an atom that is based "over many years of testing via experimentation and now that the technology allows scientists can actually visualize what an atoms looks like."(Form B: Item 3). That evening when Holly reflected on the VNOS-b survey, she assigned value to it, as well as, understood what aspects of the NOS were being asked for her to respond to. She wrote that it "was also something that she would like to incorporate into my future classroom. I think it is important to understand the overall concept of science (law versus theory versus opinion, creativity in science, the ever changing nature of science, etc) before you begin to truly understand the more in depth aspects of science." (summer learning journal).

As the semester progressed Holly began to recognize how her past had influenced her beliefs and how these beliefs were inaccurate. Holly described how middle and high school experiences led her to think of science as a rigid way of knowing. This idea of science was later confirmed in her undergraduate courses, even in those that were styled less traditionally. As the summer course progressed Holly's view on the NOS changed. In contrast to the majority of Holly's experiences, she remembered one biology lab assignment in particular that she felt most accurately reflected the way she now understood the NOS.

> We had to um create our own experiment from scratch and then execute it. (pause) Well a lot of people followed that rigid structure but what we did is we went and said well we know this happens when you add these chemicals together (I: um, hm), what if we were to change it? So we started with, basically what we already knew as an answer, and then went back and created a (research) design. Based off our design we created our hypothesis. It was kind of like all flip flopped of what you would "normally" tell a student to do. But it worked out really well except we didn't get results and instead of just giving up and that we reject our hypothesis as you would normally be taught to do, we (I: um, hm) said well, maybe it's because of this. And we went back and changed things and changed our hypothesis and everything and it was kind of an ever changing thing instead of this is step 1, this is step 2, this is step 3 kind of thing. (Interview, July 17)

By the end of the summer experience Holly was more informed in the way she understood the structure and function of laws and theories as tentative ways of understanding. Several illustrative examples from her second responses to the VNOS-b support this claim. Holly responded in question one, "Theories explain and thus if they weren't flexible enough to change as new information was made known, then having theories would be pointless. Changing and redeveloping theories allows scientists to have the most accurate explanation of phenomena for the current knowledge base." Then in question three Holly wrote, "A scientific law makes predictions about the outcome of phenomena given certain conditions while a theory provides an explanation for phenomena…A law is no more valid than a theory and vice versa. Also, both laws and theories are subject to change..." In response to question seven Holly wrote, "I would like to add however that science does not provide a definitive answer to all questions. In fact, in many cases there is no one correct answer." At the end of the summer Holly's responses relating to the creative and imaginative nature of science were also quite informed. She wrote at the end of the summer course for questions four and five,

> For example, if an experiment is not turning out as planned a scientist might have to be creative/ imaginative in the actual way they collect the data in order to gather any data at all. After the data has been collected a scientist might have to be creative in their manipulation/interpretation of the data if the data does not make sense when employing conventional interpretation methods… Likewise, without creativity science would be very limited as it often takes creativity to come up with new ideas and experiments…

At the end of the summer, Holly still seemed uncertain about her views on the empirical nature of science. Holly responded similarly to question six for both administrations of the questionnaire, writing "Scientific knowledge is made up of material that has been tested and established as true. This includes not only scientific laws and facts but also many theories. Scientific opinion on the other hand does not have definitive evidence behind it." Holly confirmed this response in the interview on July 17.

Holly stated, "…knowledge is based on what I would like to consider rigid facts. Like observations, or um, you know, data from experiments or different technologies that tell us different things. That kind of stuff that's more of a rigid you know 2+2=4 type thing…" However, Holly did state later in the interview that, "there's no one answer and um things like that, that tells us not to take what we think as absolute truths or create them as absolutes because there could be evidence backing up something else. And they could be equally valid in the eyes of the evidence, which is what we really have to look at."

Holly's past experiences had not only informed her initial understanding of the NOS, but also contributed to a significant amount of frustration for her as she began to learn about teaching science. The first few weeks of class for Holly threw her into a zone of frustration and discomfort that had never been experienced. She would complain to family and friends that she "wasn't learning anything," and that the class was a "bunch of fluff." (Interview 1) However, in the interview at the end of the summer, Holly said,

> Well it ended up not being that in the end and I ended up loving the course. It definitely changed my whole perspective as to how a class should be run. As opposed to being very teacher based, being very student based. Because in the end I didn't realize I learned, but my knowledge base has expanded drastically. And it wasn't that easy A, where you can sit back and take a huge test like a traditional test. You know there was a whole lot of thinking involved and writing involved and which seemed easy at the time which made me enjoy the assessment but I also had to be very specific and driven in how I approached my answer to those things.

As Holly embarked on the practicum experience at Deer Crossing Middle School, she was both excited and nervous. Holly was excited at the prospect of learning from some of her peers, but nervous when she started thinking about all the responsibilities of teaching. In the final interview at the end of the practicum experience Holly stated that one main reason for this nervousness was that there had been a lot of changes in the way she thought about teaching and so she was anxious to see how these would "play out". She felt that when she first wrote about her teaching philosophies, she "was initially more concentrated on content, but now would insert more real world applications and allow students a chance to develop an appreciation for that sort of thing."

Lesson Study Team at Muddy Banks Middle School

The lesson study team completing their practicum experience at Muddy Banks Middle School consisted of two preservice teachers: Josie and Lydia.

Josie. Josie is a single, white woman in her early twenties. Josie has not always lived in the southeast. Much of Josie's life was spent in the northeastern region of the United States. Josie is proud to re-tell one of her first memories of when her parents found her in the backyard dissecting a dead mouse. Her interests in "the natural world and everything in it" have not waned. (Live Text portfolio) While earning an undergraduate degree in biology, setting goals toward a degree in science education was a natural fit for Josie. Josie specifically recalls the impact visiting an aunt had on her career decisions.

> One of my aunts is a teacher, and when I would visit her, I always went to her school and helped out in the class. I watched the way she inspired her students and knew that I would be honored to do the same. Between my passion for science and for helping others, science education became a no-brainer during college. (electronic portfolio)

As Josie made the transition toward earning her master's degree in secondary science education, she was anxious to get started with the courses. "I'm very excited because I feel like this class will teach me how to teach, which I cannot wait to do!" (summer learning journal)

As an undergraduate, Josie volunteered in several science related capacities. During this time Josie was an active member in a local herpetological society, volunteered at a dental clinic, and traveled abroad to work as a field guide. These experiences had informed Josie's views on the NOS in several ways. As Josie responded to the VNOS-b questionnaire on both occasions during the summer, she began to question whether some of her understandings had actually been taught or something she inferred as a result of doing science for the last twenty years. (summer learning journal)

One particular aspect of Josie's NOS understandings that did not change during the summer was the creative NOS. As evidenced in Josie's response to question five on the VNOS-b, she held somewhat informed views of the creative and imaginative NOS upon being initially assessed. Josie wrote, "Oftentimes it takes imagination to figure out and understand where your findings fit. Also, if your results are unexpected, imagination and creativity are helpful in making sense of these results." Josie did elaborate on this at the end of the summer to say, "…sometimes there are factors limiting our ability to collect data. So sometimes using our imagination and being creative helps figure out ways around these limiting factors…" On the contrary, Josie held and maintained more novice views on the empirical NOS during the summer. Josie repeatedly used the electron cloud model of an atom as validation of the evidence used in science to provide explanations. "Scientists are about 99.99% certain about this structure. Scientists have used evidence from chemical experiments. In other words, using different solutions to determine the chemical and physical properties of an atom." In an interview in July at the end of the summer course, Josie was asked if she saw how the NOS tube activity was similar to some work in science. While Josie explained during the interview that the effects of the different tests “led different groups to draw different explanations,” the connection between this indirect evidence and the atomic models was not made clear.

As the summer course was coming to an end Josie also articulated in much more detail the tentative NOS, along with its limitations. While Josie had written of the tentative NOS in earlier responses to the VNOS-b, it was the details and examples provided at the end of the summer semester that indicated Josie had come to broaden her understandings toward more informed understandings. Josie responded to question seven on the VNOS-b in the following way:

> Science is simply not exact. There is a definite limit on our resources and what we can actually know. Astronomy, in particular, is not an exact science, maybe because we have very limited access to the universe/atmosphere. Right now, we just don't have the ability to completely understand the universe, or to collect all of the necessary data. In addition, All people have different schema theories, including scientists, which can affect how they analyze or interpret data. (Form B: Item 7)

Josie’s understandings of the functions of laws and theories in science were also changed over the course of the summer semester. At the onset of the summer course, Josie wrote that we should teach theories “because they are the closest things to scientific fact that we, as humans, are able to know at this time.” (Form B: Item 1) Josie also wrote that “Scientific theories are not proven, but are essentially laws in the making.” (Form B: Item 3) As she was thinking back to one of the explicit NOS activities toward the end of the summer course, she wrote the following in her learning journal.

> I didn’t realize that both (theories and laws) can be proven wrong. Also, the biggest misconception I (and many of my classmates) had was that a theory becomes a law if it’s supported enough time. However, there is not a hierarchy when it comes to theories and laws. This is amazing to me, because I’m pretty sure that I was taught that there was. Very eye opening and made me realize not to take my knowledge of certain concepts for granted, and also not to assume I understand everything!

In the second administration of the VNOS-b Josie wrote that, “The difference between them is that theories tend to explain, while laws simply state… there does not have to be a theory for every law. (Form B: Item 3)

Josie’s experiences during the summer and fall courses continued to inform her beliefs about teaching. After the first teaching experience in the summer, Josie began to think about motivating disinterested students, her own needs for preparation, maintaining relationships with students, and the role of vocabulary as it relates to the effectiveness of a lesson. Josie had hopes that the courses would provide her insight to resolving such dilemmas, as well as, allow her to build a repertoire of practical examples of “how science should be taught and structured.” (summer learning journal) After the fall practicum experience, Josie wrote about using inquiry based teaching strategies to support “intellectual development of students in a science classroom,” by organizing students to promote collaboration and discussion. (electronic portfolio) As Josie summarized her practicum teaching experiences, she explained,

> I have continually used opportunities in my student teaching classroom to implement effective strategies to create a supportive and engaging learning experience. Where inquiry was lacking, I employed it, and where misconceptions lingered, I supported the students so that they could correct them. In addition, anytime I taught in my mentor teacher’s classroom, I re-arranged the desks so that they were set up in groups to promote collaboration. (electronic portfolio)

By the end of the first month in the practicum experience, Josie had started to find her way at Muddy Banks. Her cooperating teacher had been increasingly giving Josie teaching responsibilities. Josie was excited by all the teaching experiences she had been afforded. She wrote on the web based forum about the mutualistic relationship that had evolved between her and the cooperating teacher, stating, that “Mine was really excited about me teaching - she loves that she's learning new teaching styles and techniques from me. Her attitude is: It's been awhile since I was in school, and I would love to see the latest greatest techniques they're teaching you!" Posts from the online forum indicated that Josie was trying to use each of these experiences to develop her own teaching practices.

Lydia. Lydia is a single, Hispanic woman in her early twenties. While Lydia's grandparents are from Hispanic background, Lydia has grown up in this southeastern region. Lydia does not necessarily identify herself by her cultural background, often forgetting that this is important to others. Lydia's middle and high school experiences were "mainly made up of Caucasian students with very few African Americans and no Hispanic students" (interview, January 18). When Lydia started the graduate program she felt lacking in her understanding of how to teach science. Linda perceived this was because, "Having majored in biological sciences in my undergraduate degree, I had few opportunities to be exposed to different teaching methodologies. This was all very foreign to me at the beginning." (summer learning journal) As Lydia reflected on the summer semester as a whole, she even saw a need to re-read the assigned articles in order to improve her understanding. She wrote that she felt this would be important because "like the first time I read them all it was hard to fully comprehend… because I cannot relate them to actual experiences." (summer learning journal)

Analysis from Lydia's responses to the VNOS-b indicates that those views, both novice and somewhat informed, which were expressed at the onset of the graduate program became more concrete for Lydia over the summer semester. For example aspects of NOS, such as the functions of scientific theories and the relationship between theories and laws, which were novice at the beginning of summer, were reaffirmed in subsequent responses and in a follow up interview. One such illustrative example is in response to question three where Lydia wrote, “Once the scientist has developed his theory and tested it repeatedly, he presents it to the scientific community. Then it is open for fellow scientists to test themselves. If it is proven right over and over again by multiple scientists then it can become scientific law.” In a later response to question seven Lydia confirmed this novice understanding by writing, “Scientists can find indicators backing up their theories and consider them evidence. But these are just theories, not law. Until we get a better understanding, possibly with advanced technology, the debate will continue because it is just too hard to evaluate right now.” Both of these answers were affirmed at the end of the summer in written responses and in the follow up interview.

On the other side of the continuum some views that were somewhat informed at the beginning of the summer, moved toward more informed understandings by the end of the summer. One such illustrative example is in Lydia’s understandings of the tentative NOS. Lydia first wrote in response to question one that “Scientists once thought they understood atoms and the nucleus, then we learned about electrons. Scientific theories are constantly evolving as technology advances and we are able to learn more.” Then when asked again at the end of the summer, Lydia emphasized, “For the most part I still agree with my previous answer about scientific theories and the methods of either amending theories, proving them correct, or disproving a theory. The last option of disproving a theory is important because we did learn that science is not finite nor is it forever.” As Lydia reflected on the NOS content being taught in the course she stated,

> Again nature of science to some extent means different things to different people. But I am definitely developing my understanding of this concept. Some parts are obvious like the understanding of science as an investigatory means of gathering information on the world around you…I definitely think it is important to have a good understanding and a broad base of knowledge to pull from so that you can cover all the bases in your classroom with the students. (summer learning journal)

For Lydia it was easier to recognize how NOS "fit in with the benchmarks because they are more broad guidelines than specific requirements" from the state standards. (interview, January 18)

When Lydia began her practicum experience this was also evident. While observing her cooperating teacher during the first few weeks Lydia did see space for NOS to be explicitly integrated. As Lydia's practicum experience began she spent the first day observing four different classrooms with unique teaching styles. Lydia was feeling overwhelmed, but tried to be optimistic in her on-line posts. She explained that this anxiety was "always the case at the start of something new" and recognized that she was still getting acclimated to middle school "students' cognitive abilities and behavioral/social level" along with "a few special needs kids and a bunch of ESOL kids". (web based forum, August 22) Lydia wrote shortly thereafter that "The further we get into this practicum, the better I feel about it. I am still overwhelmed with the amount of work this semester…Going into this I was sure I wanted to teach high school biology, but now I am keeping my mind open." (web based forum, August 30) Lydia had even spoken to her cooperating teacher about NOS. The cooperating teacher was familiar with NOS standards and attested to integrating NOS regularly. In addition, the cooperating teacher was supportive of the impending lesson study, reassuring the participants at Muddy Banks that this would be a valuable experience.

Data Collection

Data collection took place during the summer and fall 2009 semesters (see Table 1). Initial data collected during the summer 2009 course consisted of only the preservice teachers' responses to the VNOS-b questionnaire. This also served as a time for developing a relationship with the preservice teachers', learning about them as individuals, as students, and as team members, earning their trust and developing rapport for the upcoming lesson study. Then, in the fall 2009 all preservice teachers enrolled in the summer introduction to science education course were required to enroll in the theory and pedagogy course and practicum experience. During this semester of the participants' practicum science teaching experiences, data was collected about their participation in a lesson study and final NOS understandings. The preservice teachers' decisions to participate in this study did not influence the type of instruction or support received. All preservice teachers received the same NOS and lesson study instruction as part of both courses.

Description of the NOS Experience in the Summer of 2009

The preservice teachers' understandings of NOS were initially assessed using VNOS-b (Lederman et al., 2002) at the beginning of the summer course (see Table 2). This instrument is described in full detail in the earlier section on data sources. Results from the VNOS-b (Lederman et al., 2002) influenced the NOS instructional decisions. NOS activities found in Appendix A (Lederman & Abd-El-Khalick, 1998), outside reading (McComas, 1998; McComas, 2004; Schwartz, 2002), and other reflective learning opportunities were selected in order to provide isolated experiences with

Table 1

Timeline of Data Collection

Research Question	Data Source	Timeline for Data Collection
How does the reflection that occurs in lesson study influence the transfer of nature of science tenets into classroom practice?	Web based weekly reflections Lesson Study portfolio Field Notes Final interviews	Ongoing during Fall 2009
How do preservice teachers' understandings of NOS change as a result of the lesson study experience?	VNOS-b open ended questionnaire and follow up interviews if needed Final interviews	Beginning Summer 2009 End of Summer 2009 End of Fall 2009

Table 2

Timeline for NOS Experience, Summer 2009

Class	Date	Description of NOS Explicit, Reflective Instruction
1	June 8	VNOS-b Reading Assignment: "Science for All Americans, Chapter 1: The Nature of Science", online version (http:/www.project2061.org/publications/sfaa/online/chap1.htm)
3	June 10	"Tricky Tracks" (Lederman & Abd-El-Khalick, 1998)
7	June 17	"The Tube" (Lederman & Abd-El-Khalick, 1998) Reading Assignment: "Dispelling the Myths" (McComas, 1998)
12	June 25	"Dispelling the Myths" (McComas, 1998)/Concept Cartoons (Keeley, 2008) Reading Assignment: "Keys to Teaching the Nature of Science" (McComas, 2004
15	July 1	Misconceptions of Laws and Theories (part 1) Teaching NOS Word Choice Concept Map (part 2)
19	July 8	Integrating NOS in problem based learning units
22	July 14	VNOS-b

particular tenets of NOS where results among the participants were consistently naïve. The NOS experiences planned for the participants were modeled after reviewed literature on the successful transfer of NOS understandings into classroom practice as indicated by Clough (1998), Bell, Lederman, and Abd-El-Khalick (2000), and Schwartz and Lederman (2002). By the end of the summer course all participants were offered a minimum of four explicit NOS class sessions and responded to the VNOS-b (Lederman et al., 2002) twice (pre and post instruction). Follow up interviews after the VNOS-b were additionally conducted with three of the six participants.

The participants' first NOS experience followed the suggestions from Lederman & Abd-El-Khalick (1998) for the activity "Tricky Tracks". This activity was selected for several reasons. First, as this course represented the start of a new career and education path for these participants, it was important to establish an environment that would encourage active participation in discussions. Second, as informed from the participants' initial VNOS responses, a prevailing misconception about the empirical NOS centered on ideas about observation laden evidence and data sets leading to single conclusions. As indicated in the literature, this particular activity provides participants with an opportunity to explore their understandings of these NOS ideas through whole class discussion that is centered on the human interpretations of observations, the ongoing work of science, and the way fossils provide multiple explanations of past life. As outlined in Appendix A, the instructional plan for "Tricky Tracks" followed the suggestions of Lederman & Abd-El-Khalick (1998). In this class session there was additional opportunity to contextualize the experience through examination of how the targeted NOS tenet can inform classroom practice. To do so, participants were asked to work in small groups to examine the state's science standards as it related to the integration of NOS in content. This was the first time all six of the participants had seen the standards. In final whole group conversation, rationales for teaching NOS were clearly stated. This included assertions about the need to integrate these understandings as cognitive outcomes in their future classrooms.

In the second NOS experience, the black box activity titled "The Tube" (Lederman & Abd-El-Khalick, 1998) was used to provide a springboard for discussion. This experience was selected from the NOS activities in Lederman and Abd-El-Khalick (1998) in order to provide a second opportunity for the participants to explore those same empirical NOS tenets highlighted in the first experience, but with the additional idea of scientific models representing theoretical entities, tentativeness of scientific knowledge, and the creative and imaginative NOS. Participants were guided in their exploration with a handout and the constant monitoring and facilitation of class discussion. As indicated in the lesson guide for this NOS experience participants were asked to reflect on their understandings of NOS before and after "The Tube" activity. This reflection was prompted by a continuum where participants self rated their NOS understandings (see Appendix A). After time for reflection, whole group discussion included a brainstorming session of ways the activity could be used in future classroom practice.

Prior to the third NOS experience participants were required to read McComas (1998), an article which explained proper and improper conceptions about the NOS. This experience was structured much differently than the prior two, as the specific instruction aimed to support direct conversation about the research based myths associated with "The Principal Elements of the Nature of Science: Dispelling the Myths" (McComas, 1998).

Concept cartoons such as those found in Keeley (2008) and illustrated in Figure 2 provided a medium for which these conversations occurred. After sharing with the participants various concept cartoons and the general structure associated with these formative assessments, students were organized in random groups with one of the fifteen myths described in McComas (1998). In these groups students were asked to create their own concept cartoon of their particular myth. Once participants were finished, a “carousal walk” (Keeley, 2008) ensued where participants read each group’s cartoon and determined which of the fifteen NOS myths was being illustrated. As this NOS experience concluded, the participants shared each of their concept cartoons with the whole group.

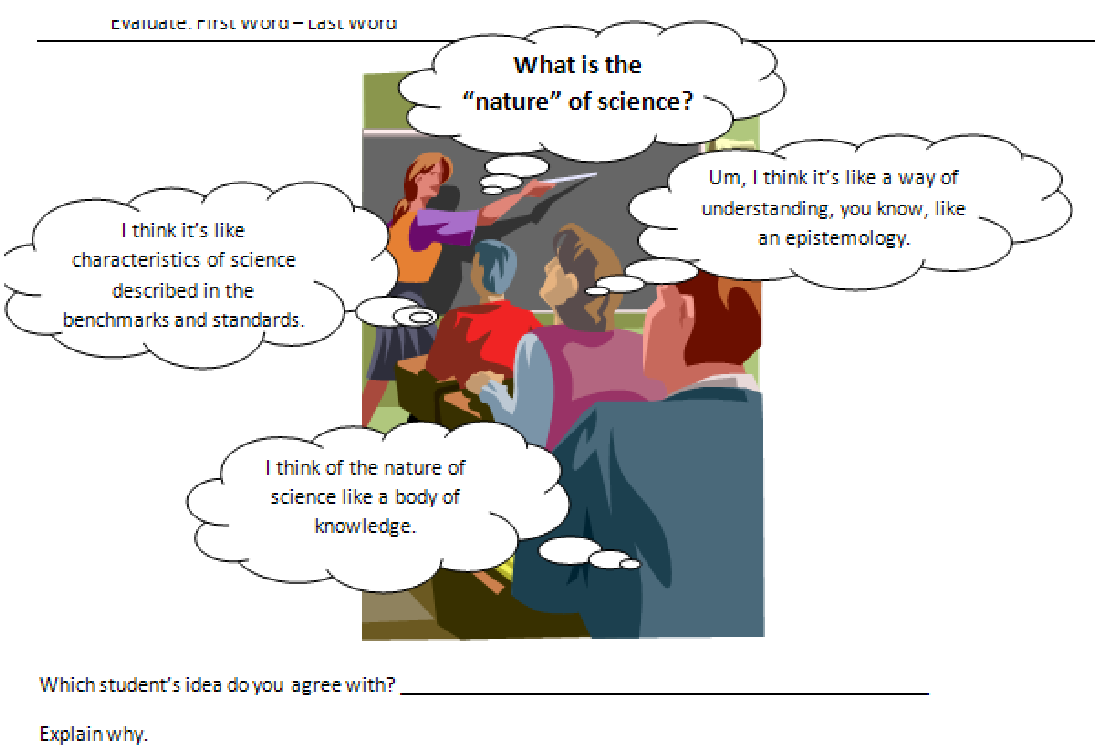

Figure 2. Nature of science concept cartoon.

Focus in the final explicit NOS experience served dual purposes. First, it became apparent in the group discussion during the third activity that the participants were most surprised by their improper conceptions about scientific laws, theories, and hypothesis. Therefore, the first portion of class was used in providing the participants an opportunity to explore their misunderstandings. With learning units in mind, participants brainstormed specific laws and theories that were either a part of the underlying basis for their units of instructions and/or an explicit part of the instructional design. These responses are illustrated on the left within Figure 3. Then, with provided resources [e.g., Benchmarks for Scientific Literacy (AAAS, 1993); NSES for K-12 (NRC, 1996)], the participants were asked to work through their misunderstandings of the terms to formulate a more proper definition or explanation for these terms as they are used by the scientific community. Participants' responses are illustrated on the right within Figure 3. Once all responses had been reported, whole group discussion ended this portion of the NOS experience. During this whole group discussion, participants commented on the

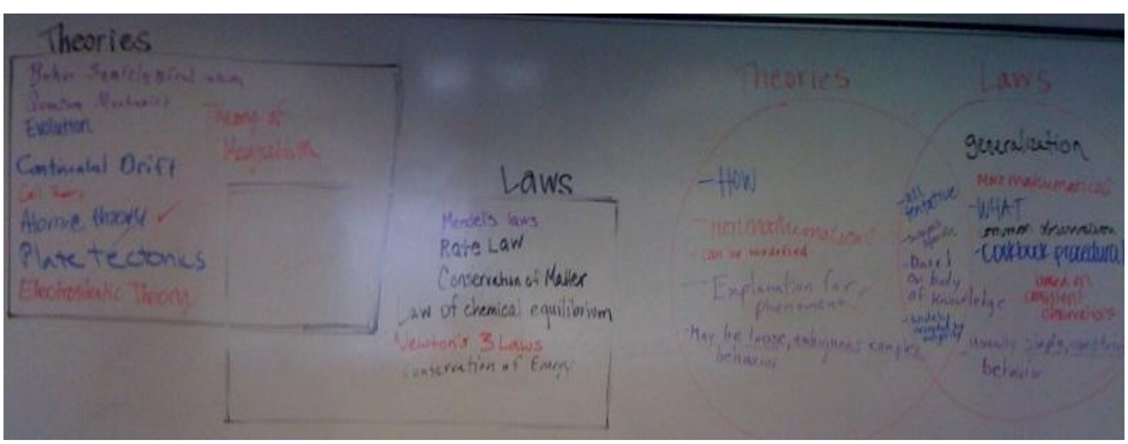

Figure 3. Participant responses during theories and laws NOS Experience

ways that the misconceptions surrounding laws and theories in science had been part of their science background reinforcing the misconception.

These discussions offered an appropriate segue in to the second portion of class that was intended to focus on the importance of word choice when teaching NOS. Class discussion began with the participant's contributing their initial comments about the assigned readings. These readings were selected to provide participants with research based approaches to improve students' NOS understandings (McComas, 2004; Schwartz, 2002). As shown in Figure 4 participants were provided a concept map and word bank to begin formalizing some of the ideas that were presented in the articles. As participants struggled with completing the concept map, class discussion ensued about the articles' suggestions for teaching NOS.

During the final two weeks of the summer course, participants were responsible for developing problem based learning units with NOS integrated in both implicit and explicit ways. The problem based learning units were defined as units of instruction centered on a particular issue or situation. For the remaining two weeks of the course, time was allocated at the end of class for participants seeking additional individual or small group guidance in developing this unit. As part of the assignment requirements, participants were also required to use the comment feature on Microsoft Word to identify and comment on areas within their problem based learning units where NOS had been integrated in both implicit and explicit ways.

At the conclusion of this summer session, the preservice teachers' understanding of NOS was reassessed. In class discussion participants had expressed several concerns about the VNOS-b questionnaire. These concerns included its length, hand writing

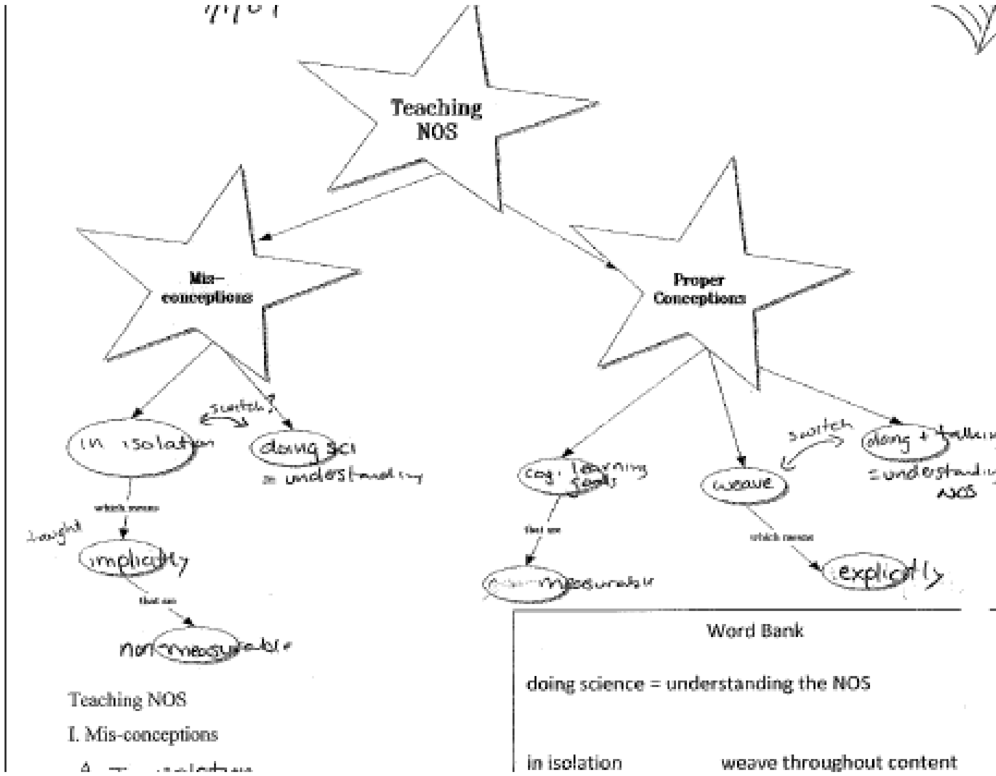

Figure 4. Teaching NOS concept map.

versus typing responses, and request to access to their first responses so that they could edit directly from the document. After discussing these possibilities with the supervising instructor of the course and a member of the dissertation committee, several accommodations to the traditional format of administering the VNOS-b were agreed upon. It was first determined that providing the questions from the VNOS-b through the university's web based learning website would be optimal. It was felt that doing this would not compromise the validity of the test instrument and also allow participants to type their new responses. However, there was concern expressed about the possible limitations that would result by providing the initial responses (e.g., creating bias, minimal detail). After all things had been considered, it was agreed to also provide participants their initial VNOS responses for this second administration.

Participants were provided these accommodations for responding to the VNOS-b for this second administration, along with unrestricted amount of time to complete the VNOS. As a final component of these NOS experiences, follow up interviews were scheduled for three of the six participants. These follow up interviews were conducted during the following three weeks prior to the beginning of the fall semester.

Description of the Lesson Study Experience

In fall 2009 the graduate students were in their second semester of the alternative certification program. During this twelve week semester, the graduate students observed classroom practices, reflected, and practice taught in middle school science classrooms. Simultaneously, graduate students enrolled in EDSC 7550, “Theory and Pedagogy of Science Instruction,” a course focused on examining issues, curriculum, strategies, and research in science education. The combination of these two experiences is commonly referred to as the practicum experience. This practicum experience is consistent with national standards for science teacher training programs and provides a medium for the preservice teachers to expand upon ideas from the summer course and experience teaching first hand (INTASC, 2002; NSTA, 2003). The syllabus for this course has been included as Appendix H. The contents of this syllabus are based on previous work in the pilot case study and former syllabi developed by other professors. Assignments and course schedule outlined in the syllabi include a brief description of the lesson study portfolio, as well as an outline of time dedicated to introducing the participants to lesson study. Appendix B provides an outline of the introductory class “workshop”. While Table 3 provides a summary of these experiences, a more detailed description of the participants’ lesson study experience follows.

Table 3

Timeline of Lesson Study Experience, Fall 2009

Class	Date	Description of Lesson Study Experience
2	August 26	Practicum experience begins. Assigned Reading for 09/04 (Kusnick, 2008)
4	September 9	Introduction to Lesson Study
5	September 16	Question/Answer Session about Lesson Study
6	September 23	Modeling of Lesson Study
7-13	September 30 - November 11	Lesson Study Team Check-ins
14	November 18	VNOS-b

Prior to the class session allocated as an introduction to Japan's Lesson Study, participants were assigned reading Kusnick (2008), "Teaming up for better teaching." In this article, Kusnick (2008) overviews lesson study, providing a summary of its process as well as insight to common issues found by those participating in a lesson study. As the introductory "workshop" began, participants were asked to reflect upon their understanding of lesson study to answer true or false to five statements that would address common misconceptions outlined in Lewis (2002a). As discussion began, participants were asked to participate in discussion that would allow informal assessment of whether they knew the statements to be true. As a result of this, several informal generalizations about the participants' understandings became evident.

Most participants thought that the statement, "Lesson study is lesson planning," could be both true and false. All participants agreed that it was false to characterize lesson study to mean writing, "lessons from scratch" or "a rigid script." From discussion it also became evident that participants' understandings of the term "research lesson" used in this context led to some initial confusion. After clarification, most participants were unsure if the statement, "The research lesson is a demonstration lesson or expert lesson." Lastly, from class discussion most participants generalized the purpose in lesson study similar to that of basic research.

Guided by suggestions from Lewis (2002a), participants were next provided background information about lesson study in Japan and rationales for its use in the United States. In this delivery, I spoke about standardized test scores, reform documents, and indicators of scientific literacy among competing nations such as Japan and the United States. With this rationale for lesson study provided, participants were then asked to take time to reflect upon Japan's lesson study cycle as presented in Figure 5 and begin to point out positive characteristics as well as critiques for its implementation. Participant responses were consistent with concerns and implications shared in research (Fernandez, 2002; Fernandez & Chokshi, 2002; Lewis, 2002(b); Lewis, Perry, & Hurd, 2004). These concerns included such things as time required in implementation, support of colleagues and peers at the schools where they would be completing their practicum experience, and coordinating the logistics of completing the lesson study cycle.

Participants were then shown video excerpts from the video "Can You Lift 100 kg?" accessed from www.lessonresearch.net. In an effort to highlight various aspects of the lesson study cycle, predetermined stops were based on recommendations from www.lessonresearch.net. The class "workshop" concluded with discussion on rationales for the particular lesson study assignment that the participants were being asked to complete. These rationales included both big picture ideas such as learning to teach NOS, developing knowledge and dispositions for reflection; but also more immediately

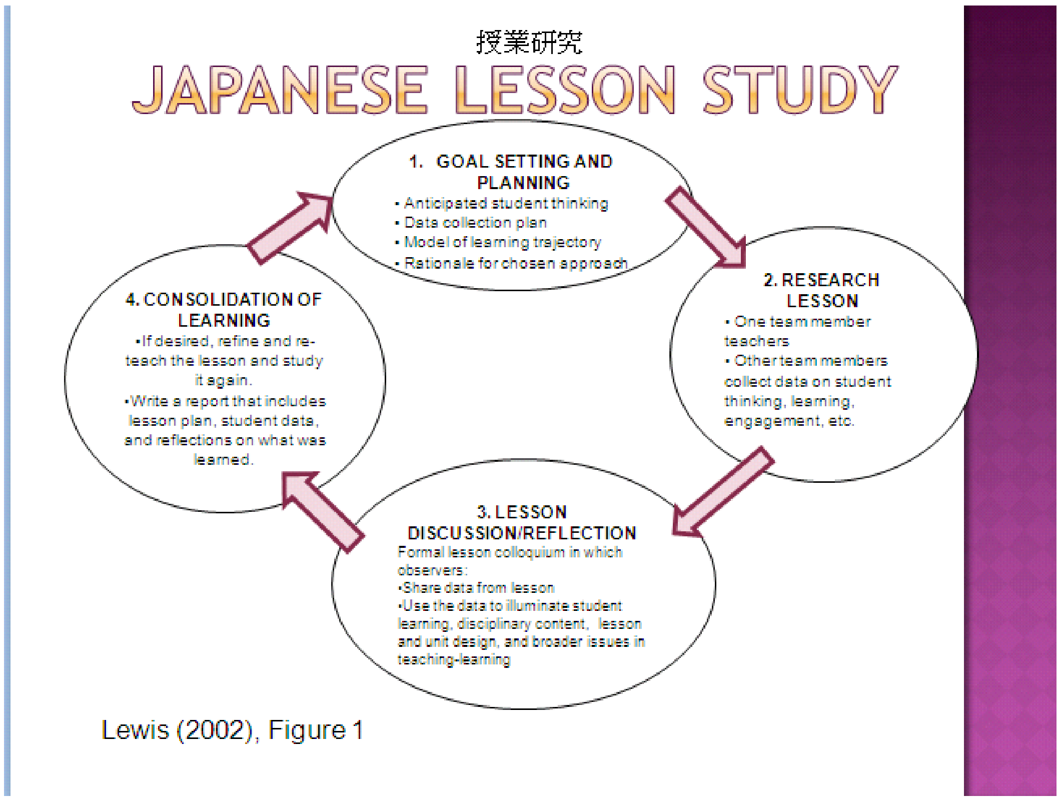

Figure 5. Visual representation of Japan's lesson study cycle.

relevant goals such meeting INTASC (2002) standards as part of their graduation portfolio requirements. Discussion about the ways Japan's lesson study was being modified in this situation, as well as, the ways it was remaining intact was facilitated through a handout provided for the participants (see Appendix C). Emphasis was placed on NOS learning goals serving as an avenue for scientific literacy and the participants' roles in promoting this learning goal as future science teachers.

As indicated in Table 4, the next class consisted of a question-answer session. The visual representation in Figure 6 was used to facilitate this discussion. This figure was also included on the provided handout (see Appendix C). Most of the participants' questions were specific to the requirements associated with lesson study portfolio assignment (see Appendix C). Details about the logistics of establishing lesson study

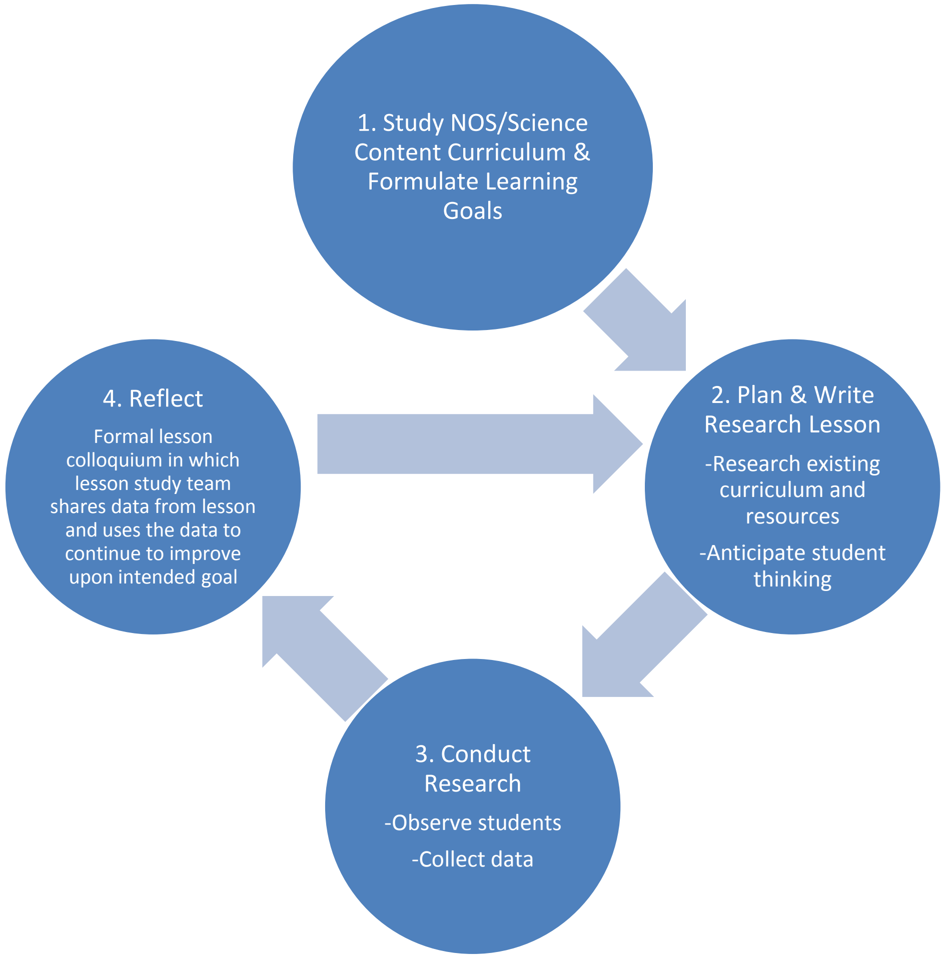

Figure 6. Visual representation of modified lesson study framework.

teams and how the participants would ideally work together to complete a lesson study cycle were discussed. Participants were redirected to the provided handout and informed of its availability through their web based forum. Questions asked by the participants also indicated uncertainty in the curriculum goals that were to be the focus of their lesson study. In this discussion emphasis was again placed on the need to focus on integrating NOS curriculum and students' learning of particular NOS tenets integrated within science content.

In the final class time allocated for presenting lesson study, the professors of EDSC 7550 and I modeled one cycle of lesson study. As the class session began, the participants were told that the lesson planned for today served multiple purposes, one of which was to model lesson study and the other was to provide an example of using an inquiry based approach to teaching the history of science (HOS) as an integrated component of science content. The participants were instructed to be mindful about their roles, and the switching back and forth between being an active and passive participant that would be required. As the modeling of lesson study began, the “lesson study team” debriefed before the delivery of the research lesson. The participants listened as one of the professors explained the learning goal and research lesson that the “lesson study team” had collaborated to develop. During this debriefing, participants heard the “lesson study team” discuss positioning for data collection and the type of data to collect. As it became time to “deliver” the research lesson, participants were reminded of their dual roles. These roles were to be actively engaged in the research lesson for the purposes of both experiencing the HOS lesson and also to observe data collection during the delivery.

During delivery, the other professor and I “collected data” on the participants’ responses to the explicit NOS questions and whether participants were doing NOS implicitly or explicitly. As the delivery was concluded, participants were reminded to switch roles during the “reflection” portion of this first delivery. As the professor teaching the HOS lesson began to reflect upon the research lesson’s effectiveness, I began taking notes as “members” of the “lesson study team” contributed to the discussion. Once my contributions had been included in the reflection, the professor who delivered the “research lesson” began suggesting modifications to the delivery that would improve the “students’” learning goals. Once these phases of the lesson study had been modeled, the participants were addressed directly. This lesson study experience concluded with discussion about what could have been expected to occur if the lesson study cycle had been completed. As the fall semester progressed, participants were encouraged to consider me as one of their lesson study team members. My role was to assist them in considering the logistics, developing the research lesson, collecting data, and reflecting. As outlined in Table 3, “Lesson Study Check-ins” meant that in the weeks that followed participants would talk to me about their specific situations through electronic communication (e-mail, text, or phone) and during regularly scheduled class time. As the semester continued to wind down, lesson study teams began to complete their lesson study. Portfolios meeting the required evidence of participation in a lesson study were turned in electronically to the lead teaching professors on or before the due date.

After all participants had completed the lesson study, final responses to the VNOS-b questionnaire were requested. Again, participants were offered an electronic and a paper version of the VNOS-b. With no time restrictions, and the prior responses provided, the participants were asked to reflect on their earlier responses then modify these responses to more accurately reflect their NOS understandings. At the time of administration participants’ questions about the reasons for completing the VNOS led to some discussion about how the depth of their answers would be used to analyze their NOS understandings.

Data Analysis

Yin (2006) presents ways of analyzing case studies, noting that analysis of case study evidence “is especially difficult because the strategies and techniques have not been well defined” and that “playing with the data” is often necessary in order for a general strategy to emerge (p. 109). Yin (2006) further explains that the initial theoretical propositions reflected in the research questions and literature review will give priority to particularly relevant analytical strategies. Consistently, initial data analysis for this case study began with using protocols outlined in Lederman et al. (2002) and Ward and McCotter (2004). Table 4 overviews the sequencing of analysis and corresponding data sources with analysis strategies. These strategies are further explained in the subsequent sections. Once data was analyzed using these instruments, cross case comparison strategies were employed. This allowed for an opportunity to "play" with the data and present it in a manner consistent with case study methods.

As Table 4 indicates analysis of preservice teachers' NOS understandings was based on the NOS assessment work of Lederman et al. (2002). The applicability of this work as it relates to this dissertation project reverts back to the particular theoretical

Table 4

Timeline of Data Analysis

Research Question	Timeline for Data Analysis	Analysis Instrument	Data Sources
How do preservice teachers' under-standings of NOS change as a result of the lesson study experience?	Beginning of Summer 2009 End of Summer 2009 End of Fall 2009	Lederman et al. (2002)	VNOS-b open ended questionnaire and follow up interviews if needed Final interviews
How does the reflection that occurs in lesson study influence the transfer of nature of science tenets into classroom practice?	End of Fall 2009	Ward and McCotter (2004)	Web based weekly reflections Lesson Study portfolio Field Notes Final interviews

propositions guiding the selected data sources (Yin, 2006). For example, Lederman et al. (2002) are in agreement with reform documents (e.g., AAAS, 1993; NRC, 1996), characterizing NOS by "the values and epistemological assumptions" underlying the work of scientific processes. Second, both in research conducted separately and collaboratively, the researchers have extensively devoted attention to the relevance of informed understandings of NOS (e.g., Abd-El-Khalick, 2000; Lederman, 1992). Finally, Lederman et al. (2002) developed the VNOS with individual classroom interventions in mind; Interventions that aimed to transform learners' NOS views through the combined efforts of the intervention itself, reflection, and follow up interviews. Because of these reasons which are consistent with the theoretical propositions described in Chapter 2, the use of Lederman et al. (2002) was an appropriate strategy for analyzing the participants' NOS understandings. Furthermore, this approach provided rich, descriptive NOS profiles also consistent with participant descriptions necessary for a quality case study (Yin, 2006).

The NOS profile of the participants in this dissertation is a critical component for exploring how lesson study influences perspectives about teaching and learning of NOS. In this study, responses from completed VNOS-b questionnaires and interview transcripts were used in analysis similarly to the way ascribed by Lederman et al. (2002). Different from Lederman et al. (2002) was the potential for additional data sources in the reflections posted on the web based forum or in conversations recorded in field notes. Nonetheless, these data sources were not structured and would have added to these participant descriptions only if data was contributed through a sharing of lived experiences over the prolonged engagement between the participants and me or each other.

The VNOS-b questionnaire is included as Appendix D. From the completed VNOS-b questionnaires and interview transcripts participants' responses were first analyzed following closely to the recommended protocol of Lederman et al. (2002) to discriminate between novice and informed understandings of the participants' NOS understandings. Tables 5 through 8 present several NOS illustrative examples from Lederman et al. (2002) along with example responses from the participants in this dissertation. These tables include the participants' views on the empirical NOS (Table 5), scientific methods (Table 6), tentative NOS (Table 7), and the function of theories and laws in science (Table 8). In this analysis, there is not a "restrictive one-to-

Table 5

Sample Analysis Strategy for Participants' NOS Understandings (Empirical NOS)

Code	Illustrative Example from Lederman et al. (2002, p. 514)	Example Responses from Participants
Novice	"Science is concerned with facts. We use observed facts to prove that theories are true." (Form B: Item 6)	"Scientific knowledge is knowing theories, their strengths and weaknesses, understanding their limits, being able to evaluate the quality of data and the validity of data gathering techniques." (Form B: Item 6)
More Informed Views	"Much of the development of scientific knowledge depends on observation… But I think what we observe is a function of convention. I don't believe that the goal of science is (or should be) the accumulation of observable facts…" (Interview)	"It (atomic models) is an example of using experimental evidence to explain something which we cannot see. No one can see an atom (yet) so mathematical models are used to predict how we think an electron orbits around the nucleus of the atom…." (Form B: Item 2)

Table 6

Sample Analysis Strategy for Participants' NOS Understandings (Scientific Methods)

Code	Illustrative Example from Lederman et al. (2002, p. 514)	Example Responses from Participants
Novice	"Science deals with using an exact method…That way we know we have the right answer." (Form B: Item 4)	"Science and certain types of art are similar in that they are precise. Each piece has a place in a greater puzzle. There is a method to each." (Form B: Item 4) "They are also similar in that new methods are still being discovered in both art and science." (Form B: Item 4)
More Informed	"When you are in sixth grade you learn that here is the scientific method and the first thing you do this, and the second thing you do that and so on…That's how we may say we do science, but (it is different from)…the way we actually do science." (Form C: Item 1)	"While the collection of and portrayal of data should be as objective as possible, the imagination is used during and after data collection…once data is collected, scientists should make simple and reasonable conclusions based on their study. However, when trying to determine why something occurs, there is a lot of room for imagination to step in and make suggestions....these suggestions often serve as grounds for scientific research." (Form B: Item 5)

one correspondence between an item on the questionnaire and a target NOS aspect" (Lederman et al., 2002, p. 512). For example, a participant may have an "informed" understanding of the tentativeness of science but have a "novice" understanding of science's subjectivities.

Analysis of participants' NOS understandings occurred at the beginning of data collection in the summer of 2009, the end of the summer courses, and then again at the end of the practicum experience in the fall of 2009. Analysis on these three occasions was important in answering the research questions, “How do preservice teachers’ understanding of NOS change as a result of the lesson study experience?” Understanding the participants perspectives’ about NOS prior to the lesson study experience was critical in not only creating a rich participant description, but also to provide a measure of any shifts in these perspectives as a result of the lesson study experience.

Merriam (1998) identifies reliability in qualitative research when a separate researcher can be given the same data set and generate findings consistent with those in the study. Reliability of this analysis was established once a second researcher analyzed a subset of raw data in comparison to the participant descriptions created from this data. Of the six participants included in this study, one participant from each lesson study team was independently analyzed by the second researcher. As suggested by Lederman et al. (2002) any discrepancies were resolved through discussion and consulting the data from the questionnaire responses, with particular attention to the interview transcripts. This same approach to ensure interrater reliability extended in the analysis of levels of reflection.

After analyzing views on the NOS, participants’ levels of reflection were analyzed. During the practicum experience reflection opportunities were structured to include the web based forum, lesson study portfolio, and final interviews. Analysis of levels of reflection was guided by the work of Ward and McCotter (2004). Ward and McCotter (2004) developed a rubric to analyze preservice teachers’ levels of reflection (Appendix G). They label four levels of reflection including routine, technical,

Table 7

Sample Analysis Strategy for Participants' NOS Understandings (Tentative NOS)

Code	Illustrative Example from Lederman et al. (2002, p. 514)	Example Responses from Participants
Novice	"If you get the same result over and over and over, then you become sure that your theory is a proven law, a fact." (Form B: Item 3)	"Scientific theories are not proven, but are essentially laws in the making. They represent the best idea we have about how something works. Like the Theory of Evolution. Because evolution takes place over so many generations, it's difficult for us to have specific, factual evidence of it occurring. We have evidence, of course, but not a lot compared to laws such as Newton's Law - "for every action there is an equal and opposite reaction." This is something that we can test over and over again, and have specific, numerical data in support of it with no other possibilities in sight." (Form B: Item 3)
More Informed	"Everything in science is subject to change with new evidence and interpretation o that evidence. We are never 100% sure about anything because…negative evidence will call a theory or law into question, and possibly cause a modification." (Form B: Item 1)	"Theory can, and often does, change over time. This is because as new information is uncovered or discovered, what we previously thought was correct could need to be altered. A perfect example of this is the atomic theory. Over time the atomic theory changed to reflect the most current knowledge. Theories explain and thus if they weren't flexible enough to change as new information was made known then having theories would be pointless…" (Form B: Item 1)

Table 8

Sample Analysis for Participants' NOS Understandings (Function of Theories and Laws)

Code	Illustrative Example from Lederman et al. (2002, p. 514)	Example Responses from Participants
Novice	"Laws started as theories and eventually become laws after repeated and proven demonstration." (Form B: Item 3)	"A theory has been tested multiple times and has not been disproven; however it has not been established as a law (meaning that it cannot be disproven even after attempts to do so). Many theories are unable to be proven as absolute fact, such as the theory of evolution, however at the same time they cannot be disproven." (Form B: Item 1)
More Informed	"A scientific law describes quantitative relationships between phenomena such as universal attraction between objects. Scientific theories are made of concepts that are in accordance with common observation and go beyond and propose new explanatory models for the world." (Form C: Item 5)	"A scientific law makes predictions about the outcome of phenomena given certain conditions while a theory provides an explanation for a phenomena. An example of this would be that Mendel's law of independent assortment predicts what will happen to alleles on a chromosome during meiosis if those alleles are not linked (predicts given certain conditions) while the theory of evolution cannot predict how a species or group of species will evolve over time but it provides us with an explanation of what has happened in the past. A law is no more valid than a theory and vice versa. Also, both laws and theories are subject to change and are content specific." (Form B: Item 3)

dialogical, and transformative. In their (Ward & McCotter, 2004) research, these labels were categorized based on an examination of the preservice teachers focus, inquiry, and change in reflective documents. These labels along with anticipated characteristics are found within the Appendix G. According to the rubric, the most mature reflection is transformative in which the preservice teacher focuses on student learning and reframes understanding such that it changes practices.

From a grounded theory approach, Ward and McCotter (2004) present this reflection rubric after extensive research with preservice teachers, exemplars from the Renaissance Teacher Work Sample, and six exemplars from Collaborative Inquiry: Reflection, Questions about Student Learning providing detailed sections on each level of the rubric accompanied with samples of preservice teachers' reflective writing (p. 246). Ward and McCotter (2004) state,

> As teacher education programs attempt to articulate and measure outcomes for their programs, our reflection rubric provides a means for evaluating reflection as a core program goal. Our reflection rubric would also work well as a research tool for evaluating the effectiveness of a wide variety of strategies designed to promote teacher reflection such as cases and journal as well as newer innovations such as the use of electronic portfolios and digital video. (Ward & McCotter, 2004, p. 255-256)

The specific data sources in the lesson study portfolio (research lesson, data collection and/or observation tool, final reflections) along with the potential for reflection on the web based form and the final interview, represented a wide variety of structured reflective strategies. Providing these additional opportunities for reflection was an aspect of data collection missing in the pilot study. The structured opportunities for reflection specifically included in the modified version of the lesson study to support reflective practices in teaching and learning of NOS makes the work of Ward and McCotter (2004) an appropriate instrument for analysis.

Similar to Lederman et al. (2002), Ward and McCotter (2004) included a rubric with illustrative examples from their extensive research with preservice teachers. This rubric was continuously referred to during analysis of the preservice teachers' reflective documents. Ward and McCotter (2004) indicate three dimensions where most preservice teachers consistently functioned. These dimensions are labeled as focus, inquiry, and change and separately presented in Tables 9, 10, and 11. Table 9 presents characteristics of the focus dimension, illustrative qualities of this dimension as described by Ward and McCotter (2004), and sample data from the participants in this study. Table 10 presents characteristics of the inquiry dimension as defined by Ward and McCotter (2004) and sample data from the participants in this study. Similarly, Table 11 presents characteristics of the change dimension from Ward and McCotter (2004) and sample data from the participants in this study. Within these dimensions, variations in the way reflection occurs were also analyzed. Again, using the illustrative examples from Ward and McCotter (2004), the levels of reflection for the participants in this study were coded. These levels of reflection are presented on a continuum from routine to transformative. This analysis provided substantial insight to how the reflection that occurs in lesson study potentially promotes the teaching and learning of NOS.

After analyzing participants' NOS understandings and levels of reflection, I looked across each of the multiple sites to first describe their experiences in a narrative type form. I then began to discuss these experiences as unique or typical experiences based on all of the participants' narratives. In cross case analysis I specifically looked for discussion points about the participants' engagement within the lesson study framework, disposition, and outcomes. Cross case comparison allowed me to most accurately represent the outcome of the particular phenomena, later leading to a discussion of implications. Yin (2006) states that participants within a unit of analysis for a case study might represent (a) existing theory, (b) a rare or unique case, (c) typical, (d) revelatory, or

Table 9

Sample Analysis Strategy for Levels of Reflection (Focus Dimension)

Focus Dimension Levels of Reflection	**What is the focus of concerns about practice?**
Routine Qualities	**Self Centered Concerns; Primary concerns may include control of students, time and workload**
Illustrative Examples from Data	"…some of the students are testing me. For instance, Mrs. X doesn't allow the students to use the bathroom during class unless it is an emergency (because they have time in between classes) and I have noticed a few students ask her to sign their pass and when she says no they come ask me (not thinking I just saw her say no). Of course, I stick with her on these issues and they have become less frequent as the week has progressed but it still worries me that they are trying this." (web based forum, August 27)
Technical Qualities	**Specific Teaching Tasks such as planning and management, uses assessment and observations to mark success or failure without evaluating specific qualities of student learning for formative purposes**
Illustrative Examples from Data	"This week the lessons were concentrated on lab safety and the scientific method. They took a quiz on lab safety, completed two labs that helped them become confident with the scientific method, and worked on two worksheets that allowed them to draw conclusions and make hypotheses based on given information." (web based forum, Aug 22)
Dialogic Qualities	**Focus in on students, assessments, and interactions with students**
Illustrative Examples from Data	"One thing that my mentor teacher does that I really liked was if the students had not completed their homework on a lab day they were not allowed to being the lab until they had finished the homework and if they didn't complete the lab then they don't receive full credit for the lab. I think of this as a great way to get the students to do their homework because they look forward to labs and want to participate." (web based forum, August 22)
Transformative Qualities	**Personal involvement with fundamental, pedagogical, ethical concerns and how these impact students and others**
Illustrative Examples from Data	"I have this one particular student in one of my classes that I could tell have a true interest and curiosity for science but his grades were horrible. I noticed that he was slacking when it came to completing assignments, both in class and for homework, and his test grades reflected that lack of effort. About three weeks ago the students were working on an in class project and he was doing a great job drawing a picture of weathering on his groups poster so I walked over and complimented his work. His eyes lit up for a moment but then he said "yea but I'm not smart, I can only draw". I quickly corrected him saying that he was smart and that I knew if he would try as hard with his other work and studying as he was with this project he could and would do very well in the class. Well, he smiled and said ok and went back to work. A few days later the students had a quiz over the info presented in the group projects and he made and A!!! I made sure to tell him good job and that I knew he could do it and ask what he did differently. He told me that he studied and paid attention during the presentations because I told him that he could make an A. That made me think.....he had probably never been told that he could succeed before. I wonder how many of my students would do better if someone would just take the time to tell them that they believe in them. Any thoughts?" (web based forum, November 7)

Table 10

Sample Analysis Strategy for Levels of Reflection (Inquiry Dimension)

Inquiry Dimension Levels of Reflection	What is the process of inquiry?
Routine	**Questions about needed personal change are not asked; blaming problems on others or limited time and resources**
Illustrative Examples from Data	“Has anyone had trouble combining the teaching ideas of their mentor teacher and of the supervisor into one lesson plan? I have tried to jump through hoops to try to communicate clearly with my mentor teacher, but sometimes notes are taken on a subject before I teach it, which takes away from the ability to effectively do "Engage/Explore". I have tried to compensate for when I'm being observed by showing how I ideally would have structured the lesson, had they not had prior information, but this is not working very well either. Anyone else experience the same thing? I find being a student teacher is very frustrating because I am submitting to the wishes of two different people.” (web based forum, November 12)
Technical	**Questions are asked by oneself about specific situations or are implied by frustration, unexpected results, exciting results, or analysis that indicates the issue is complex.**
Illustrative Examples from Data	“Today I did Target Time (a daily warm up activity) with the class. During the discussion of Target Time, I was really trying to work on my Wait Time 1 and Wait Time 2. Usually Wait Time 1 is less of an issue, but my Wait Time 2 is gradually getting better from what it was. Also I am trying to build off of wrong answers in order to clear up misconceptions. However I have noticed a few things when I tried this! The first is that the teacher and students are not used to this kind of structure. If a student thinks they have the wrong answer, they are tentative in defending it, so it is important that I not give feedback one way or the other. However, my mentor teacher does not use this in the classroom. So even if I'm teaching, if I wait for them to answer or expand on their answer, he jumps in and tells them to answer. Or if a student gives a wrong answer, he immediately jumps in and tells them why they are wrong. It's kind of difficult to practice teaching inquiry in an environment that has been free from it for so long! Any suggestions?” (web based forum, October 24)

(Table continues)

Inquiry Dimension Levels of Reflection	What is the process of inquiry?
Dialogic	**Situated questions lead to new questions. Questions are asked with others, with open consideration of new ideas. Seeks the perspective of students, peers, and others.**
Illustrative Examples from Data	"But what I really want to talk about is the quiz that the students took on Friday. They have been learning about the Earth's layers for over a week and took a fill in the blank quiz on Friday. There were very few A's (1 100 and 3-5 92's) a couple of B's and C's (I'd say 20ish out of 120) but most of the student's failed. When we asked the student's if they had studied most replied no (and those that said yes are the ones who made the B's or better). I hate to see the student's fail like this but what do you do when they admit to not studying the material like they should have? I mean, we actively worked on the material for over a week plus they had homework each night that was simply to study! Any suggestions as to how to get the student's to study?" (web based forum, September 7)
Transformative	**Long term ongoing inquiry including engagement with model mentors, critical friends, texts, students, careful examination of critical incidents, and student learning. Asks hard questions that challenge personally held assumptions.**
Illustrative Examples from Data	"I was talking with my cooperating teacher about a lab activity and he asked when we should do it. I told him that, according to good inquiry, we should do the lab first and give the students an experience without an explanation so that they can make observations without prejudice and really explore. He turned around and said that students would not have any understanding of what was happening and instead we should teach them first then let them do the lab so they could experience what they have been learning about. I told him that half of our students wouldn't be learning anyway (due to their lack of engagement) so we might as well give them something fun to do that they can experience and perhaps they would learn from that. He did not like the way I put that. I quickly threw out there that we could experiment by doing it one way with one class and the other with the other. ACTION RESEARCH! He was a little more into that, but we did not come to a consensus yet." (web based forum, November 4)

(e) serve longitudinal purposes (pp. 22-26). When exploring how lesson study may have influenced NOS understandings, cross case analysis revealed that the participants in the three lesson study teams represented that of the typical experience. When examining how levels of reflection influenced the transfer of teaching and learning NOS, cross case analysis revealed unique outcomes for each lesson study team.

Table 11

Sample Analysis Strategy for Levels of Reflection (Change Dimension)

Levels	**Change:** How does inquiry change practice and perspective?
Routine	**Analysis of practice without personal response, as if there is a distance between self and the situation**
Illustrative Examples from Data	
Technical	**Personally responds to a situation, but does not use the situation to change perspective.**
Illustrative Examples from Data	
Dialogic	**Synthesizes situated inquiry to develop new insights about teaching or learners or about personal teaching strengths and weaknesses leading to improvement or practice.**
Illustrative Examples from Data	"After having A LOT of students complain that they hate taking notes from the board (and I agree, it's not fun) I decided to try something new. I broke the class down into 6 small groups and had the students take notes in these groups. There was a note-taker (who told the group what to write), a reader, and presenter in each group (those groups that had more than 3 people had an extra reader and an extra note taker).. Once the students started working in these groups something miraculous happened-one particular student who has refused to take notes before or even interact with myself or the mentor teacher was LEADING his group. I saw a side of this student that I didn't know existed. I was blown away by his attitude towards the class changed as soon as he had some freedom in the activity. I made sure to complement him on his outstanding behavior and leadership skills to which he just smiled." (web based forum, September 29)
Transformative	**A transformative reframing of perspective leading to fundamental change of practice.**
Illustrative Examples from Data	"I have a tendency to talk too fast and so I use wait time to slow myself down and I have noticed that it gives the students more time to think about their answers and so the answers they provide are more thoughtful and more often correct than when I just called on the first person who raised their hand. The only thing is that you have to be careful that if no one is responding you throw out a leading question to help them instead of just standing there staring at the class." (web based forum, Oct 24)

As explained in this section, data analysis began by gaining an understanding of the participants' views on the NOS and the levels of reflection that occurred during the lesson study. This was followed by cross case comparison, which provided evidence that the preservice teachers' experiences in conducting the lesson study shared commonalities, while at the same time provided insight to some of the practical difficulties associated with lesson study in alternative teacher certification programs in the United States. This data analysis was informed by the described rubrics and the knowledge of the researcher which was additionally informed by the literature and pilot case experiences. It is therefore critical to expound upon the trustworthiness of this qualitative research.

Trustworthiness of the Qualitative Research

Data collection measures for ensuring a quality research design strategy outlined by Yin (2006) will now be described in further detail. These criteria include construct validity, internal validity, external validity, and reliability. Of these four criteria, only three are applicable in an exploratory case study. Internal validity is not a criteria as it only applies to explanatory or causal case studies.

Construct Validity

Construct validity as defined by Yin (2006) establishes that the data sources are appropriate for the concept being studied. Construct validity can be established by the researcher during data collection and composition of the study. The use of multiple resources, establishing a chain of evidence, and asking participants to review a draft of the case study are all recommended ways for establishing construct validity (Yin, 2006). Each of these criteria was met in this dissertation study. Multiple sources of evidence appropriate for exploring the transition of NOS curriculum and reflection during a lesson study were collected. Included in these sources are participant generated documents, record of observations while in the field, and interviews. Additionally, a chain of evidence was established through electronic formatting of all of these documents. These documents are accessible through the dissertation chair or myself and organized in a way that others could follow if so desired. Finally, the participants involved with the research were interviewed after the data collection phases. During this interview participants were provided their narrative accounts of the lesson study and analysis of NOS understandings. This interview prompted a better understanding of the preservice teachers' experiences and clarified any possible misunderstandings on the participant generated documents. These final interviews also allowed the participants to provide additional insight to their experiences.

External Validity

Yin (2006) states that external validity is established during the research design phase of a study and further asserts the importance of knowing whether a study's findings are generalizable beyond the immediate case study. This can be accomplished by testing the findings in a second and third setting. While in this dissertation project the findings will only be tested once, the established construct validity will allow the opportunity for other researchers to use the identical research plan in order to establish greater external validity. The nature of this line of inquiry could similarly be extended over several years, creating numerous data sets from which to strengthen external validity. The time restraints of this dissertation project however do not allow for such, and therefore, is assuredly something to consider based upon these initial results.

Reliability

Reliability in a case study is necessary so that a later investigator might follow the same process, drawing the same conclusions and findings (Merriam, 1998). The goal in reliability for a case study is to minimize the biases and errors (Yin, 2006, p. 37). Several measures for ensuring reliability in this dissertation were part of the case study protocol. First, the use of a case study protocol and database during data collection of this dissertation project provided reliability measures essential for a quality case study. The case study protocol defended in the prospectus presentation guided the data collection efforts for this dissertation project. Yin (2006) states a case study protocol should include an overview of the case study project, field procedures, case study questions, and a guide for the report (p. 69). These criteria were met during the prospectus presentation and approved by members of the dissertation committee. As a second measure of reliability, the chain of evidence provided in a database would allow for any future researcher to follow the same process outlined in the protocol, drawing consistent conclusions and findings.

As a final measure of reliability in the analysis, interrater reliability was established. Each of the sources of evidence was coded into levels of reflection guided through Ward and McCotter (2004) and Lederman et al. (2002). To establish interrater reliability this data was then separately analyzed by an independent researcher. This separate researcher and I talked about our separate analysis results, coming to an agreement at any time there was a difference in participants' levels of reflection or NOS understandings. After interrater reliability was established, I then independently coded analysis across the multiple sites for themes to include in parts of the presentation of data and discussion section (Bogdan & Biklen, 2007). This final presentation of data analysis and findings were then shared with each of the participants as a means of member checking.

Summary

The proposed dissertation study is a qualitative study using a single case study method to explore preservice teachers' experiences in teaching NOS within the context of lesson study. Based on the significant work of Yin (2006), evidence to the quality of the design of this case study has been established. Thorough consideration has been given to the proposed line of inquiry, as is evident by the multiple data sources and intended analysis of this data that has been included as part of the research strategy.

CHAPTER 4

FINDINGS

Introduction

The dissertation study explored six preservice teachers' use of lesson study while integrating nature of science (NOS) tenets in their fall practicum experiences in middle school classrooms. The organization of the participants within their school placements conjoined with the context of the lesson study cycle produced multiple realities to be explored. This dissertation was guided by the following research questions:

1. How do preservice teachers' understandings of NOS shift as a result of the lesson study experience?
2. How does the reflective practice that occurs in lesson study influence preservice teachers' transition of NOS tenets into classroom practice?

The findings of this dissertation are presented as a case study consistently focused on process, context, and discovery (Merriam, 1998, p.19). As the data unfolded it became evident that each of the lesson study teams had something unique to be shared. At the same time, general themes emerged about the teaching of NOS and shifts in NOS understandings. The findings of this dissertation study are presented so that the experiences of each selected lesson study team provide the context of analysis. Analysis of the participants' shifts in NOS understandings and levels of reflection are intertwined in this context. From these findings cross case analysis then more succinctly explores themes that emerged from the preservice teachers' experiences teaching NOS using a lesson study.

Lesson Study at Lolash Middle School

The lesson study team at Lolash Middle School was comprised of three preservice teachers: Brad, Linda, and John. Over the course of 2-3 weeks, they developed a 2-day research lesson for seventh grade students that were focused on NOS curriculum of questioning claims. Figure 7 illustrates that the specific claims to be questioned were placed in the context of a particular soap manufacturer and its role in assisting in the clean-up of oil spills. Figure 7 also highlights the instructional flow of the research lesson specific to the lesson study of these participants. These participants primarily developed this research lesson in isolation. This research lesson did not include any suggestions from supervising teachers, textbooks, or other outside experts. Although, these participants would seek my suggestions when they wanted confirmation of planning appropriate pedagogy or were at a standstill in development due to lack of pedagogical content knowledge or some other factor.

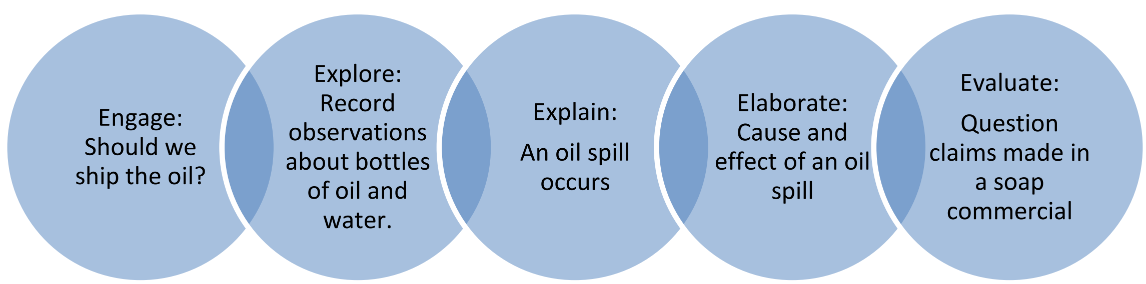

Figure 7. Overview of Research Lesson at Lolash Middle School

Brad, John, and Linda successfully followed the modified framework of lesson study. Linda volunteered to teach the research lesson for its first delivery, while Brad and John volunteered to observe and collect data. Due to the length of this research lesson, some structured reflection occurred between the two days, but the more formal reflection occurred at the end of the second day of delivery. During this reflection, the university supervising teacher, myself, and all three participants engaged in dialogue aimed at improving the student learning of NOS. After this structured reflection, Brad volunteered to teach for the second delivery, with myself and Linda observing and collecting data. Similarly, some reflection occurred between day one and two, but a more thorough reflection occurred after the second day. This reflection again included the university supervising teacher, myself, and the three participants.

In the description that follows, elaboration of each phase of the lesson study is presented. In this presentation of their lived experiences, the details which show instances of planning for explicit NOS teaching are found, but with delivery only present in the reteaching phase of the lesson study. As this lesson study team reflected on these teaching practices, the shifts that occurred in their understanding of teaching and learning NOS and the associated levels of reflection are emphasized.

Planning for the Lesson Study

Ideally the planning phase of lesson study involves conversations about specific areas where students are struggling. The agreed upon focus of the lesson study then leads to collaboration among colleagues, outside experts, and other resources. In planning for the lesson study, the preservice teachers' specific consideration of others perspectives and cycles of situated questions indicated that they functioned within the inquiry dimension;

however the way that these questions were being asked and the types of questions being asked often led to more routine levels of inquiry. As outlined in the course requirements and as part of the instruction provided prior to the practicum placement, designing a research lesson that focused on students understandings of NOS was the intended focus for the lesson study team. As the preservice teachers at Lolash Middle School began to collaborate and plan for conducting their lesson study, the participants' focus ranged from routine to dialogic levels of reflection and included much more than NOS. Ward and McCotter (2004) indicate that focus is technical when it is "on specific teaching tasks such as planning and management, but does not consider connections between teaching and issues," (p. 250). Ward and McCotter (2004) identify routine levels of reflection when the focus is on "control of students, time and workload…avoiding blame for failure" (p. 250). Ward and McCotter identify dialogic levels of focus when the concern "is on students…to interpret how or in what ways students are learning in order to help them" (p. 250). The participants' planning experiences for the lesson study will now be expounded upon with analysis of levels of reflection intertwined.

Early in the fall semester Brad, John, and Linda discussed with me and separately among each other, that there was no opportunity at Lolash to observe inquiry teaching strategies. Collectively they were concerned about the students' lack of experience with this type learning and what this would mean in terms of student behavior and participation in their research lesson. This type focus is leveled as technical, as there was no consideration of the impact of the cooperating teachers' instructional choices in relation to those strategies advocated by the university. Linda explained her associated frustration with "making everyone happy" and finding the right balance between using inquiry like the university wants (web based forum, fall 2009). The perceived lack of inquiry based models and feelings such as these led to immediate concerns about conducting the Lesson study in a meaningful way, yet the participants remained focused on working through the logistics of meeting their course requirements. In a later situation the cooperating teachers at Lolash expressed to the participants their own concerns about the impact of the lesson study on the county's mandated scope and sequence of the school's curriculum framework; however, the focus for the participants continued to be on meeting the course requirements. When John broached the subject of conducting the lesson study with his cooperating teacher he was told that he would "probably be asked by the administration why we would waste a day teaching a lesson which is not going to be covered on the standardized tests." John expressed his discomfort with having to provide a rationale to an administrator, prompting him to begin to make attempts to use a different classroom for conducting the lesson study. This incident illustrates the participants' focus on the situations specific for them to Lolash, and the technical levels of reflection with which they were operating.

As these logistics of coordinating for the lesson study continued to be worked through, the participants also began to collaborate on the development of the research lesson. The shift toward dimensions of inquiry became evident through the evolving research lesson. Within this dimension, the lesson study team begins at dialogic levels of reflection. For example, after consulting with the cooperating teachers, the team decided to develop a research lesson that would serve as a summation for the most recently covered ecology unit. Over the next few weeks the participants were asking questions of each other, their cooperating teachers, and me. Reflection during this inquisitive stance was characterized by focus on specific teaching tasks such as planning and management of time and students. This is consistent with routine levels of reflection within this dialogic inquiry. Additional examples of routine levels of reflection while in this inquiry are evident in the student activities and tasks that were shared. These ideas were focused on fine tuning the specific explorations and engaging activities relating to the ecology content, exemplary of technical focus within this inquiry. Through this collaboration, the research lesson evolved from the single idea of using the context of an oil spill to the inclusion of an oil and water exploration, viewing a soap commercial, and opening discussion to question claims made by the soap manufacturer. John explained that during the explanation phase of the research lesson one idea had been for students to explore the effects of oil on rocks was changed because “over the weekend they had ‘tested’ the experience in order to anticipate student responses, etc. and realized that it did not have the expected effects.” (field notes, e-mail) This was changed to coordinate two groups working such that one group was observing the liquids within bottles and the one group was at back sinks mixing the two which was all part of the phase previously explained. These learning tasks, while pertinent, were not the intended focus of the lesson study, which was teaching and learning NOS in explicit ways. Ignoring the need to make instructional decisions that can be assessed for their effectiveness in assisting students in having more informed NOS understandings also indicates that these participants were reflecting at routine levels within this inquiry.

Nevertheless, in one of the later collaborative sessions between John and me, the level of reflection did shift toward a more dialogic focus. Dialogic focus is identified when the concern “is on students…to interpret how or in what ways students are learning in order to help them" with specific consideration of others perspectives and cycles of situated questions (Ward & McCotter, 2004). In this instance I was pushing John to think about how learning was to be assessed. We were discussing options for the end product that would be evidence of students learning the intended NOS concept of questioning claims. As John was explaining what he, Linda, and Brad had in mind, I outlined a graphic organizer that would lead students toward the successful development of evidence based claims. I explained that from my perspective this was more appropriate NOS curriculum for these students and consistent with the learning goals outlined thus far. John expressed his uncertainty with providing a guide while I argued the need for such a guide especially when considering the students' age and lack of inquiry experience. John explained that he felt the guide would influence students too much and prevent independent thinking. When the other lesson study team members were consulted, they agreed with John, leaving the last draft of the research lesson as an open format for students to question claims made by the soap manufacturer. While my experience and perspective were not taken into consideration, this does not take away from the dialogic levels of reflection that were occurring during this inquiry into student learning of NOS.

In final preparations for delivery the participants again worked collaboratively to determine how data collection should occur during the deliveries of the research lesson. The inclusion of a participant-generated data collection tool within the lesson study framework instantaneously structures the participants' inquiry. This data collection tool holds the potential for the participants to transition toward dimensions of change. This transition is dependent on the types of questions asked during this inquiry, and how the data collected influences change in practice or perspective. Figure 8 illustrates the focus structured by the participants actually limits the potential of this inquiry at technical levels. This is evidenced in questions like, “How many kids voted to initially NOT send the oil?” and “How many kids voted to clean the oil spill with the soap?” Since these questions focus “on specific teaching tasks” and do “not consider connections between teaching issues,” nor do they evaluate “specific qualities of student learning for formative purposes” they are categorized within technical levels of reflection (Ward & McCotter, 2004, p. 250).

Initial Delivery of the Research Lesson (Day One)

On this first day, John and Brad were responsible for data collection. Both admitted that once the delivery of the research lesson began, they “completely forgot about data collection” because they got “so wrapped up” in watching what was going on. (field notes) While the inclusion of a data collection guide in the lesson study framework

How many kids voted to initially NOT send the oil? (day 1)	
How many kids voted not to AFTER playing with the oil and water separately? (day 1)	
How many kids voted not to after playing with the oil and water mixtures and olive oil and rocks? (day 1)	
Make a tally mark whenever somebody questions a claim that we are making in discussion. This might be a good thing to look for during our “Community Misconception” discussion. (day 2). If you wish, you can write down some of the questions that kids ask below.	6 (1 student in back row contributed 3 of these tallies.)
How many kids voted to clean the oil spill with soap? (day 2)	1

Figure 8. Lolash Middle School Participant Generated Data Collection Tool

is intended to prompt analysis of student learning, the nature of this case study does not allow for control over the actual experiences of the participants. Therefore, while the use of the participant-generated data collection tool could have moved the participants toward an inquiry into their perspective of teaching and learning, the level of reflection for this first delivery most consistently focused on practice at technical and dialogic levels.

I visited Lolash for direct observations of their experiences on the second day of delivery. Since I was not present for this first day of delivery, John volunteered to share with me all that had transpired on this first day while Linda was preparing for her second day of delivery. It is important to note that the following events and reactions are entirely from John's perspective, but that they were member checked by his other lesson study team members in a final interview. In addition while John was sharing his experiences, some reflection of the first day did occur. This was a unique set of experiences for this lesson study team. During the delivery of the research lessons it was expected for the lesson study framework to engage participants within the inquiry dimension by using their data collection tool to focus observations for later analysis. In this team's experience, incidents of reflection occurred between the two days of delivery.

As John began to share with me about the first day of delivery, he talked about what Linda was doing and how the students responded. John was visibly excited to share about how all the students were highly engaged in the first day's tasks. John was still in awe at the way "all the kids were involved, kids wanted to mix the two, there were some safety things that became really obvious and we talked about this already when we reflected at the end of the day, but it was just amazing!" (field notes) Seeing the effects of planning these tasks for the students was exciting for the lesson study team at Lolash.

Yet the team did not question why the specific situation provided an opportunity for these high levels of engagement nor if the opportunity allowed students to meet the learning goals. The omission of any analyses in this reflection therefore categorizes these instances of reflection as focused on the practice of teaching within a technical level. As described earlier, Ward and McCotter (2004) identify a technical level of reflection within a participant's focus when reflection centers on teaching tasks, uses observations to measure success, and does not evaluate student learning formatively.

As John recalled how wide eyed students were during the oil and water exploration and how eager they were to make a decision, John also began to talk about how students were looking to their peers quite a bit, often making a decision along the same lines as their peers. As John was thinking aloud about this, he commented that "perhaps this should be structured a little differently so that students were more likely to answer what they really thought." (field notes) In this instance, John is still using his observations to interpret the success of the research lesson without evaluating the specific qualities of what the students are learning. This is representative of technical levels of reflection.

John then began talking about the explanation phase of the research lesson. Focus shifted toward a dialogic level of reflection as John addressed how the implicit approach to teaching NOS transpired. John recollected that when students were presented with photographs of oil spills, the intentions were for students to make predictions about the effects of an oil spill on an ecosystem. For John, Linda, and Brad the students' mixed reactions to the photographs indicated that this instructional decision was a success, but John and Linda also noticed that "students were not writing that great of predictions."

(field notes) Most students were more concerned with whether the birds died, others were "clearly hurt by the images, but all were interested." (field notes) This lack of student focus on the task indicated to John and Linda that there needed to be a modification in the delivery of student expectations. This also indicated that the lesson study team was using "interactions with students to interpret how or in what ways students are learning in order to help them," which is indicative of a dialogic level of reflection within the focus of student on task behaviors at a technical level of inquiry and routine change (Ward & McCotter, 2004, p. 205).

In an effort to guide the lesson study team toward an inquiry into the intended focus of the lesson study (teaching NOS explicitly), I asked if the students' experiences thus far supported implicit or explicit NOS teaching. The lesson study team all agreed that NOS was an implicit part of student learning at this point. I then asked if a change in the research lesson might initiate explicit teaching of NOS. Linda stated that "asking specific questions about what the students were doing and connecting it to the actual work done by scientists would have been an easy way to do this." John and Brad agreed, but recalled that guiding questions had actually been included in the research lesson. When I asked Linda if she referred to the research lesson during delivery she replied, "No…and I remember after the first lesson (um) when I was teaching, John was like, you never really explicitly said what you said you were going to say. And I was like oh yeah, you know like that's true and then I was like okay I need to make a mental note…" (field notes) Linda's response that she would make a "mental note" for the upcoming delivery also indicates that the relevance of this NOS focus in the lesson study had also been dismissed. This is further evidence of these participants situated within the change dimension at a routine level. The participants did not ask "questions after initial problems were addressed" or "use the situation to change perspective" (Ward & McCotter, 2004, p. 250). These responses indicate that after this first day of delivery the lesson study team maintained a technical focus within this inquisitive stance toward analyzing NOS teaching practices. This is evidenced both in the questions not being asked and the lack of analysis of their teaching practice. Furthermore, this also indicates that in spite of the planning for teaching NOS explicitly in the first day of delivery, the actual teaching of NOS occurred implicitly.

Initial Delivery of the Research Lesson (Day Two)

It is important to note that participants' university supervisor and I were present to assist in data collection on this day. It was planned for the second day of the research lesson to begin with the elaboration phase where students were to be engaged in whole group conversation about cleaning an oil spill. As the delivery of the elaboration phase got under way, students were prompted to think about how they would clean the oil spill, viewed the soap commercial, and then again faced with the question of how to clean an oil spill. As in the first day of delivery, the research lesson for the second day included guiding questions that would have made NOS an explicit part of the students' learning. However, this again was not part of the delivery. Instead delivery ensued with a town hall meeting, where students were given roles of community members and instructed to prepare for the town hall meeting with their own suggestion as to how the town should clean up the oil spill as well as prepare for arguments that other community members might present.

As shown earlier in Figure 13, data collection for the second day included tallies for each time a student questioned a claim and a total number of students that opted to use soap to clean the oil spill. The university supervisor and I used this participant generated data collection tool; however, John and Brad, who also served as data collectors during this second delivery, both struggled to collect data. Neither recorded the information requested by their own participant-generated data collection tool.

While this recollection of events does allow an opportunity to gain insight into the experiences of the participants on this second day of delivery, more pertinent to the inquiry of this dissertation project is how reflection about this research lesson influences the teaching and learning of NOS. It can be stated from the events that have unfolded thus far, that the earlier inquiry into teaching NOS explicitly on the first day of delivery did not lead to a change in practice for this second day of delivery. This further supports the findings that the earlier analysis of practice was "without personal response" therefore identifying the participant as disengaged from change (Ward & McCotter, 2004). In addition, the data collection tool created by the participants continued to be ignored by the participants themselves. How this may have influenced the dimensions of inquiry will now be explored.

Reflection of the Initial Research Lesson

The lesson study team reflected upon this first delivery of the entire research lesson in Linda's university supervisor's office, and then conference called me since I was en route to campus. As the group reflection began, Linda shared her thoughts with all of us first. Linda felt the first day's lesson was successful. She stated, "We stuck with the plan, and the plan worked." As Linda continued to reflect aloud about the second day of delivery, she began talking about the differences in students' level of enthusiasm between the two days. Linda felt students were less responsive on the second day and nowhere near as engaged. Linda felt this had a major impact on the student learning outcomes of the lesson, though admittedly did not have data to support this feeling. In this instance of looking back on the last two days, Linda's focus was at a technical level of reflection. This is evidenced through her focus on the students, using their enthusiasm as a way to gauge the success of the research lesson. Furthermore, she attributes the "sticking to the plan" as an effective teaching strategy. Linda does not acknowledge any possible problems, and fails to ask critical questions or analyze the research lesson for the intended NOS learning goals.

Linda's university supervising professor, Lamor, then began to share his findings with the team. Lamor told the group that he did not see where NOS was being addressed, that "questioning claims was not NOS at the depth that could and should be expected". Lamor felt there needed to be a more concrete way for students to make and critique evidence based claims. The lesson study team considered this for a moment, and then John confirmed that this would be more ideal. Linda was somewhat taken aback by Lamor's statement though. She responded somewhat differently, "If what they had planned was not NOS, then I guess I do not know what NOS actually is." Lamor clarified his understanding of NOS by stating that "NOS is more than making the claim, but also being critical, knowing the difference between a scientific claim and an opinion." Lamor suggested providing students with opposing claims, letting them research evidence that supports these claims, then through group discussion address the validity of the resource. I supported this suggestion by also proposing that the research lesson include a more concrete guide for the evaluation that would allow an opportunity for students to be more successful and explicitly promote NOS.

In this critical instance the opportunity for the participants to ask questions about needed changes in practice or perspective about NOS was brought to the forefront of conversation, shifting this inquiry into potentially dialogic levels of reflection; however, Linda shifted to routine levels of reflection once this dialogue challenged her understandings. Later in class Linda even expressed her frustration with the line of questioning and explained that she somewhat resented the university supervisor's involvement and perspective. Avoiding this inquiry and taking a definitive stance on the inquiry further exemplifies a routine level of reflection for Linda. At the time there seemed to be no evidence of a shift in her understanding of NOS.

On the contrary, John expressed that he liked the ideas, indicating a receptiveness to reflect at a dialogic level within this inquiry. John asked specific questions about how this might look with Lamor providing additional suggestions. As Lamor made suggestions, John expressed concern about time constraints. John felt that it was very unlikely these kinds of changes could be put in place over the next 24 hours. This shifted John's focus in routine levels of reflection. As conversation continued though it was realized that most of the changes being suggested would be in the second day of the research lesson, making the suggested changes more feasible. This shift in focus back to specific instructional tasks and the time needed to make modifications indicates a change in focus that is consistent with dialogic levels of reflection within the dimension of change. John's continued questions of Lamor about how he envisioned the teaching of NOS, while shifting between routine and technical focus, still indicates that he is open to this perspective in order to strengthen his own teaching practices. Change characteristic of dialogic reflection implies that the participant "synthesizes situated inquiry to develop new insights about teaching or learners…" (Ward & McCotter, 2004, p. 250).

The framework of lesson study supports an inquiry into one's teaching practices by providing a space for reflection that leads to modifications to the research lesson. How this initial reflection that prompted this inquiry influenced the actual practice or perspective of the participants can be evidenced in the modified research lesson and the subsequent delivery.

Developing the Modified Research Lesson

The development of the modified research lesson provides an opportunity to explore how the reflection that occurs after the first delivery influences the intended practice or perspective of the participants. After class, John, Linda, and I discussed some specific ways that NOS could be taught explicitly and at the depth recommended by Lamor and me. I encouraged them to read the notes and comments made on the data collection tool as well as strongly consider a type of graphic organizer for a modification to the evaluation phase. This open consideration of ideas is indicative of a dialogic level of reflection by the Lolash lesson study team. Nevertheless, once the participants left campus collaboration did not ensue. This provides evidence that within this space structured for change to occur, the inquiry stopped and focus became routine. The participants disengaged from the earlier inquiry into "analysis of practice without personal response," which is identified as routine levels of reflection within the change dimension (Ward & McCotter, 2004). In the final interview when asked about this lack of collaboration, Linda said they "were trying to revise it to make it better and I was not understanding how the revisions could come together to make it better, and I didn't necessarily take it personally but I just struggled with it." (January 2010) It is important to note, as it pertains to how the teaching and learning of NOS is influenced by the lesson study framework, the choice to disregard the suggestions made by the university supervising professor and me. In the final interview, the lesson study team was also asked to elaborate on their rationales for making these particular modifications, rather than considering more in depth NOS learning goals. Linda and John stated that time restrictions and feelings of being "burned out" were their two main reasons for not making the needed changes. Brad agreed with them but also added, "I like had the flu the whole time. So…I wasn't exactly up for anything." (Interview, January 2010) This failure to acknowledge the need for change in the research lesson and blaming limited time to their compromised instructional decisions again indicates that the participants were overall functioning at a routine level of reflection within this inquiry.

In the end most of the responsibility associated with making changes had been placed on John. This shift in the process away from asking questions about needed changes in the research lesson indicates that the other participants stopped reflecting altogether, with the exception of John who out of necessity had to continue thinking about ways to improve the research lesson. Admittedly, John was trying to make sure he met the course expectations, but became increasingly frustrated by "the idea that the expectations weren't made clear." (Interview, January 2010) This indicates John is asking questions in a way consistent with both technical inquiry and focus. For example, additional findings in the modified research lesson that were submitted in the lesson study portfolio showed no changes to the first day of delivery, excluding the addition of bold highlighting in the area where the guiding NOS questions were listed. Highlighted areas in Figure 9 illustrate the changes that were made for day two of the research lesson. Modifications to this phase are most significant in the structuring of students in their group placements and the type of guidance provided in meeting the expectations for evaluating students on their collaborative ability to make and critique evidence based claims. This focus on specific teaching tasks such as classroom management and the development of a learning guide again indicates a technical level of focus within this inquiry.

Phase Five: Evaluate students' Understanding of the Concept

Activity: State "As scientists we must think ahead and ask as many questions as we can! The oil company told us that a spill might happen, but if it did, it would be easy to clean and not spread very far or very quickly. What did we find out through observations?"

- Ask students to share the observations we made and wrote on the board

Oil company did know there was a possibility of an oil spill. They did not say it would be quick and easy, but they did not prepare for it to be as bad as it was.

"As a result, we all must work together as a community to clean up the oil spill."

Split class into three groups: Local Community, Local Government, Oil Company
"Who would be in these groups?" – at least 3 from each: ask to class
Give them handout: While role playing each group write Response 1 (they come up with) for each question. Then read hand out and write Response 2.

Last 5-10 minutes of class – students share responses they have written.

Assessment: student writing in groups assess the class as a whole for learning what types of statements are evidence based versus otherwise. They have learned to question claims and make their own claims. I am not sure how to assess them as individuals.

Figure 9. Modifications in the Research Lesson.

Reteaching the Modified Research Lesson

As described in the initial teaching of the research lesson, the two day nature of this team's research lesson results in some incidents of reflection after the first day. Similar to the initial teaching of the research lesson, John initiated communication with me to discuss the first day of teaching. The incidents of reflection described below are from John's perspective and also contribute to our understanding of how the delivery transpired on the first day of reteaching the research lesson.

John had volunteered to re-teach the modified research lesson to a new group of students. As the research lesson for day one did not include any modifications, John taught the lesson in its original structure. Later that day John e-mailed the university supervising professor and me to let us know how things had transpired for the students in the first round of reteaching. John's email included some technical level of reflection focused on classroom management. For example, John wrote, "Third period was very hard to control and actually ended up with some homework for over the weekend. Our lesson will have to be adjusted for them. 4th went fairly well, but due to time constraints I cut out the hands in oil and water part of the experience…" This unquestioned decision making in regards to abandoning the exploration further illustrates that John was maintaining technical levels of reflection in this dimension of inquiry into the research lesson.

John also expressed his surprise at the students' initial decision not to ship oil when prompted by questions during the engage portion of the research lesson. John wrote, "I was really impressed they came up with this. It did leave me on some shaky ground, as far as recovering back to the lesson, but it worked out." This again illustrates

John is functioning within a technical level of inquiry. It also illustrates that John initially focused on how the students were learning, but then reconnected this focus back to the specific teaching tasks. This, too, is a technical level of reflection within the focus of the inquiry.

On the second day of delivery I again visited Lolash to assist the lesson study team in data collection. Before delivery John and Linda were quickly trying to provide students with feedback on their vocabulary handout from the day before. Based on the modified research lesson, students were to share their ideas by posting on the board any highlighted responses found on their papers. It was intended for these responses to initiate conversation among the class. This modification in practice indicated a dialogic level of reflection focused on student learning, where a formative assessment was being used “to interpret how or in what ways students are learning” (Ward & McCotter, 2004, p. 250).

Delivery began as intended. At the point at which implicit NOS ideas had been scripted in the research lesson, John did ask similar questions as the students were discussing their statements. In a follow up interview the lesson study team discussed why they wanted these questions to be an implicit approach to NOS. Linda said, “we just wanted them to start thinking about the effects science can have on real life stuff…” The lesson study team hoped to be setting the stage for making NOS explicit later in the research lesson. The lesson study team did not question this instructional decision nor make any indication that their earlier reflections had changed their perspective. This is again evidence of routine levels of reflection within this inquiry. Additionally, from the highlighted changes in the research lesson that were specific to this second day, John implemented the change in grouping strategies, but did not model for students how to develop an evidence based claim using the lesson study's handout. This further exemplified the routine change being experienced by these participants during this inquiry. Further confirmation of this routine change was evidenced when the explicit teaching of NOS was not a part of delivery. Students' conceptions of NOS were also not assessed as had been part of the plans in the research lesson.

Unlike the first delivery, data collection by the participants during this second delivery was completed. As evidenced in Figure 10, observations were recorded about specific student actions during different phases of the research lesson. Comments not shown within Figure 10 included such things as "generally on task," "really on task," and "off task while writing." This focus on classroom management is consistent with a technical level of reflection and would presumably be important in guiding the inquiry associated with the final reflection.

How many kids voted to initially NOT send the oil? (day 1)	6 NO 19 YES
How many kids voted not to AFTER playing with the oil and water separately? (day 1)	2 changed
How many kids voted not to after playing with the oil and water mixtures and olive oil and rocks? (day 1)	2 more changed
Make a tally mark whenever somebody questions a claim that we are making in discussion. If you wish, you can write down some of the questions that kids ask below.	1 (just a bit during Target Time discussion) 1 awesome: What happens if the ship is hurt? 1 Can we mix it? |
How many kids voted to clean the oil spill with soap? (day 2)	definitely mostly NO

Figure 10. Data Collection during Delivery of the Modified Research Lesson.

Reflection on Modified Research Lesson

The Lolash lesson study team was exhausted after the final delivery of their research lesson. At the time, no one had much energy or motivation to be thorough in a reflection. Everyone agreed to talk later. At that time they would then determine what needed to happen in order to meet the portfolio requirements. I provided the team with my data collection sheets before leaving, encouraging them to e-mail me if they were comfortable with my inclusion in their final reflections. As shown in Figure 4.4, Linda’s data collection sheets were used to help her in providing input for the final version of the research lesson. When asked about the final reflections and how they had occurred, the lesson study team shared that they had done this electronically with each of the three bouncing the research lesson around modifying it in ways they felt would improve student learning. In an effort to analyze data from this inquiry to determine if the questions about teaching and learning NOS had been asked, the submitted portfolio was first analyzed. The changes that were agreed upon indicated specific guidance with developing evidence based claims. This associated level of reflection is that of a dialogic focus. Furthermore, while the inquiry of the participants was directed at making NOS an explicit part of instruction, there was no indication of data analyses about these teaching issues. There was also no evidence to indicate that this inquiry asked questions relating to the issue of student conceptions of NOS, nor addressed potential problems in the research lesson’s instructional decisions as it pertained to NOS. Therefore, this compilation of data from the submitted lesson study portfolio indicates that the lesson study team was functioning at a routine dimension of inquiry and shifting between dialogic and technical focus of student learning.

Summary

During the lesson study experience instances of reflection were interspersed. Tables 12-17 summarize analysis of the participants’ experiences and the associated level of reflection. These tables are presented in sequential order consistent with the framework of the modified lesson study. Supporting data for this analysis is additionally provided. This is to assist in establishing construct validity and reliability in the qualitative research that has been presented. While multiple data sources were used to create this complete picture of the Lolash Middle School team’s experience, much of the supporting data is evidenced in the lesson study portfolio and first hand observations while in the field with these participants.

Table 12

Summary of Analysis while Planning for the Research Lesson

Dimension of Reflection	Levels of Reflection	Supporting Data
Focus	Routine	Field notes (e-mail communication)
	Technical	“making everyone happy” (web based forum) Drafts of research lesson (Lesson Study portfolio) “Over the weekend they had ‘tested’ the experience in order to anticipate student responses, etc. and realized that it did not have the expected effects.” (field notes, e-mail communication)
	Dialogic	Drafts of research lesson (Lesson Study portfolio) Field notes
Inquiry	Dialogic	Drafts of research lesson (Lesson Study portfolio) Field Notes

Table 13

Summary of Analysis during First Delivery of Research Lesson (Linda)

Dimension of Reflection	Levels of Reflection	Supporting Data
Focus	Technical	Participant Generated Data Collection Tool (Lesson Study portfolio)
	Dialogic	"Students were not writing that great of predictions." (Field Notes) Field Notes
Inquiry	Technical	"All the kids were involved…and we talked about this already when we reflected at the end of the day, but it was just amazing!" (Field Notes) "…perhaps this should be structured a little differently so that students were more likely to answer what they really thought." (Field Notes) Field Notes
Change	Routine	Modified Research Lesson (Lesson Study portfolio) "I remember after the first lesson (um) when I was teaching, John was like, you never really explicitly said what you said you were going to say. And I was like oh yeah, you know like that's true and then I was like okay I need to make a mental note…" (Field Notes) Field Notes

As previewed earlier, it is important to note from Table 13 that Linda volunteered to teach, with most of the observations and reflection that occurred coming from John's perspective. Additionally because this was a two day research lesson, some reflection occurred between the two days of delivery and prior to the structured reflection that followed the second day of delivery. Summary of analysis during this structured reflection is shown in Table 14.

Table 14

Summary of Analysis in Structured Reflection of the Research Lesson

Dimension of Reflection	Levels of Reflection	Supporting Data
Focus	Routine	Field Notes
	Technical	"We stuck with the plan..." (Field notes, Linda)
Inquiry	Routine	"If what we had planned was not NOS…I guess I do not know what NOS actually is." (Field Notes, Linda)
	Dialogic	Field Notes

Table 15

Summary of Analysis while Developing the Modified Research Lesson

Dimension of Reflection	Levels of Reflection	Supporting Data
Focus	Technical	Lesson Study portfolio
Inquiry	Routine	Lesson Study portfolio Field Notes
	Technical	Lesson Study portfolio "Just …when you think that you're doing what someone wants and it's not, then you feel lame…" (Final Interview, January 2010)
Change	Routine	"… I was not understanding how the revisions could come together to make it better…" (Final Interview, January 2010)

Collectively the tables show that the participants at Lolash Middle School were reflective throughout the lesson study. Reflection was consistently focused on classroom management issues such as on task behavior and levels of enthusiasm associated with specific tasks. When reflection entered the inquiry dimension, the participants consistently shifted between routine and technical levels of reflection. This was evident

Table 16

Summary of Analysis while Reteaching the Research Lesson (John)

Dimension of Reflection	Levels of Reflection	Supporting Data
Focus	Technical	"I was really impressed they came up with this. It did leave me on some shaky ground, as far as recovering back to the lesson, but it worked out." (field noties, e-mail communication, John only) Lesson Study portfolio
Inquiry	Routine	"We just wanted them to start thinking about the effects science can have on real life stuff…" (Final Interview, January 2010) Lesson Study portfolio
Change	Routine	Lesson Study portfolio Field Notes

Table 17

Summary of Analysis during Reflection on Modified Research Lesson

Dimension of Reflection	Levels of Reflection	Supporting Data
Focus	Dialogic	Lesson Study portfolio Final Interview, January 2010
Inquiry	Routine	Lesson Study portfolio Final Interview, January 2010

in the way the participants rationalized issues and reacted to exciting or frustrating results by placing outside blame or without pursuing analysis. Collaboration in the development of the initial and modified research lesson did result in dialogic levels of inquiry; however, perspectives were disregarded upon entering dimensions of change in actual practice. From the experiences of the participants at Lolash Middle School, we also learn that the routine levels of change most likely influenced the lack of in-depth transfer of explicit NOS teaching into their classroom practice.

How the lesson study influenced the transfer of NOS into classroom practice was first evident in the second delivery of the research lesson. On the second day, John successfully made NOS curriculum an explicit part of class conversation. All prior instances of NOS had been implicit. In data collection of the second delivery, shown in Figure 15, Linda also recorded that this transfer had occurred. She exclaimed, “good – hit home on NOS!” Linda’s comments also indicate that she was beginning to think about the role evidence based claims might have on more rigorous NOS instruction. The final research lesson submitted in the portfolio also included a guide for leading students toward developing evidence based claims, rather than the original open discussion format.

Data collected indicates that the participants’ individual understandings of NOS were not changed as a result of this lesson study experience. Final VNOS-b responses for each of the participants were requested at the end of the fall semester. None of the participants elected to elaborate upon or modify their responses from the end of the summer. When the participants were provided an overview of their individual analysis, each of them agreed with the presentation of their understandings. Brad did request an explanation for the naive rating on his views about the empirical NOS. During the interview, Brad discussed that he was aware of all these influences in scientists’ work but that, “when I wrote that answer it was more in terms of…that scientists aspire to be objective.” This clarification indicates that Brad may be leaning toward informed views on the empirical NOS, but without elaboration or specific examples would still be considered to have naive views.

During the fall semester, Linda also indicated on the web based forum that she was beginning to recognize some of the issues associated with teaching NOS. She wrote about the misleading structure of textbooks, stating the following:

> really and truly gives a false sense of how these things were really discovered and what science really is. It truly takes the creative aspect of science out, and as you know, that is an essential part of nature of science…I think it would be great to take some liberty and go deeper and honestly that would tie in nicely with nature of science if nothing else. Maybe once standardized tests include nature of science, things will change! (web based forum, fall 2009)

Linda’s recognition that textbooks serve as an obstacle to the actual practice of NOS informs us to how she perceives the teaching and learning of NOS. This further supports analysis of her informed NOS views.

Lesson Study at Deer Crossing Middle School

While Japan’s lesson study framework typically includes many colleagues of various contributing capacities, this particular lesson study included only one preservice teacher, Holly. As described in the participant description in chapter three, Holly was the only participant completing her fall practicum at Deer Crossing Middle School. An exploration of her experiences found that she had a lot to share with us about how transformative levels of reflection within focus and inquiry can lead to a change in teaching practice and perspective within the structure of lesson study.

Holly took several weeks to coordinate and plan for a one day research lesson for sixth grade students that integrated NOS ideas about general ways that scientists work. The instructional sequence of the research lesson shows that students would engage in conversations about the work of science and how scientists work, then explain this work by "doing science work" in a mining, and a concluding discussion (see Figure 11). In developing this research lesson Holly sought assistance from other teachers, such as her cooperating teacher, special education teachers, and other peers within the school. Holly's isolated placement at Deer Crossing resulted in her deciding to teach both the initial and second delivery of the research lesson. During the first delivery, the cooperating teacher and I served as observers and data collectors. The cooperating teachers' teaching responsibilities resulted in her being unable to participate in the structured reflections between deliveries, so only Holly and I were engaged in dialogue at these times. This dialogue did result in modifications and a reteaching of the research lesson. Additionally, during the second delivery only I served as an observer and data collector, and similarly the subsequent structured reflection included only Holly and me.

Following Figure 11, elaboration of each lesson study phase is presented. In this presentation of Holly's experiences, instances of planning for and teaching NOS in explicit ways are found in both deliveries of the research lesson. While Holly found herself being pushed to plan for ways to help struggling students and develop an effective way to assess students' NOS understandings, she began to reflect at dialogic and transformative levels within the focus and inquiry dimensions that correlate her change in practice at dialogic levels. Emphasis on the shifts that occurred in her understanding of teaching and learning NOS and the associated levels of reflection will now be explored.

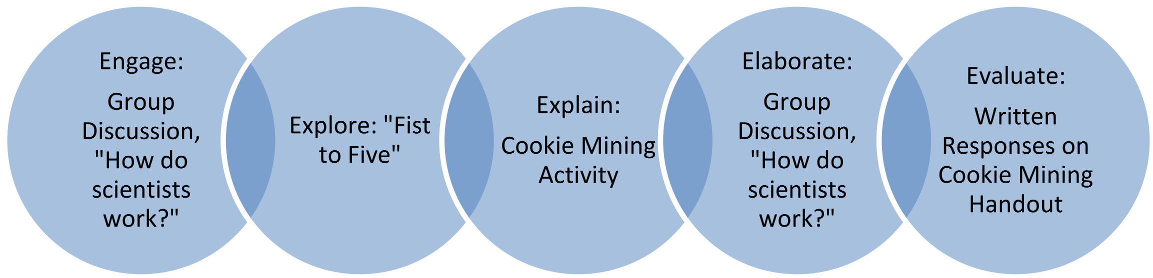

Figure 11. Overview of Research Lesson at Deer Crossing Middle School.

Planning for the Lesson Study

After being introduced to the lesson study cycle and the assignment requirements, Holly talked with her cooperating teacher about conducting the lesson study. The cooperating teacher was very supportive of conducting the lesson study, offering several suggestions of exploration labs that Holly could use as a starting point for the research lesson. After collaborating with a special education and another science teacher, Holly e-mailed me an activity that was called “Mining for M-M-M Good Minerals Lab.” Holly explained in the e-mail that she had already worked with her cooperating teacher to change the original version of this activity to be what she considered more inquiry based. In the e-mail, Holly stated, “…feel free to edit it and make comments!!! (I look forward to any and all criticism and help.)” At the onset of this lesson study Holly is asking questions with peers and others about teaching science. This therefore situates these instances within a dialogic level of reflection within the inquiry dimension (Ward & McCotter, 2004). This outreach to others and openness to consider additional ideas allowed Holly an opportunity to experience collaboration and gain the perspective of others in spite of being isolated in her practicum placement.

Over the next two weeks Holly continued to collaborate with other teachers at Deer Crossing Middle School and me to develop the research lesson. While Holly's cooperating teacher was supportive of conducting a lesson study, when asked for insight to ways the research lesson could be better developed she was less supportive. In the final interview, Holly stated that the cooperating teacher thought the activity "had worked well the way it was designed and that she did not see the importance nor relevance of integrating NOS in the activity." To circumvent this additional obstacle and difference in perspectives, Holly continued to seek other resources, including going to other teachers in the school to seek advice and suggestions in the development of the research lesson. These additional interactions indicate that Holly continued to ask questions about teaching science, not stopping after her initial conversations with others. Holly also did not critique the cooperating teacher's decision, but instead sought ways to gain others' perspectives. These actions further illustrate that Holly is reflecting at dialogic levels within the inquiry dimension.

In the final interview Holly said she thought the "other pairs of eyes" would benefit more students. When asked about specific ways the other teachers had contributed to the way NOS was planned in the research lesson, Holly said "another student teacher in the building had suggested reducing the length of the questions being asked, and um a team teacher that also served special needs students suggested that the initial engage portion of the lesson needed to be very explicit in guiding students." (Interview, January 2010) Holly knew that other teachers had successfully used this activity with students, so she felt "their input was much needed in order to successfully determine how and in what ways NOS concepts were a natural fit." (Interview, January 2010)

When the final version of the research lesson was e-mailed to me it resembled much more of an inquiry based approach to teaching, with additional evidence of teaching NOS in an explicit way. This focus on NOS and using inquiry were Holly's largest concerns. In an earlier conversation after class Holly had explained that she was trying to develop this lesson similarly to the way an earlier "Cookbook Lab No More" assignment had been structured. In this assignment from the summer pedagogy course all of the participants had been required to find a structured lab provided from traditional textbooks, and then modify the lab to fit pedagogy more supportive of open inquiry. This focus on "fundamental pedagogical ….historical concerns and how these impact students" indicates that Holly is also focused in transformative ways. (Ward & McCotter, 2004, p. 250). After class that week Holly and I were talking about these instructional decisions. Holly was comfortable with the research lesson and thought that the integrated NOS learning goals were an "easy fit." In the final interview Holly also said that she and I talked, she still sought final input from the same teachers she had talked with earlier in the planning. Each of them were "positive about the changes" in instructional decisions, assuring Holly that they were appropriate and would do a "good job of getting at the intended learning goals" (Interview, January 2010). This indicates that Holly is shifting toward a transformative inquiry as well.

Further evidence of Holly reflecting at transformative levels within the dimension of focus can also be found in the participant-generated data collection tool shown as

Figure 12. Once the instructional sequence of the research lesson had been worked out, Holly began to think about how to collect data on students' learning of the intended NOS learning goals. Holly had e-mailed me for input on developing this tool. When we talked after class, our conversation centered around ways to focus on students' conceptions about how scientists work collaboratively, competitively, and in various places other than labs. Holly thought about this a few days and later e-mailed me the data collection tool seen in Figure 12.

From Holly's data collection tool and the original research lesson plan found in the Lesson Study portfolio it is evident that Holly is focusing the lesson study on students' conceptions of NOS. This focus in the data collection tool also indicates Holly is planning for an additional layering of dialogic reflection "on students…Uses assessments and interactions with students to interpret how or in what ways students are learning in order to help them" (Ward & McCotter, 2004, p. 250).

Data Collection worksheet:
Pre-Lab assessment
Who is actively participating (or attempting by raising hand)?

Number of boys:
Number of girls:

Count the number of students with correct and incorrect assumptions about the following ideas.

1. Scientists collaborate with others

Correct: Incorrect:

2. Scientists are competitive

Correct: Incorrect:

3. Other (fill in other answers provided by students)
____
____

Correct: Incorrect:

Figure 12. Data Collection Tool for Deer Crossing Middle School.

Initial Delivery of the Research Lesson

It is important to note that Holly's solitary experience at Deer Crossing Middle School leads to no opportunity to determine how a lesson study team might have reflected during this first delivery. Therefore, exploring the delivery of the research lesson serves separate dual purposes. First, we want to explore Holly's experiences teaching NOS so that any specific instances that might be reflected upon later have been contextualized prior to discussion. Second, we want to gain insight to how the teaching and learning of NOS transfers into her classroom practice. As one of the data collectors in the delivery, a record of these events was documented in field notes, then member checked by Holly during a final interview.

During delivery I was sitting on the left side of the classroom ready to collect data for the research lesson. Holly's cooperating teacher had agreed to collect data on the right side of the room. Students were entering, some were getting settled for the class, and others were talking with their peers. Holly engaged students with the opening question, "What do scientists do?" Hands quickly rose. Students provided such responses as "study earth's surface," "labs," "create new things," "determine plausibility," and "varies". From these answers, students were then asked to think about each and determine if they agree or disagree with these responses. After giving students a few seconds, Holly directed them to show her a fist if they disagreed and give her a five if they agreed. This strategy was called "fist to five" and something that Holly's cooperating teacher had encouraged her to use. As Holly began whole group discussion, she stated, "Ok, show me fist to five if you think that scientists work in labs." Of the twenty four students, twelve showed a five, indicating that they think scientists work in labs. The other twelve indicated that they thought scientists work wherever it made sense. "Ok, show me fist to five if you think scientists create new things." As Holly was progressing through the list of jobs that had been provided by the students, the whole group discussion that evolved provides evidence that students' conceptions about these particular NOS concepts was pre-assessed and they became an explicit part of teaching and learning.

In the transition to the cookie mining activity, Holly made it explicit to students that they would be coming back to these NOS ideas at the end of the class. As the first delivery continued, Holly monitored the students' actions during the mining activity. She then brought closure to the research lesson by facilitating whole group conversation back to the NOS. Holly first began by asking, "So, how many of you ended up working with someone to get the most out of your cookie?" At first only a few students raised their hands. Then, Holly stated, "I saw many of you talking to your neighbors and I think that's great. You know scientists do collaborate with other scientists so that they can figure stuff out. So let me ask you again, how many of you collaborated with someone near you?" With this, eighteen of the twenty four students raised their hands. Holly facilitated the remainder of the discussion around competition for profits and funds and the reality of working in a lab versus in the field. Holly connected examples from their mining activity for concrete examples of the NOS ideas relating to collaboration, competition, and work space. Holly's NOS closure was both planned in the research lesson and successfully delivered.

Reflection on the Research Lesson

Holly and I used the next hour to reflect and analyze data that was collected. As Holly thought back to the delivery, she first stated in a kind of relieved manner, “Well, that went okay.” I confirmed and asked her what she thought went well. Holly first talked about the students’ responses to the opening questions relating to the NOS. Holly was kind of surprised by the students’ responses. This made her think that perhaps the students were beginning with a better understanding of the NOS than what she had assumed. This focus on students and using these unexpected results as a gauge for what they understand about NOS is an indication of a technical inquiry focused at dialogic levels of reflection. For example, Holly also talked about some of the students looking at their neighbors’ responses when they were asked to use the “fist to five” strategy. Holly felt this may have solicited inauthentic data. When Holly brought up the data, I shared with her the number of students that answered the initial and concluding NOS questions in specific ways. We agreed that the students’ written responses may have to be more carefully evaluated to get the most accurate assessment of their NOS understandings. Holly continued to reflect within dialogic levels in the focus dimension as she recalled that students were first reluctant to admit their collaborative practices. Holly found it surprising that she had “to make collaboration okay for them” by telling them she thought it was “an awesome thing to do”. Holly noticed a definite increase in the number of students who admitted that they had used their neighbor to help them earn more money once she said this. We agreed that making collaboration an expected part of the mining activity would need to be made an explicit part of the instructions. As observations informed Holly’s future instruction, the shift toward technical levels of reflection within the focus dimension began to be at the center of her concerns. If in this moment Holly had reconnected students misconceptions about the NOS (e.g., scientists work in isolation therefore the students should have worked in isolation), then this focus might have been more transformative.

As Holly kept thinking through the research lesson, she switched from thinking about NOS to the tasks associated with the actual mining portion of the research lesson. This part of reflection shifted between technical and dialogic levels of reflection focused on a separate learning goal than the NOS, which was the intended focus for the lesson study. Holly's frustration with the amount of redirection required prompted this focus, indicating these instances to still be situated within a technical inquiry.

Developing the Modified Research Lesson

Holly did not understand why following the procedures had been such a struggle. Holly was also surprised by the number of students who did not know how to solve the related math problems. These were two specific aspects of the research lesson Holly felt needed to be modified. While in agreement with the need for change, I redirected focus toward the NOS learning goals for the research lesson by also recommending a way to more formally determine if the students could connect their activity with NOS learning goals.

From reflection, Holly and I decided to modify the student handout. We very quickly evaluated the original version to identify ways it could be changed to address all of the shared concerns. In this continued dialogic level of reflection, focus was on students. We worked together to create a modified handout that we thought would provide instructions that would allow them to be more successful in completing the mining activity and then connecting their experiences to the NOS. In this modified handout students were asked to follow instructions within a data table and record the needed information on the right. We also agreed that allowing students to use calculators might circumvent some of the students' frustrations with calculations. In addition, Holly and I decided that if specific NOS questions were included on the handout, this might provide a more accurate snapshot of the students' NOS understandings before and after the activity and class discussions. By requesting written responses to these questions we also hoped to resolve the issue with students looking to peers before showing their "fist to five" and provide us an opportunity to assess the students' ability to articulate how they understand the connections between the actual work of science and what they have just experienced.

Holly and I were engaged in a dialogic inquiry by situating the questions we were asking of each other about the students' experiences. Based on our interpretations of the student interactions and data collected during delivery of the original research lesson, we addressed and worked toward making changes to specific teaching tasks that was hoped to remedy concerns. According to Ward and McCotter (2004) these instances of reflection would be considered both a technical and dialogic focus within dialogic levels of inquiry. These dual levels of focus best represent the actual incidents that unfolded during this structured time for reflection. For example, in this inquiry Holly shifted between thinking about student interactions and how they were learning (dialogic) to specific modifications in the tasks that could resolve the teaching and learning issues (technical) of both the NOS and science content. Whether these modifications become a part of the change that occurs during the second delivery will allow an opportunity to analyze levels of reflection within the dimension of change. This second delivery will now be elaborated upon, with specific instances where change in practice may have occurred highlighted.

Reteaching the Modified Research Lesson

As the bell rang and Holly engaged students in the research lesson similarly to the initial delivery, the anticipated student responses to the NOS questions were indeed ways that students responded. However, the way these students related to the questions was different. For example, when Holly asked if scientists collaborate with others, some students brought up that scientists work with lots of different people, and “especially the government.” Students in this class also brought up several aspects of science they had seen on television, such as “Sport Science”, where they had seen media about Area 51. Another different response provided by these students was that scientists would use their imaginations when they worked. These students also provided specific purposes for doing science, like inventing medicines, finding cures, and “other things that make our lives easier.” As Holly posted student responses and transitioned to the “fist to five” strategy, all students were engaged and participating. Holly again emphasized to students that they would be revisiting these ideas at the end of class.

Holly then distributed the (modified) student handout for the cookie mining activity and asked students to read the introduction. After a few minutes, Holly asked a student to read aloud the introduction, distributed the prepared materials and instructed students to work on “mining” their “ores” by following the steps provided. Holly did emphasize to students that collaboration was an expected part of the activity, indicating that she did respond to the situation in the first delivery. This would be leveled as dialogic change, as Holly used the "inquiry to develop new insights about teaching….leading to improvement of practice" (Ward & McCotter, 2004).

As students delved into the activity, Holly again monitored their interactions. Students were openly sharing ideas about ways to get the "ores" out of the "mine." As Holly began to facilitate the post lab discussion about the NOS concepts, the majority of students were engaged in the "fist to five" strategy. Holly asked students questions similar to the "Conclusions" questions included on the modified handout. Students were raising hands and providing accurate responses. Holly directed students' attention to the conclusion questions on the handout and asked that they respond on their papers. By putting into practice the discussed ways for improving student learning of NOS, this provides evidence that Holly transitioned to dialogic levels of reflection within the dimension of change. Furthermore, this provides evidence that reflection influenced the transfer of NOS into Holly's classroom practice.

Reflection on the Modified Research Lesson

Holly and I went back to the media center of Deer Crossing to reflect on the outcomes of this second delivery. Holly talked a little about how she thought the modifications helped guide the students in the "mining" activity. She felt like she didn't need to answer as many questions about the procedures this time. Holly realized again though that she "needed to provide the students with a calculator or determine a different way to help with the computation" that is part of the activity. Initially Holly was not focused on the NOS learning goals, but the areas that caused her frustration from the first delivery. This indicates a technical focus within a technical level of inquiry. I encouraged Holly to continue thinking about ways to improve the research lesson, and I stated that I thought this second delivery generated much better participation and student engagement. I began to talk about some of the student responses to the explore/engage portion, specifically the comments about Area 51, and that I would be interested to see the student responses from the original to modified handout. Holly shifted toward dialogic focus within this technical inquiry as she explained that she perceived a certain level of effectiveness in the way that the students were involved in the NOS learning goals within the research lesson. She wrote,

> After the students finished the lab I utilized the last ten minutes to revisit the student idea that I had written on the board prior to the start of the lab. During this post-lab discussion of the NOS concepts I went down the list on the board relating each idea to what they did in their lab and how they did the lab. By holding this post-lab discussion I was able to evaluate if students corrected their own misconceptions as well correct any misconceptions that they students continued to have. (Lesson Study portfolio)

During this reflection we discussed the option of using a cause-effect chart that would guide student thinking toward in-depth student responses. I pointed out that each of the conclusion questions alluded to NOS ideas, but that without the explicit use of the term combined with explicit teaching of these ideas, NOS remained implicit and we missed an opportunity to really make gains in improving students' NOS ideas. In the final portfolio, Holly changed the conclusion questions as seen in Figure 13. The most significant change from the earlier student handout is the inclusion of question five which guides students to think about the similarities in the effects of mining a cookie, and how that might translate to the affects of actual mining on land.

From this change in the student handout, it is evident that Holly is continuing to reflect on ways to improve her teaching practice from "careful examination of critical incidents, and student learning" focused in a cyclical process of interpreting "how or in

Part V: Conclusions (Answer in complete sentences)

1. How is your chip mine like a real one?

2. What happened to the land while you were mining?

3.How can you prevent land damage?

4. Explain what you think the purpose of this lab was (there is no wrong answer – unless it is not written in complete sentences):

5.

Effects of "mining" on cookie	**Effects of mining on mountains/land**

Figure 13. Published version of student handout.

what ways students are learning" (Ward & McCotter, 2004, p. 250). During this final reflection Holly begins to engage in transformative inquiry within the focus dimension at a dialogic level of reflection while continuing to work toward dialogic change. While Holly is situating in these dimensions and levels of reflection it is also important to note that Holly does not situate the earlier inquiry into each of the questions posed to the students, simply adds a fifth question. There was real potential for Holly to use the observations and subsequent dialogue in the lesson study to examine each of these conclusion questions, then make changes in the structure or wording that could have allowed insight to the students' depth of NOS thinking. There are several reasons this dialogic inquiry did not lead to "a transformative reframing of perspective leading to fundamental change in practice" (Ward & McCotter, 2004, p. 250). These possibilities are best explained by Holly herself.

Holly wrote about the type of perspective necessary for benefiting from a lesson study. Holly wrote “that you have to be willing to change if and when you see that something isn’t working as well as you thought it would. This willingness to change can really make a difference in the amount of learning that can take place during a lesson.” This type of insight into teaching and learning maintains Holly’s quality of reflection within the change dimension at a dialogic level. In the final interview Holly expounded upon this statement, saying that she thought “You kind of have to be a reflective practitioner to begin with.” As she elaborated on this point, she said,

> You have to, as a person, realize that you’re not going to always be right, you know, having that view of there are better ways...I know a lot of veteran teachers see their way as the best way, the only way. If you’re a reflective practitioner, you have to have that realization that there at least could be a better way and be open to trying different things. And you have to be open to positive criticism from others, but also toward yourself. (Interview, January 2010)

Toward the end of the lesson study, Holly’s open consideration of these fundamental dispositions necessary for continued improvement of practice further illustrate a leap toward transformative focus within a transformative inquiry at a dialogic level of change. Nonetheless this perspective also provides insight to the possibility that Holly never reached dialogic transformative dimensions of change as a result of her own unwillingness to make that leap.

Summary

Holly’s experience with lesson study was unique in many respects. At the forefront of this was her isolated placement at Deer Crossing Middle School. While it might be expected that this solitary placement would limit reflection, it did not deter Holly. Tables 18 through 20 summarize the structured times of reflection afforded Holly in her situation. Structured time for reflection was fostered during the planning of the research lesson, between the first and second delivery, and after the second delivery. While again significant restrictions were placed on the time and perspectives during these structured times of reflection, Holly did not see this as a limitation. Holly was able to complete the lesson study cycle with reflection focused on teaching NOS and at levels that indicate potential for a transformation in perspective and practice.

Table 18

Summary of Analysis while Planning for the Research Lesson

Dimension of Reflection	Levels of Reflection	Supporting Data
Focus	Transformative	Field Notes (e-mail communication) Final Interview (Spring, 2010) Lesson Study portfolio
Inquiry	Dialogic	Field Notes (e-mail communication) Final Interview (Spring, 2010) Lesson Study portfolio

Table 19

Summary of Analysis during Reflection and Development of the Modified Research Lesson

Dimension of Reflection	Levels of Reflection	Supporting Data
Focus	Technical	Field Notes Lesson Study Portfolio
	Dialogic	Lesson Study portfolio Field Notes
Inquiry	Dialogic	Field Notes Lesson Study portfolio
Change	Dialogic	Field Notes Lesson Study portfolio

Table 20

Summary of Analysis during Reflection on Modified Research Lesson

Dimension of Reflection	Levels of Reflection	Supporting Data
Focus	Technical	Lesson Study portfolio, Field Notes
	Dialogic	"After the students finished the lab I utilized the last ten minutes to revisit the student idea that I had written on the board prior to the start of the lab….By holding this post-lab discussion I was able to evaluate if students corrected their own misconceptions as well correct any misconceptions that they students continued to have." (Lesson Study portfolio)
	Transformative	"You have to, as a person, realize that you're not going to always be right, you know, having that view of there are better ways..." (Final Interview, spring 2010)
Inquiry	Technical	Field Notes Lesson Study portfolio
	Dialogic	Field Notes (reflection comments on modified research lesson) Lesson Study portfolio
	Transformative	Published Version of Student Handout (Lesson Study portfolio,) "…If you're a reflective practitioner, you have to have that realization that there at least could be a better way and be open to trying different things. And you have to be open to positive criticism from others, but also toward yourself." (Final Interview, spring 2010)
Change	Dialogic	"You kind of have to be a reflective practitioner to begin with." (Final Interview, Spring 2010) Lesson Study portfolio

How lesson study influenced the transfer of NOS into classroom practice was evident at the onset of Holly's experience. Table 18 summarizes the dialogic and transformative levels of reflection that occurred during the planning phase. Most illustrative of this was Holly's strategy for getting "other pairs of eyes" on the research lesson during the planning phase. Table 19 summarizes the reflection that occurred during the structured time between deliveries of the research lesson and the development of the modified research lesson. Partial explanation for these levels of reflection is Holly's solitary placement, with no additional team members contributing to the data collection and only my perspective in how modifications could be accomplished. This lack of additional peers available for the following reflections unquestionably influenced the outcome of these lesson study phases when Holly was within the dimension of inquiry. As a result of this the supporting data for this analysis is additionally limited to those artifacts provided in the Lesson Study portfolio and field notes.

Table 20 summarizes final reflections about the outcomes of the lesson study. Pertinent and unique to Holly's situation is the way she discusses the type of disposition needed to learn from conducting a lesson study. Data analysis shows Holly's levels of reflection ranged from technical to transformative within the dimensions of focus and inquiry. Analysis also shows that Holly consistently functioned within the dialogic level of reflection with the change dimension. The lack of transformative levels of reflection within the change dimension presumably impacts Holly's long term practices. If transformative change had been represented it would imply that there had been "a transformative reframing of perspective leading to a fundamental change of practice" (Ward & McCotter, 2004, p. 250). In the final interview I sought to verify this analysis by asking Holly if she had taken any opportunities to teach NOS explicitly once the lesson study had been completed. Holly said,

> No, not really, I would try, but either I would not have time to, or it would kind of be on the back burner because of the pressure from the mentor

> teacher to get content in. I wouldn't have time or because I would try to address it and then there wasn't student reception of talking about it and so instead of struggling with them, I just kind of gave up. (Interview, January 2010)

These choices in teaching practices after the lesson study cycle had been completed implies the need for additional support in order to transform Holly's long term practices as it relates to teaching NOS explicitly.

As Holly stated in the final interview, various circumstances and lack of support resulted in her just kind of giving up on teaching NOS explicitly. In addition, Holly did not see that the lesson study changed any of her own perspectives of NOS. Therefore, opportunities to teach or learn from this experience in a way that improved NOS perspective were not part of the change experienced at this time. This lack of change in perspective was also evidenced when Holly did not add to any of her VNOS-b responses from the end of the summer course. When seeking validation of this analysis in the final interview, I specifically asked Holly if she came to realize anything about her own perspective of NOS as a result of this lesson study. Holly stated that she did not necessarily have an "ah-hah moment when some aspect of NOS became crystal clear", but that,

> when I would be listening and watching her (collaborative teacher) teach, or like writing my lesson…I would encounter that kind of stuff. Especially in the beginning when I was just watching her, and when, you know, we had just finished talking about that kind of stuff this summer. It was fresh on my mind. And there were times I was just like…this would be a perfect opportunity to incorporate something about NOS, even if it was just the no right answer things; that came up a lot.

Holly elaborated on her ideas of when the tentative NOS could have been an explicit part of the collaborating teacher's instruction, stating, "I would have loved to put in some of those, especially the hands-on experiments or activities that you gave us… I would have loved to do those with the kids just to make them think, especially about the no one right answer when it comes to science." Holly's ability to see when NOS could have been a part of instruction supports analysis of change within dialogic levels of reflection, as she has been successful in developing new insights about teaching and learning. These are qualities of dialogic reflection according to Ward and McCotter (2004) because a shift toward transformative levels of reflection would have indicated that there had been an actual "fundamental change in practice," something that Holly shared was not part of her practice during her practicum experience after the lesson study had been completed.

Lesson Study at Muddy Banks Middle School

The lesson study team completing their practicum experience at Muddy Banks Middle School consisted of two preservice teachers: Josie and Lydia. Similar to Holly, Josie and Lydia developed a one day research lesson. This research lesson was developed for seventh grade students and focused on NOS curriculum related to the collaborative NOS, technology used in science, and a growing body of scientific knowledge. Figure 14 overviews the instructional flow developed by Josie and Lydia, with the support of their cooperating teachers. As Figure 14 illustrates, the NOS ideas were contextualized within biology understandings of cell organelles and their functions. Josie and Lydia were continuously guided by their cooperating teacher's suggestions and resources, as well as, sought my suggestions along the way. As evident in Figure 14, their planned research lesson indicates students would develop a blueprint model of their school then determine which structures within the school were appropriate analogies for the structures of eukaryotic cells.

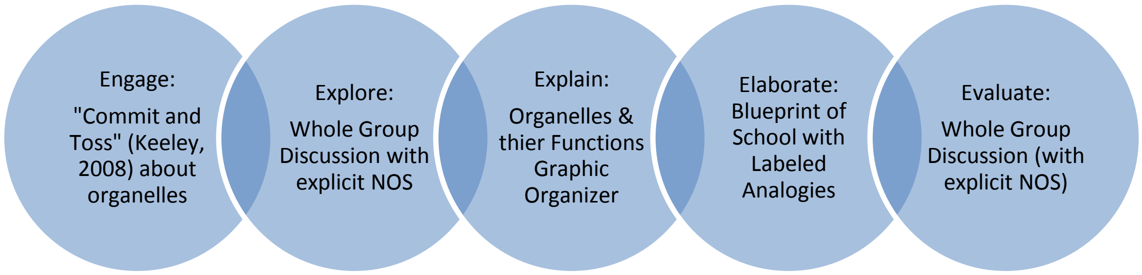

Figure 14. Overview of Research Lesson at Muddy Banks Middle School

In this lesson study Lydia volunteered to deliver the research lesson. During the initial delivery, Josie and I served as observers and data collectors. Structured reflection occurred immediately after the first delivery, and included myself and the two participants. This structured reflection did result in modifications and reteaching of the research lesson. Lydia again volunteered to deliver this modified research lesson, while Josie and I observed and collected data. Intertwined in the following elaboration is emphasis on the instances of reflection about teaching and learning NOS.

Planning for the Lesson Study

The collaborative nature of the science department allowed for ease in discussing the lesson study with the cooperating teachers. Both Lydia and Josie asked their cooperating teacher if there was particular content that would be more beneficial. Josie's cooperating teacher suggested developing a research lesson about cellular structures, as this was something that students had historically struggled with and she was always looking for different ways to teach these concepts. Similarly, Lydia's cooperating teacher felt timing and past student difficulties with these concepts would make this an appropriate research lesson. As a starting point, the cooperating teachers provided Lydia and Josie with some of the activities that had been integrated in the past. Josie and Lydia worked on developing the research lesson with the guidance of their cooperating teachers. This type of inquiry into the teaching and learning of science indicates a dialogic level of reflection, as the exchange of ideas, experience of the cooperating teachers, and student learning were all part of the focus for developing this research lesson. In addition because the focus of this planning begins with known past student struggles in mind this indicates an initial focus at dialogic levels.

In continued dialogic qualities, two weeks before the lesson study Josie and Lydia e-mailed a copy of their first draft of the research lesson asking that I provide feedback. I returned the draft with comments focused on making NOS a pervasive theme explicit in the research lesson. Josie later wrote, “We're looking at your comments and are meeting tomorrow to talk about them and about how to modify our lesson to make it better. I agreed with many of them that I saw! Thank you so much for your input.” As time was winding closer to the day of delivery, e-mail correspondence continued to be used to collaborate on ways to collect data during delivery.

During these instances Lydia and Josie were focused on the specific requirements of the lesson study assignment and wanting to ensure that all teaching tasks had been planned for in an acceptable way. Reflection that occurred during this time was technical within a focus dimension. For example, Lydia wrote that she and Josie were thinking, “Our main data collection tool will be our observations of student input during the discussion of NOS related topics in the engage portion of the lesson. We will be listening and evaluating the students’ understanding about the characteristics of science as we pose questions and listen to their discussion." By structuring data collection within these questions, Josie and Lydia were setting up the dimension for inquiry into this situation to be focused at dialogic levels. Josie and Lydia were thinking that the outline of the research lesson itself and student work could be used to record specific comments made by the students and then tally any duplicated responses. While I encouraged more specific focus by developing an outlined data table to direct our focus during delivery, Josie and Linda did not see that this was necessary. Josie and Lydia felt confident in both their research lesson and structure for conducting the lesson study, and with final approvals from their cooperating teachers, they were ready for the day of delivery.

Initial Delivery of the Research Lesson

During the planning phase of the lesson study Lydia and Josie had decided that Lydia would deliver the research lesson both times. They felt they were "controlling for variables, such as delivery styles and student relationships," and therefore the results would be more accurate with Lydia delivering. So as Lydia began to deliver, Josie and I divided the room, then watched students while collecting data on the students' handouts and the research lesson. Elaboration on how this delivery transpired is important for providing evidence as to how the lesson study may have influenced the transfer of NOS into classroom practice. This elaboration is also relevant in providing context for the structured instances of reflection that occur after delivery.

The level of excitement was high as students became engaged in the "Commit and Toss" (Keeley, 2008) about cell organelles. Students began talking to each other about the organelles on their paper, trying to see what different answers had been given, and Lydia tallied the variety of organelles provided. As Lydia moved the students toward the exploration phase, she was using the scripted questions to elicit student conceptions about the collaborative NOS, technology used in science, and the work of science in general. Lydia explicitly connected these ideas to what we understand about cellular structures and the way scientists explain what we understand to the public. Students were listening and hands were rising to add to the discussion. After Lydia provided instructions for the explain phase of the research lesson, students were asked to turn to their "elbow partner" and re-state the instructions. Based on what Lydia was overhearing, she did not think students were accurately re-telling the instructions, so she regained all of the students' attention to re-tell the instructions. This next time when students told their "elbow partner" the instructions, the class was much louder and students were accurately telling each other what needed to be done.

Students began this assignment and then continued through the remainder of the research lesson which included the development of school blueprints that were to be analogous to cell organelle structure and function. A short discussion ensued that connected the creativity and collaboration that would be required in developing analogies to present organelle functions to the creativity and collaboration required in science. Students were anxious to get started with the assignment and were working diligently until Lydia regained the students' attention to summarize the main points of the lesson. Lydia encouraged students to raise their hands when they had something to contribute to what she was saying. A few students were attentive and would nod their heads at times; however, most were still trying to get the assignment turned in and prepared for the next class. As the bell rang, students began to move at a quicker pace to head to their class while Lydia provided last second instructions for getting the classroom reorganized.

Students headed out quickly once they had cleaned their areas and turned in their assignments.

An exploration of this delivery elicits several details that need to be elaborated upon. First, it became evident that Lydia successfully made NOS an explicit part of instruction before students began working on their blueprints. Nonetheless, these ideas were not successfully revisited to bridge connections between the students' work and the earlier NOS ideas that were part of discussion. Second, the openness of the participant-generated data collection tools could have resulted in some reflection occurring at critical moments within the delivery. To ascertain whether this is something that occurred for Josie during delivery, I asked about what kinds of observations she recorded on the research lesson or the student handout. Josie admitted that she had gotten distracted watching both Lydia and the students, and had forgotten to formally record many of her observations. Josie was going to need a moment once we got to the media center to write more notes on what she had observed. Since no critical moments were immediately reflected upon by Josie, Ward and McCotter (2004) level this as a routine focus within a routine inquiry. Routine inquiry indicates that "questions about needed personal change are not asked," and routine focus indicates the "focus is on self-centered concerns…control of students, time…" (Ward & McCotter, 2004, p. 250). Nonetheless, Josie's later recorded observations, my data collection, and Lydia's initial reflection influenced the conversations during the structured time of reflection led to analysis of the way questions were being asked and any change in practice or perspective that this might have prompted.

Reflection of the Research Lesson

Lydia, Josie, and I moved to the media center so that we could talk without disturbing the next class. Lydia reflected first. Initially, Lydia was reflecting on aspects of the research lesson unrelated to NOS, and was assessing the success of the research lesson based on observations. This technical level of reflection within the focus dimension is a recurring quality of the reflections after this first delivery. For example, in our conversations Lydia began by saying that she thought the students were on task, recognizing some students had to be repeatedly redirected. Lydia also noticed "one student who totally missed the point and created a pyramid." Lydia commented, "I like that he was being creative, but he couldn't come up with the parts of the pyramid that were like each organelle. For the most part though, I think the students worked well." Lydia then thought about each separate phase of the lesson and the students' tasks during the phases. Lydia commented that she needed to "make expectations more clear." Lydia felt that during the engage and evaluate phase there were two critical moments in the lesson when this needed to be improved. At this point of the reflection Lydia had shifted toward more transformative inquiry. For example, Lydia saw the first critical moment as when students did not think to use their books during the engage, but did think they should when trying to determine the functions during the explore phase. Lydia thought about how the instructional decisions led to a student misunderstanding, therefore leading to a time where students were unsuccessful in the planned task. Lydia also felt students struggled with creating analogies. She saw that "only a few loud voices provided the definitions. The others were unclear about what an analogy is. So when it came to coming up with a part of the school that was like the organelle, students were just filling in things but not really understanding or explaining why that part was like the organelle." Recognizing these critical incidents where instructional decisions related to students' struggles is a transformative level of reflection within the inquiry dimension (Ward & McCotter, 2004).

As Lydia continued to reflect aloud, she began to shift focus toward NOS, the intended focus of the lesson study. Lydia had already decided that while she had the students' attention after the "commit and toss", she needed to "go ahead and start the whole group discussion about the NOS aspects." Lydia commented, "Student responses were superficial, but I was glad that they were answering and making some connection. Need more in depth discussion….I need to be more clear with my directions and get everything out in one first discussion. Discuss the creativity aspect of scientific thinking while I have their attention." This dialogic focus toward the intended NOS learning goals is situated within a technical inquiry dimension, as there were some analyses of student interaction with the intended NOS learning goals, but no space for additional consideration of others ideas as to how the teaching and learning of these NOS ideas could be more effectively addressed.

After Lydia reflected, she asked, "So, what did you see?" This shifted Lydia's technical inquiry toward qualities of dialogic reflection. Josie and I both began to comment on aspects of the delivery that Lydia had mentioned. In addition, I shared my observations about the exploration of NOS prior to the student blueprint assignment. I saw that students were confused about the types of technology scientists use to assist them in their explorations. For example the students were confused about the use of a microscope and a telescope. I explained that from my own past teaching experience this misuse of terms is quickly corrected once students are redirected. Since this seems to be something that is already known, perhaps we will want to consider a way to circumvent this in the reteaching. Josie and Lydia agreed. Complimentary of Lydia's way to guide the discussion so as to lead the students to continue thinking of tools used to assist and communicate findings, I also agreed with her that the answers seemed superficial. If there were a way for her to get students to provide her with examples of significant events, concepts, people, etc. that they have already learned about, then this might guide more in-depth student thinking. Josie saw that Lydia might even want to guide the students less in generating responses as she felt that "the questions you were asking were leading" students' answers. Josie suggested, "provide more wait time" to see if this would elicit different and more in-depth responses. Lydia admitted that she struggled with this and that thought that was a good idea. Upon admission of this personal teaching weakness Lydia begins to enter the dimension of dialogic change. This is further supported by the continued instances of dialogic inquiry, where the lesson study team was focused on the intended NOS learning goals and openly considering ways to resolve the harder question of how to facilitate greater rigor in the NOS portions of the research lesson.

As dialogic inquiry continued, instructional decisions were questioned. I suggested that we think about changing the transition between the NOS discussion and finding the functions of the organelles. I also suggested that we allow students to collaborate with their small groups to determine the functions of organelles, then share that collaborated knowledge with the whole class. This would promote additional emphasis on the collaboration that occurs in science as well as promote a conversation about collective bodies of knowledge that scientists build upon. Lydia started thinking about how this would change her delivery and wanted to go back to the research lesson to find specific spaces to develop a few guiding questions that would get at what was being suggested. While this focus on the teaching tasks is technical in terms of planning and management, it is still representative of a dialogic inquiry since there is an openness to consider others' perspective that might improve the teaching and learning of NOS. As an additional example of this dualistic level of reflection, one of the last things Josie and I brought up in the reflection time was about the need for a conclusion. We understood that time prevented Lydia from following the instructional plan as written, so we thought that Lydia might want to add a timer to the drawing activity so that she did not run out of time for the concluding NOS discussion. The focus is technical, yet the inquiry is dialogic.

Furthermore, during the time Josie and I were talking to Lydia about our observations, she was typing our suggestions directly into an electronic version of the research lesson. Lydia had decided to take this approach in order to be efficient in documenting the modifications and provide her a chance to process how this would look in the delivery. This multi-tasking is unique to this lesson study team, and an important aspect to consider in terms of how this might have influenced both the quantity and quality of reflection toward dimensions of dialogic change.

Reteaching the Modified Research Lesson

Similarly to the set up in the first delivery, Josie and I divided the classroom for data collection and Lydia delivered the second delivery of the modified research lesson. Lydia recalled that she

> taught 2nd period incorporating the feedback and our adaptations to the lesson plan. I was a little bit concerned going in with how my class would receive the lesson. I felt pretty confident in my ability to teach the content and manage the classroom. The one thing that I wasn't 100% confident about was incorporating the NOS portion and really tying it into the lesson and getting them to think in a scientific habit of mind. (Interview, January 2010)

As the second delivery ensued the explicit teaching of NOS was prompted with the question, “Can we see cells?” From this, students were guided through a conversation about the use of technology to assist scientists, how scientists collaborate in their work, and how scientists communicate their findings. Ideas in this discussion were also connected to the topic of that morning’s advisory meeting about collaboration. Students showed clear recognition of what collaboration meant, but were unable to provide examples or an explanation of how scientists collaborate. Lydia provided students with classic projects that involved teams of scientists working, like the Human Genome Project. This discussion was evidence of explicit teaching of NOS during the second delivery as well as a change in questioning techniques that led to greater student involvement and greater depth in thinking about the NOS. From this unfolding of events, it can be determined that the earlier inquiry into teaching NOS did shift toward a dialogic change.

As students were provided an overview of the task, Lydia again delivered the research lesson with the suggested modifications. Lydia first instructed students to collaborate with their table mates to determine the functions of the various organelles. Students quickly finished this task, with Lydia iterating how the collaboration promoted the efficiency of their efforts. Then Lydia guided students through the expectations for making the school blueprints and the analogies to cell organelles. Students again worked until the class time ended. The students’ efforts and higher quality of work than the earlier class had prompted Lydia not to stop them early, and so as class ended she asked that they finish up for homework with again no summarizing NOS discussion.

Exploring this second delivery of the modified research lesson again provides an opportunity to see how the inquiry structured by the lesson study framework leads to actual changes in practice. Lydia's improvements in teaching NOS explicitly were at the forefront of Josie's recorded observations. Josie wrote on the participant-generated data collection tool, "loved the NOS discussion – did a great job of tying in what they were going to be doing in class." Josie's use of the participant-generated data collection tool in this second delivery also indicates that her focus during this delivery shifted from routine to dialogic levels as she began to "focus on students…interactions with students to interpret how or in what ways students are learning…" (Ward & McCotter, 2004, p. 250). Josie also recorded such things as, "many students confused cytoplasm with chloroplast (maybe some clarification needed)" and "liked how when a student gave a wrong definition, instead of correcting them, you asked the class if they agreed, disagreed, weren't sure" (Lesson Study portfolio,) This also indicates Josie has begun to shift toward technical levels of reflection in the inquiry of this delivery as she is asking questions, making comments about situations that were frustrating to the students or elicited "exciting results" (Ward & McCotter, 2004, p. 250).

Reflection on the Modified Research Lesson

Lydia had mixed reactions to the delivery of this modified research lesson. She explained that she felt nervous about how students would respond to the specific instructional approaches. The dynamics of the student population combined with successfully implementing all that had been suggested had led to anxiousness for this second delivery.

> But it actually went better than I could have imagined. The students answered my questions thoughtfully and participated in a class discussion about things such as technology use, multiple scientists, communication, and collaboration. I was able to really relate it to the cell is like a school analogy assignment we were working on that day because I related it to scientists that made discoveries about cells. And I kept relating scientific collaboration to what we do in the classroom in the table groups. We did a lot of group work and collaborated to come up with answers…And I was really shocked at how well they perceived the lesson and worked diligently. Everyone was interested, on task, and talking to their tablemates. (web based forum, fall 2010)

In this retelling of this second delivery of the research lesson, Lydia focuses "on self-centered concerns…Primary concerns may include control of students, time …" but then also discusses "specific teaching tasks….but does not consider connections between teaching issues," (Ward & McCotter, 2004, p. 250). These qualities of reflection are associated with routine and technical focus. Lydia is also situated within a technical level of inquiry, which becomes evident from the lack of an inquisitive stance into this second delivery. Lydia has stopped "asking questions after initial problem is addressed" (Ward & McCotter, 2004, p. 250).

While Lydia expresses her initial concerns, potential failure, and overall pleasure with the outcome, she states, "I feel like this lesson really became a lesson about how scientists work together and how the students do that themselves in the classroom." This shift in focus to the intended NOS learning goals indicates a move toward dialogic levels of reflection. Lydia also recalled that in the NOS discussion one student asked, "Can we see cells?" and that another student was confused "because he thought he could see his skin, so he thought those were cells. So to correct it, we ended up reviewing what a cell, organ, organ system, etc. was." (Lesson Study portfolio) These type statements shift between focus at technical and dialogic levels because the focus is on how specific instructional decisions effected student learning.

Josie shared similar observations that contributed to Lydia's initial reflection, pushing them both toward technical levels of inquiry as they both gave the impression that the NOS curriculum concerns had been resolved. During the NOS discussion, Josie heard "really authentic responses from the students." Josie was both surprised and "amazed at how the students seemed motivated by the discussion." Josie commented that she saw students of all different abilities raising their hands during this discussion, all having something to contribute to the discussion. Josie also noticed that Lydia did a good job of validating student responses, even if they were inconsistent with an accurate answer. Josie saw that Lydia would redirect the students in a way that would prompt a more accurate response. These instances are shared with no analysis of practice, simply a sharing of exciting results, further illustrating technical levels of inquiry.

One difference between Josie's input after this second delivery and the first is in the detail with which she is able to contribute to the discussion. Josie successfully used the participant-generated data collection tool to "interpret how or in what ways students are learning" indicating that her data collection during this second delivery was focused at dialogic levels (Ward & McCotter, 2004, p. 250). Additional examples of this record found in the Lesson Study portfolio show that Josie shared her thoughts about the change in expectations and how she saw and heard students talking in ways that indicated they did understand the function of organelles. Josie really liked what she heard in student conversations when they were collaborating on their blueprints. Josie recalled that students would get animated at times and that they were arguing in legitimate ways as they tried to reach an agreement on the best analogy to use in their school drawings. Josie used these observations to shift focus toward technical levels of reflection. For example, Josie suggested that in the published version of the research lesson that an example of a school blueprint along with a list of the expectations might promote greater efficiency for students in completing the assignment, which would then give time for the summarizing discussion that would re-connect the NOS ideas to what the students had completed in their work.

Contributions such as these led to the published version of the research lesson. This indicated a shift toward dialogic inquiry and routine change. The suggested modifications revolved around observations of student struggles and efficiency in the blueprint task. The absence of analysis in the teaching and learning of NOS combined with the failure to recognize space for greater depth in the NOS instruction indicate that Lydia and Josie felt this initial concern had been resolved. Lydia and Josie submitted a completed lesson study portfolio with the aforementioned modifications in the published version of the research lesson.

Summary

Lydia and Josie coordinated the delivery, modifications, and re-delivery of the research lesson for one day. Lydia and Josie felt successful in focusing on teaching and learning NOS in this lesson study. Upon this perceived success they then shifted focus in their reflections to other teaching issues, such as the need for structured closure and the development of specific guides to promote efficiency in the student tasks. Tables 21, 22, and 23 outline each lesson study phase that included reflection. The dimensions of

Table 21

Summary of Analysis while Planning for the Research Lesson

Dimension of Reflection	Levels of Reflection	Supporting Data
Focus	Technical	Field Notes
		Lesson Study Portfolio
	Dialogic	Field Notes
		Lesson Study Portfolio
Inquiry	Dialogic	Field Notes
		Lesson Study Portfolio

situated instances and the corresponding levels of reflection are first provided, with specific supporting data for this analysis.

During delivery of the research lesson incidences of reflection are not structured in the same way as the other phases. During delivery it is expected for the participants collecting data to be focused on the teaching and learning issue of NOS curriculum. If any reflection occurs at this time it is in the form of recorded student or teacher observations with a follow up comment. How the development and subsequent use of the data collection influenced the dimensions of focus, inquiry, or change is then more accurately categorized by the associated level of reflection. Therefore, the observations and other data collected by Josie during the delivery phases of the initial and second research have been included with Tables 22 and 23. Tables 22 and 23 connect this focus to the subsequent times for reflection.

Table 21 shows that during the planning of the research lesson the participants engaged in dialogue with others. This dialogue included conversations about teaching explicit NOS. Evidence of this focus and the manner in which inquiry occurred is found primarily in the lesson study portfolio submitted by the participants; but also in field

Table 22

Summary of Analysis during Delivery and Reflection of the Research Lesson

Dimension of Reflection	Levels of Reflection	Supporting Data
Initial Delivery Phase		
Focus	Routine (Josie only)	Field Notes Participant Generated Data Collection Tool
Reflection Phase		
Focus	Technical	"One student who totally missed the point and created a pyramid..." (Field Notes, Lydia only) "I need to make expectations more clear during the engage and evaluate…go ahead and start the whole group discussion about the NOS aspects." (Field Notes, Lydia only) Lesson Study portfolio
	Dialogic	"Only a few loud voices provided the definitions. The others were unclear about what an analogy is. So when it came to coming up with a part of the school that was like the organelle, students were just filling in things but not really understanding or explaining why that part was like the organelle." (Field Notes, Lydia only) Lesson Study portfolio
Inquiry	Technical	"…For the most part though, I think the students worked well." (Field Notes, Lydia only) "Student responses were superficial…Need more in depth discussion…." (Field notes, Lydia only) Lesson Study portfolio
	Dialogic	Field Notes Lesson Study portfolio
	Transformative	Field Notes Lesson Study portfolio
Change	Dialogic	Field Notes Lesson Study portfolio

notes that documented conversations between myself and the participants through e-mail and structured class times. In Table 22, evidence is provided that Josie did record observations during the first delivery of this research lesson. Evidence of the participants' reflections after this initial delivery is found in field notes and within the

Table 23

Summary of Analysis during Delivery and Reflection of the Modified Research Lesson

Dimension of Reflection	Levels of Reflection	Supporting Data
Reteaching Modified Research Lesson Phase		
Focus	Dialogic	Lesson Study Portfolio
Inquiry	Dialogic	Lesson Study Portfolio
Change	Dialogic	Field Notes, Lesson Study Portfolio
Reflection of Modified Lesson Phase		
Focus	Routine	"But it actually went better than I could have imagined. The students answered my questions thoughtfully and participated in a class discussion about things such as technology use, multiple scientists, communication, and collaboration. I was able to really relate it to the cell is like a school analogy assignment we were working on that day because I related it to scientists that made discoveries about cells. And I kept relating scientific collaboration to what we do in the classroom in the table groups. We did a lot of group work and collaborated to come up with answers…And I was really shocked at how well they perceived the lesson and worked diligently. Everyone was interested, on task, and talking to their tablemates." (web based forum, fall 2010); Lesson Study Portfolio; Field Notes
	Technical	Web based Forum, Fall 2010; Lesson Study Portfolio; Field Notes
	Dialogic	"I feel like this lesson really became a lesson about how scientists work together and how the students do that themselves in the classroom." (Field Notes); Lesson Study Portfolio; Field Notes
Inquiry	Technical	"really authentic responses from the students" (Field Notes); "amazed at how the students seemed motivated by the discussion" (Field Notes); Web Based Forum, Fall 2010; Lesson Study Portfolio; Field Notes
	Dialogic	Lesson Study Portfolio Field Notes
Change	Routine	Lesson Study Portfolio Field Notes

lesson study portfolio. The unique nature with which these participants recorded their comments while simultaneously reflecting is an important point to include in this summary.

The recurring dialogic levels of reflection that occur for this lesson study team are of particular interest. Several factors contribute to the participants' willingness and attitudes toward considering others perspectives and insights. These factors are best explained by the participants. During the final interview, Lydia and Josie felt their "mutual respect for each other," "similar attitudes," and similar "work habits" may have all contributed to the dynamics of this working relationship. In addition, Josie and Lydia felt that their past experiences in schools were similar, finding them both in "unchartered territory" upon entering Muddy Banks. Sharing this experience seemed to have opened a medium for reflection even before the lesson study began.

Then as the lesson study was drawing closer, Josie was able to observe Lydia's cooperating teacher perform some of her routine responsibilities and immediately saw her as an exemplary teacher, someone from who she could also learn from. Josie and Lydia both thought the cooperating teacher used many of the teaching approaches that had been advocated by the university. Upon sharing this with me, I asked if either of them had seen either of their cooperating teachers teaching NOS curriculum. Lydia had identified many times when her cooperating teacher supported NOS curriculum by using implicit approaches to teaching. At the beginning of her fall practicum experience she had even initiated a conversation about NOS with the cooperating teacher. Lydia said,

> I tried to talk to her about it at the beginning of the semester, when we were kind of just getting to know each other. I was talking about how I wanted to incorporate NOS and asked did she…She referred to things that were more like "habits of mind" like…I think that the, I guess she was like

> more implicit, but the way that her room was set up was conducive to nature of science and all…So, yeah, I mean, she really didn't do a whole lot with (explicit) nature of science. I think it was more implicit than explicit. (Interview, January 2010)

As eluded to earlier, Josie had observed different teaching strategies from her cooperating teacher. Josie recalled observing her cooperating teacher,

> Mine was definitely incorporating nature of science less… You know at first though, I really didn't recognize it just because I had never thought about it before. But I actually started seeing it more and more and seeing places where either she incorporated it or she could have incorporated it.

When I asked Josie and Lydia if they had integrated NOS at times other than during the lesson, both stated that before the lesson study they had not been successful at this. Lydia elaborated on this.

> I don't think that my lessons beforehand did incorporate explicit NOS teaching, and I taught a ton of it implicitly in the beginning of the semester. I think I was confused about how to explicitly incorporate it in the science topic…you know where we had a certain scientific topic that we had to cover every day, and I, in my head, before this, I had kind of the two separate. Like, you either, it was, you went over NOS topics and then you discuss the science behind it, but I didn't see how they could be together, and so I think that was part of my confusion, that I didn't understand how to incorporate NOS. (Interview, January 2010)

Josie agreed, "Yeah, I kind of tried to." She explained that she

> tried to find opportunities to incorporate nature of science in there and I know, I remember one lesson where I kind of briefly discussed with the class about how, what they would be doing was like what scientists do, and we kind of just like had an explicit conversation about how science works. (Interview, January 2010)

Data analysis of the levels of reflection that Josie and Lydia reached during the lesson study did not indicate transformative changes in their teaching practices or perspectives. This final interview allowed an opportunity for Lydia and Josie to reflect on their experiences over the entire semester. From this interview we learn that Lydia and Josie did change their perspective on how NOS curriculum can be transferred into classroom practice. Further evidence of this transformative change emerges as the two continue to share how lesson study allowed them a chance to see how the science content and NOS curriculum are intertwined. Lydia began to explain that she felt one of the benefits of the lesson study process was

> figuring how to incorporate the inner lesson. Doing it in a way that the students could not only grasp, but see how we were going over it in the context, and then also related to, you know, science in general, whether it be past scientists or how science works… (Interview, January 2010)

Neither Lydia nor Josie modified their VNOS-b responses at the end of the fall semester. While this might initially lead to the conclusion that these participants did not change their perspective of NOS, the data from this final interview presents findings that indicate their understandings of how to teach NOS were changed, as well as, their ability to recognize opportunities where NOS could be integrated.

Cross Case Analysis

From these lesson study teams of preservice teachers there is much to be learned. With the particular lens of how levels of reflection influence the transfer of NOS curriculum into the participants' classroom practice, the ideal qualities of Japan's lesson study framework were used as a springboard for cross case analysis. The framework provided by Japan's Lesson Study lends itself to certain qualities of reflection that can be used as a measure of consistency. In this modified version of Japan's Lesson Study the same is true. For example, in the planning phase of the lesson study, Japan's framework encourages the use of past research lessons, outside resources, and extensive collaboration. These same qualities were supported in this modified version of lesson study. In Ward and McCotter (2004) this is comparable to a dialogic inquiry. In addition, Japan's framework supports a teacher initiated curriculum goal with the underlying purpose to improve in an area where students have historically struggled. In this modified lesson study a curriculum goal was initiated by the university under the premise of a curriculum goal that strives toward scientific literacy, one of the nation's struggles. This is comparable to a dialogic focus in Ward and McCotter (2004). For each phase of the lesson study that unfolded for these participants, guiding questions were formulated under the pretense of close alignment with Japan's lesson study. Each phase with these guiding questions has been elaborated upon in the following tables. Data from each phase of the lesson study was then compared across all of the participants within their practicum placements. From this analysis, additional insight to the influence of lesson study on reflection and the transfer of NOS curriculum emerges.

Planning for the Lesson Study

When planning for the lesson study, participants were encouraged to develop a research lesson that focused on student learning of NOS curriculum. From the description of the study's context in chapter three, specific instructional strategies used to facilitate the participants' understanding of both NOS and lesson study have already been detailed. From the context of this study it was expected for participants to collaborate and plan with other participants in their schools to develop a research lesson that focused on explicit teaching of NOS curriculum. Within the planning phase of the lesson study, analysis was guided by the following questions outlined in Table 24.

In cross case analysis, we learn that all three lesson study teams planned for explicit teaching and learning of NOS. Specifically, each lesson study team pre-planned guiding questions that were written in the original research lesson, documented corresponding state curriculum as part of the student learning goals, and contextualized

Table 24

Cross Case Analysis within Planning Phase of Lesson Study

Characteristic	Lolash	Deer Crossing	Muddy Banks
How was the research lesson chosen?	Curriculum Scope and Sequence	Transform a "cook-book lab" to Inquiry within Curriculum Scope and Sequence	Suggested by Collaborating Teachers based on Known Student Struggles
How did col-laboration occur?	With each other	With peers and critical mentors	With peers and critical mentors
Where was focus during the development of the research lesson?	Routine Technical Dialogic	Transformative	Technical Dialogic
Type of NOS Teaching Planned	Implicit & Explicit NOS, Contextualized	Explicit NOS, Contextualized	Explicit NOS, Contextualized

the NOS curriculum within science content through the planned student tasks. Unique in the planning for NOS, the single participant at Deer Crossing Middle School also planned for formally assessing students' NOS understandings.

Analysis of the participants' focus during the planning phase was guided by the understood curriculum goal of teaching NOS. Routine and technical focus was most frequently observed in the participants at Lolash Middle School. Routine focus was identified when the participants were less focused on the intended curriculum goal, yet focused on things such as classroom management, time needed for execution of the research lesson, or goals unrelated to the NOS curriculum. Technical focus was characterized by focus on the NOS curriculum goals with specific attention given to how students could be successful in the designed tasks, while not necessarily developing a way to use the task formatively. These same qualities of technical focus were observed of the participants at Muddy Banks Middle School, with additional focus at dialogic levels. Dialogic focus was characterized by their use of past student struggles with the biology concepts to determine the context within which to develop a research lesson that integrated NOS. Holly’s transformative focus was most uniquely characterized by her personal involvement with modifying a traditional textbook lab into a research lesson that more closely aligned with inquiry based teaching strategies that had been advocated by the university.

Part of planning for the lesson study also included the development of a participant-generated data collection tool to be used during deliveries. Shown in Table 25, analysis of these data collection tools was guided by a different set of questions and unique for each of the lesson study teams. Initial analysis of these data collection tools sought to determine if NOS was at the forefront of focus. If so, then consistency between the intended student learning goals and the structure of the data collection tool were explored. If NOS was not at the forefront of focus, then similarly those separate concerns were explored.

In maintaining consistency with the framework of Japan’s Lesson Study, analysis ensued of the way observations were structured by the data collection tool created by each of the lesson study teams. In Japan’s Lesson Study this data collection is focused on students rather than teacher actions. Observations of the students could include taking notes on student reactions to the research lesson or recording bits of conversation that relate to the focus. The fundamental purpose of data collection is to make every attempt to see instruction through the students’ eyes (Lewis, 2002b). How these lesson study

Table 25

Cross Case Analysis of Participant-Generated Data Collection Tools

Characteristic	Lolash	Deer Crossing	Muddy Banks
What teaching concerns are the foci in data collection?	Number of Students Engaged Student Opinion about Context	Student Accurate & Inaccurate Responses to NOS questions	NOS understandings Science content (cell structure and function) understandings
How were observations guided?	Tally marks Space for student comments	Tally marks Space for student comments	Tally marks Space for student comments
What level of reflection in the focus dimension was being supported?	Routine	Dialogic	Technical

teams planned for data collection during delivery was guided by the questions outlined in Table 26.

Within the focus dimension of Ward and McCotter (2004), concerns outside of NOS were initially leveled as routine or technical, and those data collection tools that did focus on NOS were considered dialogic. The combined focus of the participants at Lolash resulted in final analysis of this data collection tool fall within routine focus. In this data collection tool, aspects of student tasks within each part of the research lesson were outlined for data collection. Part of this structure included specific tallies of student opinions about shipping oil after each part of the research lesson and space for recording "any claims that students question." Connections between data collection and the teaching issues of NOS are unclear, warranting a routine level of focus in the development of this data collection tool.

Table 26

Cross Case Analysis of Initial Delivery

Characteristic	Lolash	Deer Crossing	Muddy Banks
What teaching concerns are the foci in data collection?	Did not occur	Does not apply	NOS understandings Science content (cell structure and function)
How does the teaching of NOS occur?	Implicit	Explicit Contextualized	Explicit De-contextualized

Participants at Muddy Banks did not develop a separate data collection tool, yet did plan for data collection along the margins of the original research lesson. Their approach was unique among these lesson study teams. In e-mail communication prior to delivery, Lydia wrote,

> Our main data collection tool will be our observations of student input during the discussion of NOS related topics in the engage portion of the lesson. We will be listening and evaluating the students understanding about the characteristics of science as we pose questions and listen to their discussion. Furthermore, another data collection tool to assess their understanding of cell organelles will be the chart they have to fill in about the function and their city or school they create. What they choose to represent the organelles should clearly allow us to see if they understand the function of the organelle or not. (Field Notes, e-mail communication, fall 2010)

The dual focus on student understanding of NOS and science content structured this data collection at a technical level. In comparison, Holly's dialogic focus in developing this data collection tool was a result of the specific focus on student understanding of NOS, her use of known student misconceptions to format the data collection tool, and the structuring of pre and post data collection that would allow an opportunity to analyze if the instruction that occurred between conversations had changed or altered any of the students' understandings. How the participants' planning for data collection influences levels of reflection during structured times of reflection in the lesson study will be explored after cross case analysis of the initial delivery of the research lesson.

Initial Delivery of the Research Lesson

The initial delivery of the research lesson was analyzed for dual purposes. The first purpose was to analyze how data collection on the aforementioned participant-generated data collection tools actually occurred for the participants. Second, direct observations of how the teaching and learning of NOS occurred was critical for later answering, "How does the reflection that occurs in lesson study influence the transfer of NOS understandings into classroom practice?" In Table 26, teaching NOS is labeled implicitly, explicitly, decontextualized, or contextualized. These labels emerged as a result of prior literature (e.g., Akerson et al., 2000; Clough & Olson, 2004; Clough, 2006; Lederman and Abd-El-Khalick, 1998; McComas et al., 1998). Implicit and explicit approaches to teaching NOS have been researched extensively (e.g., Abd-El-Khalick, 1998; Abd-El-Khalick & Lederman, 2000; McComas et al, 1998). Implicit approaches to teaching NOS typically include times when students are "doing science" without conversations about how the students' work connects to informed NOS tenets. Explicit NOS instruction approaches are more consistently observed when conversations connecting the NOS tenets are thread throughout an activity. De-contextualized NOS is focused on engaging students to think about NOS tenets. An example would be the use of pictorial gestalt switches to help students understand the relevance of prior knowledge on observations (Clough & Olson, 2004). Contextualized NOS would be the application of an informed understanding of when modifying a traditional lab or illustrating how science works in historical or contemporary examples connected to fundamental science ideas (Clough & Olson, 2004). Table 26 summarizes how the participants' initial delivery of the research lesson evolved, with accompanying analysis identified.

Cross case analysis in Table 26 shows that participants at Lolash Middle School did not use their participant-generated data collection tool. This was openly discussed during the structured reflection time following this delivery. Brad and John were responsible for data collection during this initial delivery, and both expressed that once the delivery of the research lesson began, they "completely forgot about data collection" because they got "so wrapped up" in watching what was going on (field notes). The single participant at Deer Crossing Middle School did not have the option to use her data collection tool, as she was in the act of delivering. Josie, the participant collecting data while Lydia delivered at Muddy Banks Middle School, did collect data alongside the research lesson. Her data collection focused on Lydia's explicit delivery of the NOS tenets of collaboration and technology. Josie also collected data on comments students were making during the research lesson, student attitude during the NOS discussion, and unexpected student misconceptions about particular NOS and science related concepts.

From Table 26 it also becomes clear that two of the three lesson study teams were successful in using explicit NOS instruction. Holly's delivery was analyzed as explicit contextualized NOS instruction. In Holly's delivery at Deer Crossing Middle School, she began by guiding students through a discussion about how scientists work and how this work is used by society. This was analyzed as explicit NOS instruction because students revisited these NOS tenets after doing the activity. This delivery was also analyzed as contextualized NOS because Holly used a cookbook lab in the development of this research lesson; then restructured it to include explicit NOS, and successfully delivered these NOS tenets in the beginning and concluding class discussion. The initial delivery of the research lesson at Muddy Banks Middle School was analyzed as explicit de-contextualized NOS. Lydia’s delivery was analyzed as explicit NOS instruction because she began by guiding discussion with the students about how scientists work collaboratively and the impact of technology in their work. While students were prompted to think about NOS tenets, this delivery was analyzed as de-contextualized as these informed NOS tenets were not applied to the activity students were asked to complete, nor made an explicit part of a conclusive discussion.

The participants at Lolash Middle School delivered NOS in way consistent with implicit NOS instruction. Analysis of the delivery showed that Lydia had forgotten to ask the specific NOS questions that had been included in the research lesson for day one, was reminded by the other participants at the school, but then subsequently forgot again on the second day of delivery as well. Asking these questions of students would have led to explicit NOS instruction. Additionally, this delivery could not be considered as either contextualized or de-contextualized NOS. While students were “doing science,” the delivery of the research plan did not engage students to think about NOS tenets nor make this an explicit part of conversation.

Reflection of the Initial Delivery of the Research Lesson

Reflection of the initial delivery of the research lesson was guided by the work of Ward and McCotter (2004). Ward and McCotter (2004) developed a rubric for analyzing preservice teachers’ levels of reflections within various dimensions of practice. These dimensions have been identified as focused on specific practices or perspectives (focus), asking questions of themselves or others (inquiry), and a change in practice or perspective (change). Structured time for reflection in this modified lesson study naturally lends itself toward the dimension of inquiry, where the preservice teachers are in an inquisitive stance and asks questions of themselves and others about their teaching practices or perspectives. Within this inquiry dimension, transitioning toward the dimension of change is supported. Table 27 shows cross case analysis of which dimensions participants from each middle school were functioning.

Ward and McCotter (2004) additionally provide qualities of levels of reflection that occur within these dimensions. They label four levels of reflection including routine, technical, dialogical, and transformative. Based on an examination of the functioning dimension of the preservice teachers' focus, inquiry, and change, analysis of these levels of reflection ensued. These labels along with detailed, anticipated characteristics are found within the Appendix G. Generally stated, the most mature reflection identified by Ward and McCotter (2004) is transformative. This level of reflection is identified when the preservice teacher focuses on student learning and reframes understanding such that it changes practices. In dialogic levels of reflection, questions are being asked of others about practice or perspective and teaching issues are resolved in particular situations. Within technical levels of reflection, teaching issues are overlooked and analysis of practice occurs as if there is nothing personally at stake. In routine levels of reflection, questions about one's practice are not asked and the individual seeks to avoid blame or finds blame in other aspects of the situation. Cross case analysis of these levels of reflection within the functioning dimensions of the preservice teachers is presented in Table 27.

Table 27

Cross Case Analysis of Dimensions and Levels of Reflection after Initial Delivery

Site	In what dimension(s) of reflection were the participants functioning?	What levels of reflection were occurring within these dimensions?
Lolash	Focus	Routine, Technical
	Inquiry	Routine, Dialogic
Deer Crossing	Focus	Technical, Dialogic
	Inquiry	Dialogic
	Change	Dialogic
Muddy Banks	Focus	Technical, Dialogic, Transformative
	Inquiry	Technical, Dialogic, Transformative
	Change	Dialogic

Cross case analysis of this first structured reflection begins to show trends in the levels of reflection that occurred across the three lesson study teams. Within the focus dimension of this inquiry, all three lesson study teams focused at technical levels. Generally stated this means that the participants were thinking about the effects of the instructional tasks and how they could resolve related teaching and learning issues of those tasks. More specifically these instructional tasks were not related to the teaching and learning of NOS content. Exemplary statements of these technical levels of reflection during this structured time include, "…students were not writing that great of predictions," and "One student who totally missed the point and created a pyramid...I like that he was being creative, but he couldn't come up with the parts of the pyramid that were like each organelle…" Evident in each of these exemplary statements and consistent with field notes is that all three lesson study teams looked to the students as a measure for success or failure in the research lesson. Student interactions with the instructional tasks either through observations or formatively assessing are identified by Ward and McCotter (2004) as a dialogic focus. Nonetheless, in this technical focus the participants were not looking at student interactions within the instructional tasks associated with learning the NOS curriculum goal of the lesson study, nor had a measure of this NOS learning or sought to ask additional questions about how to help struggling students.

One expected outcome of this modified lesson study framework is that participants will take an inquisitive stance about teaching practices and perspective during this structured time of reflection. How this structured reflection influences the transfer of NOS teaching and learning, along with the participants' own understandings of NOS is of particular interest in this dissertation study. Cross case analysis shows that each lesson study team asked questions about their NOS teaching practices, thereby entering Ward and McCotter's (2004) dimension of inquiry. Within this inquiry dimension each lesson study team asked questions of each other and myself in order to gain insight to others perspectives. This is identified within dialogic levels of reflections (Ward & McCotter, 2004). Evidence of this dialogue is found primarily in field notes and in notes along the margins of the original research lesson. Indirect evidence of both this dialogue and focus is also found in the development of the modified research lesson. Consistently, one outcome of the dialogue that occurred during this structured time for reflection was that it shifted focus for all three lesson study teams between technical and dialogic levels when the focus was on NOS. Focus during this time did not always pertain to the way NOS was being taught or learned. Focus on outside curriculum such as student understandings of organelles or mining was identified with more routine levels of reflection.

Individual contexts for each of the lesson study teams NOS focus is of course unique. For example, in the Lolash Middle School lesson study team we find most evidence of these levels of reflection coming from John, who was more receptive to others' perspective about teaching NOS than Lydia or Brad. John asked the university supervisor about possible ways to gain depth in teaching and student learning of NOS, while Lydia took offense at Lamor's perspective. Lydia stated during this time that "If what they had planned was not NOS, then I guess I do not know what NOS actually is." In the final interview both her and Brad expressed frustration with Lamor's involvement, moving them both toward routine levels of inquiry. At Deer Crossing Middle School, indirect evidence of Holly's dialogue is best seen in the development of a new student handout. This new handout guided student thinking more directly, as well as, asked specific questions about NOS as part of a formative post assessment. Aspects of this also provide rationale for Holly's additional transformative levels of reflection. For participants at Muddy Banks, this dialogue led to more personally aimed technical inquiry into ways for successful delivery. For example, in the engage portion of their research lesson it was planned for whole group discussion about the work of science and how technology influences this work. Lydia reflected, "I need to make expectations more clear during the engage and evaluate….For the most part though I think the students worked well." As she continued to reflect on how students were responding to her NOS questions, she stated, "Student responses were superficial, but I was glad that they were answering and making some connection. Need more in depth discussion….I need to be more clear with my directions and get everything out in one first discussion. Discuss the creativity aspect of scientific thinking while I have their attention." (Field notes, Lydia only) Each of these exemplary reflections illustrate the shift between dialogic and technical focus on NOS.

In Lydia's last statement, she says something quite unique when she states, "Student responses were superficial…" Lydia's depth of understanding the NOS tenet that science is a social, creative endeavor allowed her to recognize this lack of understanding among the students. In recognizing this about the students, Lydia also asserts that she needs to change her own practice in order to get students to understand at similar depths. This transformative level of focus is unique for the participants at Muddy Banks Middle School. Lydia is clearly focused on her "personal involvement with fundamental pedagogical,…concerns and how these impact students and others" (Ward & McCotter, 2004, p. 250). In this first reflection we begin to see that the framework of lesson study has supported greater depth in NOS understandings and subsequent transfer into classroom practice. Additionally supportive of this assertion is the two lesson study teams at Deer Crossing and again Muddy Banks that entered dialogic levels of reflection after this initial delivery. Dialogic levels of reflection within the inquiry dimension eludes to the questions within the situations that will lead "to new questions…with open consideration of new ideas," thereby leading to potential change in practice or perspective that is explored in the modified research lesson and follow up second delivery of this modified research lesson.

Developing the Modified Research Lesson

In the development of the modified research lessons we are able to gain insight to how the earlier reflection influenced the planned instructional decisions for the second delivery of the research lesson. This is referred to as the modified research lesson. Table 28 shows how each lesson study team asked questions within the act of modification. The nature of developing this modified research lesson indicates the participants will function within dimensions of focus and inquiry. In cross case analysis only focus on teaching and learning NOS are included. How these questions about NOS are being asked and if these questions lead to a change in practice or perspective is most pertinent to understanding how the lesson study framework influences the transfer of NOS understandings into classroom practice.

Cross case analysis shows no consistency between the participants at Lolash and those at Deer Crossing and Muddy Banks. For the participants at Lolash Middle School the combination of routine and technical levels of reflection in the way questions were asked of their NOS practices led to routine levels of change. After the first structured reflection, feelings of “burn out,” and “Just the idea that the expectations weren’t made clear” resulted in a layering of frustration that potentially rendered the lesson study impotent for these participants. Lydia expressed in the final interview that “We were trying to revise it to make it better and I was not understanding how the revisions could come together to make it better, and I didn’t necessarily take it personally but I just struggled with it.”

Table 28

Cross Case Analysis of Modified Research Lessons

	Lolash	Deer Crossing	Muddy Banks
How was focus directed at NOS learning goals?	Technical	Dialogic	Dialogic
How were questions about NOS asked?	Routine Technical	Dialogic	Dialogic
How does analysis of practice change practice or perspective of NOS?	Routine	Dialogic	Dialogic

Contrary to these experiences Holly at Deer Crossing Middle School functioned within dialogic levels of reflection. This reflection was characterized by her observations of how students were sharing their NOS understandings, looking to peers for affirmation during the "fist to five" strategy, and their unexpected prior knowledge. Similarly, Lydia and Josie felt the students' superficial responses during the whole group NOS discussion may have been a result of leading questions. For these participants talking through these specific situations initiated the inquiry into aspects about their teaching practices that later guided changes in their practice. As Holly, Lydia, and Josie began to think about ways to get students to provide more authentic and in-depth responses, they functioned between the inquiry and change dimensions.

Inquiry was characterized by Josie and Lydia in a unique way. Questions were raised systematically by these participants. They decided to talk through each part of the research lesson, marking directly on the document as to how and what types of instructional changes to make. They shared ideas with each other and asked for my input, evidence of their functioning at dialogic levels within this inquiry. When they came to the part of the research lesson planned for whole group NOS discussion, Lydia re-worded a few of the questions, and Josie suggested that she also "provide more wait time." Later in their discussions when they came to the summarizing whole group NOS discussion, Josie emphasized how "important it is to have this conclusion," and Lydia whole-heartedly agreed. During this inquiry, change begins to occur for these participants at dialogic levels as well. When Josie brought up wait time, Lydia admitted that she struggled with this. Josie admitted the same. This inquiry brought out personal weaknesses for these two, further indications of dialogic change that has been shared by these two participants.

Delivery of the Modified Research Lesson

In this second delivery of the modified research lesson, cross case analysis ascertains whether the aforementioned reflections and subsequent modified research lessons are transferred into classroom practice. For each of the lesson study teams the modified research lesson provided predictive power as to how the teaching of NOS would occur. No less exploring how this delivery actually does occur is necessary as there is no guarantee that delivery will occur as planned. Similar to the initial delivery of the original research lesson, Table 29 shows analysis of these experiences. Analysis pursued by looking at whether NOS was taught implicitly or explicitly in either a contextualized or de-contextualized manner. Alongside delivery, participants' data collection during this delivery provides an opportunity to compare how data collection occurs in this second round of teaching.

Table 29

Cross Case Analysis of Delivery of Modified Research Lesson

	Lolash	Deer Crossing	Muddy Banks
What teaching concerns are the foci in data collection?	Student engagement	Does not apply	NOS understandings Science content (cell structure & function)
How does the teaching of NOS occur?	Implicit	Explicit Contextualized	Explicit Contextualized
Is this teaching reflective of changes in practice based on earlier reflections?	No	Yes	Yes

The most notable difference from the first to second round of teaching is the use of the participant-generated data collection tool by one of the participants at Lolash Middle School. For this delivery of the research lesson, roles within the lesson study team had switched. John was the delivering teacher with Lydia and Brad responsible for data collection. Lydia was successful at collecting data, while Brad again was not. Lydia used their data collection tool as it was designed. This included tallies of student votes about shipping oil before and after various instructional tasks along with space for additional notes. Of particular interest in this data collection was the detailed notes. Lydia wrote several comments about the students general on task behavior and their contributions during whole group discussion on whether oil should be shipped. How this data collection influenced Lydia's contributions during the structured time for reflection after this second delivery is of utmost importance. With this data Lydia had the potential to contribute to the way teaching and learning of NOS occurred.

Additionally important to note from this cross case analysis is the outcome of delivery in relation to the influence of the earlier structured reflection. Analysis of data from Lolash Middle School during the structured reflection indicated routine levels of change. Routine levels of reflection within the change dimension assert that analysis is conducted "without personal response – as if analysis is done for its own sake or as if there is a distance between self and the situation" (Ward & McCotter, 2004, p. 250). From this analysis it was still questionable if a change in practice would result. However, after these events unfolded it became evident that the lesson study framework was not going to support the transfer of NOS curriculum into the classroom practice for these participants at this time.

For the other two lesson study teams, the dialogic levels of reflection that occurred during the earlier structured reflection did support the transfer of discussed changes in teaching practice. Holly's delivery included a change in pacing that resulted in greater depth of discussion during the conclusion. Furthermore, Holly successfully supported the students' collaborative efforts prior to, during, and after the mining activity in an explicit manner that connected to the social endeavor of actual science work. Similarly, the participants at Muddy Bank improved the explicit teaching and learning of the social endeavor of actual science work. This was evident as Lydia reiterated the collaborative NOS throughout her delivery, even bringing in examples such as the Human Genome Project during whole group discussion. Additionally important to note about Lydia's changes in the delivery was that she also improved the teaching of NOS by contextualizing the targeted tenets. For these two lesson study teams the lesson study framework supported improvements in their NOS teaching practices.

Reflection on Delivery of the Modified Research Lesson

Reflection of this second delivery of the research lesson was again guided by the work of Ward and McCotter (2004). Dimensions are identified as focused on specific practices or perspectives (focus), asking questions of themselves or others (inquiry), and a change in practice or perspective (change). Structured time for reflection after delivering the modified research lesson naturally lends itself toward the dimension of inquiry, where the preservice teachers are in an inquisitive stance and ask questions of themselves and others about their teaching practices or perspectives. Within this inquiry dimension, transitioning toward the dimension of change is also supported, as it provides an opportunity to respond to the outcomes of the earlier inquiry and focus. Whether this occurs or not is dependent on the participants themselves. Table 30 shows cross case analysis of which dimensions participants from each middle school were functioning.

Table 30 illustrates a potential relationship between this lesson study framework and the transfer of NOS into classroom practice for these participants. From this cross case analysis we are able to see that participants at Deer Crossing and Muddy Banks Middle School, also the two lesson study teams that successfully integrated NOS using research based pedagogy in the second delivery, functioned within dimensions of change at dialogic levels. This implies that these participants synthesized "situated inquiry to develop new insights about teaching or learners or about personal teaching strengths and weaknesses leading to improvement of practice" (Ward & McCotter, 2004, p. 250). Additionally, transformative levels of reflection within the dimension of inquiry indicates that questions were asked in a way that included "model mentors, critical friends, critical texts, students, careful examination of critical incidents, and student learning" (Ward &

Table 30

Cross Case Analysis of Dimensions and Levels of Reflection after Second Delivery

Site	In what dimension(s) of reflection were the participants functioning?	What levels of reflection were occurring within these dimensions?
Lolash	Focus	Dialogic
	Inquiry	Routine
Deer Crossing	Focus	Technical, Dialogic, Transformative
	Inquiry	Technical, Dialogic, Transformative
	Change	Dialogic
Muddy Banks	Focus	Technical, Dialogic
	Inquiry	Technical, Dialogic, Transformative
	Change	Dialogic

McCotter, 2004, p. 250). These transformations become abundantly clear when analyzing the Lesson Study portfolios submitted by both of these lesson study teams. Lydia and Josie included photographs of student products with detailed captions comparing student learning between the two deliveries, commented on specific moments of teaching that they considered critical in terms of improving student learning of NOS, and additionally used data collected during the two deliveries to make final instructional decisions for the final research lesson. Similarly, Holly assessed the concluding questions added to the student handout in the modified research lesson and talked with her cooperating teacher and myself after the second delivery. From these inquiries, Holly decided to add an additional NOS component in the published research lesson that pertained to the use of models in science. Holly saw that the research lesson could also address this NOS tenet by engaging students to consider the way models are used to assist in explaining how scientists explain phenomena. She then contextualized this NOS tenet by including an additional question on the student handout that asked students to explain how their cookie activity modeled the realities of mining.

On the contrary, participants at Lolash Middle School did not enter the dimension of change nor extend beyond routine levels of reflection within their inquiry. While structure for students was reiterated as a necessity in their instructional decisions, the published research lesson in the Lesson Study portfolio did not include additional structure that would facilitate the learning of NOS in an explicit manner. Two additions to the published version of the research lesson in the Lesson Study portfolio included the use of a graphic organizer during the oil and water explorations and an assessment of students' written evidence based decisions about shipping oil. Both of these will now be expounded upon to illustrate the routine levels of reflection within which these participants were functioning.

During the oil and water exploration the participants added that "students record observation in a Venn diagram (e.g., "oil is sticky," "what is thinner.")." This additional structure indicated that students' observations were being guided toward NOS conceptions of developing explanations about observations, the empirical NOS. Nonetheless, in the published version of the research lesson there was no connection between making these observations and the participant selected NOS curriculum: "Scientific investigations usually involve collecting evidence, reasoning, devising hypotheses, and formulating explanations to make sense of collected evidence." Instead, the participants indicated that by getting students to complete a Venn diagram of their observations students will be exposed to NOS by asking, "Should we have asked more questions before making our decision about shipping oil? As scientists, we must always ask questions and not just trust the vague statements made by "authorities." This is the nature of science, to ask questions and get a better understanding through our observations." These instructional decisions were highlighted in the published version of the research lesson submitted by the Lolash lesson study team. While the participants' scripted questions elude to the empirical NOS being brought out in class conversation the connection between using observations to develop explanations as an accurate tenet of NOS and how the students' input in this conversation is not used later was critical to connecting NOS in an explicit, contextualized manner.

For example, in the second addition to the published research lesson the participants indicated that students will be guided toward making decisions about an oil spill. Connections between observations in the aforementioned exploration and how they could be used in this decision making are not part of the explicit NOS instruction. Failure to analyze this weakness in teaching practice and subsequently engage in an inquiry that might lead to resolutions characterizes the routine level of inquiry that these participants were functioning. Furthermore, the participants decided in the students' decision making to provide one additional resource to use in making their decisions. In these instructional decisions, the participants indicate that Appendix C of their portfolio includes one resource that discusses an oil spill with an accompanying handout. This contradiction of student expectations to use one provided resource while also making the explicit point of questioning claims made by authorities further illustrates the routine levels of reflection that the Lolash Middle School participants were functioning within.

In addition, during structured reflection times the university supervisor emphasized the need to somehow engage students in the act of developing their own claims, learning how to identify a valid resource, and how to write claims based on all of the planned experiences. Failure to consider the university professor's perspective additionally contributed to this routine level of inquiry.

Findings in the experiences of these six preservice teachers reveal how the reflection that occurs in lesson study influenced the transition of NOS tenets into classroom practice. From these three lesson study teams we see that the lesson study framework supported the transfer of NOS tenets into classroom practice. Two of the three lesson study teams were successful in teaching NOS in explicit contextualized ways. What we learn from cross case analysis is that both of these successful teams functioned at higher levels of reflection than those participants in the unsuccessful team.

Summary

How the framework of lesson study influenced reflection about teaching and learning NOS and was unique for all six participants. The transformation of practice and perspective by three of the six participants implies that the lesson study framework has potential in science education. Even for those participants who were unsuccessful in reflecting upon and teaching NOS, the lesson study self admittedly changed their perceptions of teaching and learning more generally. The participants' perspective of their own lesson study experiences is important for summarizing this analysis for several reasons. This perspective will support final analysis of unique qualities of the preservice teachers' that show how individual dispositions play roles in this overall success. This perspective will also provide insight to the holistic effectiveness of the case that cannot be achieved from the earlier analysis.

Several themes emerged from the participants' reflection about the lesson study processes. These descriptions were contributed by the final reflections submitted in the lesson study portfolios and the final interviews. From this data, common perceptions have been organized to describe the participants' values and frustrations associated with the modified lesson study. Three common values emerged for the participants. Each participant from the lesson study teams found value in collaboration, observing others' classroom practices, and reflection. In the frustrations that were expressed by some of the participants, there is discussion of how the participants' low self confidence and lack of experience could have contributed to their negative experiences.

Collaboration

In the group reflection submitted in the lesson study portfolio, each participant indicated that the collaboration in developing the research lesson was most valuable. The three participants at Lolash Middle School had the following to share. Lydia wrote that the "collaborations and preparations for the research lesson make me tired to think about because of how long it took, but I loved bouncing ideas off each other and using each others' ideas." John wrote that, "Sharing ideas and knowledge and really working to make it a worthwhile experience for the students was something that I found invaluable." Similarly, Brad found the collaboration "fulfilling, both because I enjoyed the give and take involved both in the lesson planning, and in the post lesson review, as well as the planning for reteaching that we did." In a follow up interview Brad spoke about enjoying the "collaborative aspect of this. I especially like the collaboration with each other, and um, with you."

Holly wrote that the collaboration she sought from others in her school attributed to the success of her research lesson. In the final interview Holly specifically discussed how the special education teacher's insight helped her meet more students' needs, especially in the way questions were to be asked of students. Holly stated,

> like because I probably would have just asked that question and waited for responses and, if I didn't get responses, gotten frustrated, but knowing ahead of time, with just opening the question may not, the kids may not be very receptive to it; I need to prepare myself for that. I didn't get frustrated when I needed to like help the students out, thinking of, you know, where they could go with their ideas. (Interview, January 2010)

Similarly, Josie and Linda felt the supervising teachers' collaborative habits and willingness to support the lesson study contributed to their confidence in the research lesson. Josie commented that she thought the way they collaborated was quite realistic for their future practices as well. She stated, "because maybe one of us would come up with an idea, maybe the other one would adapt the idea or say I like this, but maybe for this week, we could do such and such, I think that is definitely realistic…" (Interview, January 2010)

Observing Classroom Practices

Only five of the six participants were able to observe classroom practices during the deliveries of the research lesson. This is because Holly was the delivering teacher for both the original and modified research lesson during her lesson study. While this limitation prevents her contributions to this discussion, it does not take away from what the other participants have to share.

Lydia said in the final interview that she found one of the more interesting aspects of conducting a lesson study to be “seeing what we mean to come across and whether or not it actually does come across.” Lydia saw lesson study as an opportunity to look at the actual delivery, “because in your head it’s coming across and it’s in your lesson plan but if you forget to say one thing in your lesson plan well that’s the whole point…” John wrote in the group reflection that he liked having multiple “eyes on the presentation” because it “allowed us to make changes on the fly and create an active learning environment.” Similarly, Brad wrote that he thought “having another set of eyes which was exactly on the same page in the same classroom to critique the lesson was very helpful in improving the lesson before it was re-taught.” These responses indicate that the participants recognize that the lesson study framework encourages an inquiry into teaching practices through observations.

Similarly, Josie wrote that one of her favorite parts “of the process was being able to walk around and observe the students. It was really interesting to be like a fly on the wall and hear their discussions and their comments.” Josie stated in the post reflection, “The lesson study process helped me understand *how* lesson plans can be adapted and improved from class to class. The process gave me practice in understanding how to make observations, what kind of observations to make, and how to use my observations to successfully modify and improve my lesson plans.” Linda agreed, stating that most of her past observations had been to assess students’ work quality, but that during the lesson study she found value in the way observations influenced their teaching practices. She stated,

> And that’s another thing that I think was important…I think on ya’lls part, it took more focus on observing and what they were doing and like

> listening and noticing that so and so got it or didn't get it and how….what the majority of the class, where are they at, and in reflecting on, you know, teaching practices and how, how it worked for you as a teacher and how it worked for them. (Interview, January 2010)

Lydia's mention of reflection and how it influenced changes in their teaching practices brings to the forefront the underpinnings of the lesson study framework.

Reflection

Each of the lesson study team members did attest to the importance of the reflection phase. For Brad, reflecting on the research lesson was, "I think, one of the best moments during the process… sharing with my group what we thought was working and not working in the lesson. Often times, after we teach, we're not sure if the lesson was successful, because we're so focused on simply covering the content that we need to, that we can't step back and simply check to see how we're doing." In the follow up interview John said, "I kind of felt like we've really been practicing reflective practitioning...um is that a word...So I don't think it is anything unusual to reflect." However, the type of reflections over the summer "were all very personal reflections about stuff going on at specific times where as the reflection we were doing for this was not the same type of thing." Linda agreed saying, "yea, I think a lot of my online reflections was more troubleshooting and brainstorming…" During the final interview Brad still felt this way about the data collection, but wanted to add that he also saw lesson study more as a way to improve one's ability to reflect. He explained that,

> What I've taken away from this is less that the lesson study process is about fine tuning specific lessons, as it is more developing the skills to fine tune your own lessons. Um, you know, you're going through this process and focusing on a specific lesson but when you've walked away from it you've developed this skill set – ideally you've developed a skill set to be able to fine tune other lessons with – You know, ways of looking at things, ways of approaching things, and if it makes you think about well

> we did this to improve this lesson can we do the same thing to other lessons? So I think of it more yes, you're fine tuning specific lessons, yes you're fine tuning specific units, but it's also a way to encourage you to develop the skills, think about your other lessons so that you can improve as a teacher as a whole. Kind of modeling – you guys talk a lot about modeling behaviors – and I think that's what that does, model behaviors that you should be doing for all of your lessons. (Interview, January 2010)

Holly saw the value in reflection slightly differently. In the final interview Holly talked about how the reflections made her realize that she was going to have to be open to changing her own teaching practices. She stated, "that you have to be willing to change if and when you see that something isn't working as well as you thought it would. This willingness to change can really make a difference in the amount of learning that can take place during a lesson." Holly also expressed that she felt a certain disposition was necessary for this to be a positive experience. She stated in the final interview,

> I think you already kind of have to be somewhat of a reflection practitioner to do it. Because if you weren't reflective, I don't think you could do this. But it helps you develop reflective thinking because you're working in a group where you're getting others ways that they look at things, so it's not just your own personal point of view. But more so than being a reflective practitioner, I think it has to do with, I don't know how to phrase this, but like maximizing student learning, like understanding how students learn and how you can maximize it in your classroom; not even necessarily through your own actions, but because of the way a student thinks or the way a group learns, or the way an individual learns, things like that.

Similarly, Linda and Josie commented that the lesson study helped them in "developing their ability to observe, reflect, and improve student learning." (Interview, January 2010) Linda specifically stated, "I came to realize the relevance of being able to create a good lesson plan incorporating the nature of science….the value of observing and reflecting on how the lesson was taught and how the students perceived the information…I feel like I am better prepared and have the tools necessary to constantly reflect and make myself better. " Linda wrote in her final reflection of the lesson study portfolio, “I love that it made us think like the students and evaluate what would work and what did not work. It also required us to constantly observe and reflect and taught us how to make adaptations. This is critical to becoming that wonderful teacher that we all want to be.”

Data Collection

Data collection was unique for each lesson study team. The lack of structure in the specific requirements associated with this participant generated data collection tool perhaps speaks to some of the variety. The lesson study team at Lolash Middle School developed a data collection tool, but it was primarily focused on learning goals outside of NOS curriculum. Holly at Deer Crossing Middle School developed a data collection tool that was focused on NOS curriculum, but had no opportunity to collect data since she was the single participant at this school. Josie and Linda at Muddy Banks Middle School did not develop a data collection tool. These two planned for observations to be written in the margins of the research lesson. However, after the lesson study cycle was complete, Josie and Linda went back through the notes and organized data that could be presented numerically with other observations typed and organized directly into an electronic version of the research lesson. Frustrations associated with data collection were commonly associated with feelings of inadequacy in narrowing focus during the deliveries. Many participants expressed that they felt there was so much to look at once, and it was difficult, if not impossible to discern what to observe for first and record later.

Linda wrote in the group reflection that data collection held little value for her except that it highlighted ways to improve classroom management and student on task behaviors. Lydia even expressed that she felt that she “disappointed” her university supervisor during the first reflection. She felt this kind of frustration could be avoided for future preservice teachers if the opportunity to "have seen more data on what kinds of things to look for, like maybe some evidence that students were learning NOS, taking good notes, based on their essay writing, or things like that" had been part of the preparation for conducting a lesson study. John agreed that the data collection "was pretty lost on me," but he did "think that on a much easier level it could be done very effectively by a few teachers." Brad concurred, stating, "Data collection during the actual teaching was difficult, though, because I always felt like there was so much going on within the classroom that I wanted to see, that I had a hard time remembering the things I was supposed to be recording." The participants' concerns about data collection are supported by the related analysis of reflection. For example, in the second delivery Linda collected data about student on task behaviors during each of the phases of the research lesson; a focus on routine aspects of teaching.

Linda and Josie's written reflections on the lesson study experiences were similar. At the same time, each of them found the actual data collection associated with the lesson study process to be a daunting task and the process in its entirety to be something appropriate for more experienced teachers. This idea that lesson study may be better suited for veteran teachers also came up in the final interviews with the other participants.

Lack of Experience

As the participants at Lolash Middle School began to discuss the way their lack of experience may have influenced the outcomes of their lesson study, they all agreed that maybe conducting a lesson study was more appropriate for later in their careers. For example, John said, "Yea, I think after becoming established as teachers, then yes, this should be a part of your professional development…Just the idea of doing reflection, but doing it in more of a systematic way; in a scientific way as it were…" John confirmed his own thoughts after thinking back to conversations with others about their lesson studies. John shared with us that these conversations had led him to think a lesson study should be "around something that has been a problem in the past" that "we're going to try to figure out what we can do differently and will work…So for us to say that we're just going to teach something and see what happens, is very different. Very, not what I expected I should say."

Similarly, Holly held one stipulation to participating in another lesson study. She commented that it would be important for her to have other experienced teachers working with her, as she felt she "missed out on some of the stuff by being the only person in a group" and that having the opportunity to observe "someone else's experiences and what they changed and how they changed it and why they changed it, what you can see, making relations or you should be able to, I would think, between your classroom and similar experiences and similar ways of teaching, similar practices,…" was something that she would want to be able to learn from others. She recalled that this frustration came head on when she was watching the Lewis (2002b) video, "Can You Lift a 100kg?" and she was thinking to herself then, "I know I was sitting there going, how on earth am I supposed to do this when they have a group of like six or seven experienced teachers doing this lesson study with groups of, I mean it was huge groups of students, and it was completely free inquiries; it wasn't even a guided inquiry, it was just go." While Holly agreed that her unique experience worked out, she felt like there were some aspects of lesson study that she did miss because of her isolated practicum experience. When Holly was asked about conducting another lesson study in the final interview, she had mixed feelings stating, “Yes and no, I mean, in this exact, like the way we did it, probably not unless it was like an assignment type thing...” She continued by saying, “but the general, what a lesson study is, you know, teaching something and looking at how the students, how they receive it, how they complete it, what they take away from it, the student learning, all of that stuff…Definitely.”

These participants perspective of the lesson study framework and their perspective of its effectiveness are invaluable. Lewis (2002b) asserts the need for understanding how lesson study can be used in the United States. These participants’ insights conjoined with the earlier data analysis contributes to not only how we can use lesson study in the United States, but also contributes to a larger body of literature that speaks to the need for developing teacher preparation programs which support reflective practices in a way that transforms teaching practices (Hiebert et al., 2007). Furthermore, the way lesson study provided an opportunity for the participants to practice teaching NOS through real classroom experiences sheds insight to the way NOS tenets can successfully become a natural part of classroom practice. Discussion of these implications will be elaborated upon in Chapter 5.

CHAPTER 5

DISCUSSION

Introduction

Science education researchers have long held beliefs that teachers' views of nature of science (NOS) are directly related to its integration in the classroom (Lederman, 1992). A body of literature exists that informs the way science teacher education programs promote shifts in NOS understandings (e.g., Akerson, Morrison, & McDuffie, 2006; Clough & Olsen, 2004; Lederman & Abd-El-Khalick, 1998). A separate body of literature informs the way reflection can transform teaching practices (e.g., Abd-El-Khalick, Bell, & Lederman, 1998; Matkins & Bell, 2007; Schwartz & Lederman, 2002; Schwartz, Lederman, & Crawford, 2002; Schwartz, Lederman, & Khishfe, 2002; Smith & Scharmann, 2006). The purpose of this study was to explore how preservice teachers' experiences in lesson study as a reflective, analytical process influenced their learning and teaching of NOS tenets. The following research questions guided this study:

1. How does the reflection that occurs in lesson study influence preservice teachers' transfer of NOS understandings into classroom practice?
2. How do preservice teachers' understandings of NOS shift as a result of the lesson study experience?

Data analysis indicated that the preservice teachers' experiences with lesson study supported the transfer of NOS understandings into classroom practice. Specific factors within the participants' experiences which inform the case study conclusions are presented first. Examination of the specific attributes from a methodological perspective and how this informs the effectiveness of the case is presented in the second section of this chapter. The implications of this research for alternative teacher preparation programs and suggested areas for future research will follow.

Analysis and Conclusions

Based on previous discussion of the research questions in chapter four and cross case analysis, three conclusions are drawn from this study. These conclusions serve to prompt discussion about factors influencing the understanding and teaching of NOS and reflection in lesson study. The conclusions from this case study are as follows:

1. A relationship exists between levels of reflection and the transfer of NOS curriculum into classroom practice.
2. A relationship exists between levels of reflection and the participants' perspective of NOS as a valuable part of classroom practice.
3. Participants' gained pedagogical NOS content knowledge as result of participating in the lesson study.

NOS in the Classroom

The first research question of this study examines how levels of reflection using the modified lesson study framework supported participants' NOS classroom practices. Important to the findings of this study was the relationship that emerged between participants' levels of reflection and the actual teaching of NOS. As expressed in the results section and re-illustrated below in Table 31, the participants who entered dimensions of inquiry at dialogic and transformative levels also exhibited change in practice while participating in the lesson study. From participant descriptions specific factors were identified that either supported higher levels of reflection or restricted others toward lower levels of reflection. This in turn contributes to the literature (e.g.,

Table 31

Cross Case Analysis of Dimensions and Levels of Reflection among All Participants

Site	Dimensions of Reflection	Levels of Reflection
Lolash	Focus	Dialogic
	Inquiry	Routine
Deer Crossing	Focus	Technical, Dialogic, Transformative
	Inquiry	Technical, Dialogic, Transformative
	Change	Dialogic
Muddy Banks	Focus	Technical, Dialogic
	Inquiry	Technical, Dialogic, Transformative
	Change	Dialogic

Lederman, 1992) by identifying factors that contribute to the successes or failures of these preservice teachers in transferring NOS tenets into classroom practice. Two identified factors for these participants were (a) participants needed supportive teachers who saw value in teaching NOS in the schools of their practicum placements, and (b) if the supervising teachers believed NOS to be valuable, then NOS instruction occurred even after the lesson study had been completed. These conclusions are consistent with recent findings in Akerson, Buzzelli, and Donnelly (2010).

Of the three lesson study teams, the teams at Deer Crossing and Muddy Banks Middle Schools entered dimensions of change. Consistently, these two teams also planned for and taught NOS during the lesson study. Ward and McCotter (2004) associate dialogic levels of reflection within the dimension of change as one where situated questions about teaching practice lead to a change in practice or perspective. Within the context of conducting the lesson study I found that the two lesson study teams successful in teaching NOS were also most commonly engaged in dialogic levels of reflection. During this dialogue questions were asked of each other, supervising teachers, and other experts about teaching NOS in a way that would improve student learning. Therefore, using the Ward and McCotter (2004) rubric as a guide, it can be explained that this higher level of reflection contributed to the overall change in these participants NOS pedagogical content knowledge.

Abd-El-Khalick and Lederman (2000b) call for research efforts in science education which seek to identify or isolate factors which "constrain or facilitate the translation of teachers' conceptions of NOS into classroom practice" (p. 696). In the same way that the dialogic levels of reflection were supportive of three of the participants who were successful in teaching NOS, the lack of dialogic levels of reflection limited those three participants that were unsuccessful. The lack of model mentors by whom the participants at Lolash Middle School could engage in dialogue with about the teaching issues around NOS served as a nemesis in their experiences. In developing the research lesson, these participants essentially relied on my pedagogical content knowledge and their own NOS understandings which were based on their experiences in the summer and fall courses. Supervising teachers in this school that did not assist in the development of the research lesson or other aspects of the lesson study resisted the use of instructional time to conduct the lesson study. In fact, one supervising teacher requested that the lesson study actually take place in a different classroom. Unlike Holly who sought others to assist her in developing the research lesson, these participants did not seek mentors outside of their supervising teachers or me. In the final interview these participants expressed that the stress associated with finding a classroom teacher that would even allow them to conduct the lesson study coupled with the lack of support by their supervising teachers made this experience overwhelming.

In some respect Holly's experiences at Deer Crossing were similar to those experiences at Lolash Middle. For example, Holly did not have the support of her supervising teacher in developing the research lesson, data collection, or reflection; as wells as, the supervising teacher did not believe in the value of making NOS an explicit part of the classroom instruction. Nonetheless, Holly did not limit her experiences because of these obstacles, and instead sought support outside of her own supervising teacher. The distinction between Holly and the participants at Lolash Middle School is in the efforts taken to make the lesson study a valuable endeavor. What we learn from this is the need for participants to value the teaching of NOS in order to be motivated to conduct the lesson study. Akerson et al. (2008) suggest that differences in values between preservice teachers, their supervising teachers, and university teachers could inhibit preservice teachers' willingness to plan and implement NOS.

Holly assigned value to both teaching NOS and conducting the lesson study. Thus was motivated to conduct the lesson study in a way that allowed her to personally benefit from the experience. From the final interview, we learn that Holly's motivation was attributed to the way she observed other lesson study teams benefiting from the lesson study framework and wanted to ensure this same kind of professional growth for herself. This assigned value was also a contributing factor to the experiences of the participants at Muddy Banks Middle School, but from a different source. For the participants at Muddy Banks Middle School, value in conducting a lesson study originated from the support of the supervising teachers found at their practicum placements.

While Holly had to seek out these teachers, the participants at Muddy Banks Middle School were placed with supervising teachers who saw the importance of what the participants were trying to accomplish. Participants at Muddy Banks engaged in continuous dialogue with their supervising teacher throughout the development of the research lesson and then even after the lesson study. Lydia explained that her supervising teacher was supportive of both the lesson study and the specific learning goals of NOS. In the final interview Lydia expressed that she had even engaged in conversations with her supervising teacher about NOS before the lesson study began and continued to discuss NOS after the lesson study cycle had been completed. This dialogue with supervising teachers who both supported teaching NOS and conducting a lesson study undoubtedly contributed to the higher levels of reflection and transformative outcomes for the participants at Muddy Banks Middle School.

From this discussion, two themes regarding the teaching of NOS emerge. We first learn that participant beliefs' about teaching NOS contributes to the overall outcomes, particularly the levels of reflection that occur about teaching and learning of NOS. These beliefs contributed to the motivation and disposition of participants, therefore also impacting the levels of reflection that occur in the lesson study and the classroom practices of those participants. We also learn that when participants' supervising teachers were supportive of teaching NOS it resulted in not only the explicit teaching of NOS during the lesson study but also after. The beliefs of these supervising teachers are vital to the enduring practices of teaching NOS for these preservice teachers. Drawing similar conclusions, Akerson, Buzzelli, and Donnelly (2010) recently published findings about four preservice early childhood teachers during their teaching internships. From data analysis Akerson et al. (2010) concluded that one of the two main factors which hindered or supported their participants' teaching of NOS was the influence of the cooperating teacher.

Assessing Views on NOS

The second research question asks about shifts in preservice teachers' understandings of NOS as a result of the lesson study experience. Analyses of views on NOS were assessed through the VNOS-b questionnaire and responses to interview questions. From these data sources, three significant themes emerged about the participants NOS views. These themes included (a) little to no improvement in the way the participants viewed NOS based on results from the VNOS-b, (b) a need for a different way for participants to reflect upon and express their NOS understandings, and (c) a shift in the ability to recognize space for the inclusion of NOS as part of classroom practice.

At the end of the fall semester participants were provided their latest responses to the VNOS-b questionnaire from the end of the summer course. None of these participants elected to add to their earlier responses to the VNOS-b. When asked for reasons in this choice during the final interviews, each participant indicated that they were okay with their responses at the end of the summer and didn't really know how they would have changed their responses. Even during the final interviews when each of the participants were asked to respond to the analysis that was included as part of their individual participant descriptions that they were provided, each indicated that they were comfortable with these informed understandings and that the analysis was an accurate depiction of the way they viewed NOS. However, significant in the findings of this study was the ability of all of these participants to recognize NOS as a part of other teachers' classroom practices. This ability to identify whether other teachers were integrating NOS in implicit or explicit ways could indicate a way to improve the likelihood of explicit teaching of NOS, and implies a shift in the participants' pedagogical content knowledge.

All of the participants indicated that after the lesson study they began to look at the way supervising teachers were using NOS as part of their classroom practice. All six indicated that they specifically observed for NOS being a part of the students learning objectives. Josie recalled, "I know at first, I really didn't recognize it (NOS) just because I had never thought about it before. But I actually started seeing it more and more and seeing places where either she incorporated it or she could have incorporated it." (Interview, January 2010) In addition, three of the six participants indicated that they had even tried to integrate NOS in other lessons after the lesson study. This shift in the way these three participants saw a space for how teaching NOS could actually be a part of classroom practice is an important factor. It gives further indication to a transformation in teaching beliefs, specifically value in teaching NOS. This is also consistent with data analysis of the transformative levels of inquiry experienced by these three participants.

For these three participants, their few attempts to transform NOS teaching practices to emulate more explicit approaches indicates less of a shift in their actual NOS understandings and more of a shift in the way they see a place for NOS in the classroom. This has additional implications as to the relationships between understanding NOS and teaching NOS. These participants' informed NOS views indicate a limit in their own understandings of NOS, as more informed views are indicators of significant depth in conceptual understanding of NOS. This implies that preservice teachers do not have to hold the more informed NOS views for each of the assessed tenets (e.g., empirical NOS, social and cultural influences of NOS, etc.) in order to teach NOS in a way consistent with their students' standards as outlined in the National Science Education Standards (NRC, 1996). This implication is supported in "How People Learn: Brain, Mind, Experience, and School" (2000), where the authors synthesize research results to conclude that the "first factor that influences successful transfer is degree of mastery of the original subject. Without an adequate level of initial learning, transfer cannot be expected" (p. 53). In other words, informed views of NOS might be the "adequate level of initial learning" that support a starting point for the transfer of NOS tenets. At the same time this minimum level might restrict the preservice teachers in the way that they are able to build pedagogical content knowledge.

These participants held informed NOS understandings in only some of the assessed NOS tenets and were still able to gain pedagogical content knowledge about teaching NOS, while not showing any personal gains toward more informed NOS understandings. This theme among the participants leads to additional questions about the potential relationship between limitations associated with varying degrees of NOS understandings, acquisition of pedagogical content knowledge, and how both would influence the actual teaching of NOS.

After the participants' failure to respond to the VNOS-b questions in the third administration and the minimal response to questioning about the VNOS-b in the final interview, it became apparent that there was disconnect between the way participants perceived their work in the lesson study as a means for continuing to improve NOS understandings. While this could suggest that the VNOS-b was not an appropriate data source at this point in the participants' experiences, there are several factors that could have contributed to this disconnect which should be discussed in terms of changes in the research design for a future study. At the forefront of concerns is the inconsistent approach to explicitly addressing NOS that occurred during the fall semester. Participants were never explicitly confronted with the ways teaching NOS had the potential to shift their own NOS understandings. In addition, when modeling the lesson study cycle and providing rationale for the lesson study, a deepening of their NOS understandings was never part of the rationale provided. In this way, the teaching of NOS was approached somewhat implicitly through the lesson study assignment and experiences. Furthermore, the modifications to the administration of the VNOS-b (e.g., allowing participants to reflect upon earlier responses and type into an electronic version of the questionnaire) could have also contributed to the participants' choice and failure to respond in this third administration.

Effectiveness of the Case

This dissertation is a case study that explored lesson study experiences during a practicum and analyzed participants' levels of reflection and NOS understandings. The units of analysis for this case study were the three lesson study teams consisting of six preservice science teachers. The lesson study experience was designed based on several seminal pieces of literature and the prior experiences in the pilot case. Literature informing the case study includes the work of Lewis (2002b) who asserts the need to more completely understand the potential of lesson study in the United States. Additional influence originated from the work of Hiebert, Morris, Berk, and Jansen (2007) who assert the need to prepare teachers "to learn from teaching" by developing knowledge, skills, and dispositions which could contribute to the preservice teachers' abilities to study and improve their teaching over time (p. 49). Lastly, work of Abd-El-Khalick and Lederman (2000b) and Lederman et al. (2007) which asserts the need to identify factors that contribute to or impede the transfer of NOS into classroom practice influenced the case. While not an explicit question in this dissertation, the effectiveness of the case can be evaluated based on the ways the data collection and analysis contribute to these bodies of literature.

An examination of the effectiveness of this case based on how the outcomes inform the call for literature (e.g., Fernandez, Cannon, & Chokshi, 2003; Lewis, 2002b; Lewis, Perry, & Murata, 2006) within the existing body of knowledge of lesson study is asserted first. Lewis (2002b) asserts the need to more completely understand how lesson study can be used in the United States. This research contributes to our understanding of how lesson study can be used in alternative teacher preparation programs in several ways. Specifically the outcomes associated with the research design itself aid in identifying constraints and successes for these participants, as well as similar candidates in a future study. In addition, we learn from the participants' perspectives that some components within each of the lesson study phases were valued over others. In the following sections these aspects are discussed at length.

Curriculum Goals

For this study, the intended NOS learning goal was purposefully selected and imposed upon the participants. This is a modification to Japan's lesson study where the curriculum goal is teacher initiated. Rationales for imposing this curriculum goal were clearly stated and explained to the participants. It was understood by participants that this NOS focus represented a pervasive issue aimed to improve scientific literacy in the United States. Confrontation with some of these NOS tenets in the summer course had provided the participants with time to recognize their own naïve NOS views and explore reasons that these views were held. As participants began to realize that their naïve views were a result of prior experiences in science classes, socio-cultural beliefs, etc. they also realized that their future students' views would likely be similar. Specific strategies for teaching NOS in ways consistent with more informed views was part of the summer course; in anticipation of providing the preservice teachers with prior experiences from which to apply in this lesson study.

In designing the study, this curriculum focus was provided in order to guide the transfer of NOS teaching. It was expected for these preservice teachers' lack of teaching experience to render them incapable of narrowing focus toward curriculum while in a lesson study. Prior research showed that novice teachers tend to focus on classroom management, day-day tasks associated with teaching, etc. (Abd-El-Khalick et al., 1998; Bell et al., 2000; Lederman & Zeidler, 2001; Smith & Scharmann, 1999). This modification to Japan's lesson study did successfully support the preservice teachers' thinking about NOS as they developed the research lesson, conducted research, etc. during the lesson study cycle. While the focus was not entirely on NOS for all of the lesson study teams, there were prolonged instances when conversation concentrated on teaching and learning NOS for all of the participants. This is promising for both NOS and lesson study.

Furthermore, by imposing this curriculum goal the participants were engaged in guided inquiry, allowing the alternative certification program to maintain consistency in a reform based approach to preparing these preservice teachers for actual classroom practice. However, one inconsistency was realized after the study was concluded. The participants were never explicitly told how the lesson study cycle modeled guided inquiry, but were rather informed of the ways it modeled teacher initiated professional growth focused on student learning. This approach to presenting lesson study was perhaps inappropriate in regards to the types of prior experiences these participants had which informed their teaching knowledge base. Nonetheless, of the six participants, three were successful in focusing on the intended NOS curriculum goals during the entirety of the lesson study. The other three participants, while unsuccessful in maintaining focus on NOS did come to realize the importance of this intended focus after the lesson study was discussed during their final interview. This suggests that the modification to the curriculum focus provided to these participants may be useful in implementing future lesson studies.

Developing the Research Lesson

From final interviews, web based forum postings, and fields notes, we find that all of the participants valued collaboration in developing the research lesson. The collaboration efforts of the three lesson study teams were individually unique. The lesson study team at Lolash Middle School did not collaborate with supervising teachers at the school, but they did collaborate with each other and me. Similarly, Holly at Deer Crossings collaborated with other teachers, peers, and me; but not her own supervising teacher. The lesson study team at Muddy Banks was the only team that had the full support of the supervising teachers. For all of the lesson study teams this collaboration was extensive and resulted in feelings of ownership in the research lesson. Bransford et al. (2000) assert that "two major themes emerge from studies of teacher collaborations: the importance of shared experiences and discourse around texts and data about student learning, and a necessity for shared decisions" (p. 54).

Participants at Lolash provide an opportunity to understand how their lack of discourse and sharing o experiences with their supervising teachers created restricted their overall experiences in teaching NOS and effected their disposition in conducting a lesson study. Further evidenced is in the counter actions of the single participant at Deer Crossing who opted to seek additional insights in the collaboration phase. These opposing experiences allow us to identify an aspect of disposition necessary for teaching NOS when there is lack of support. In "How People Learn: Brain, Mind, School, Experience" (2000) the authors explain,

> People often need help in order to use relevant knowledge that they have acquired, and they usually need feedback and reflection so that they can try out and adapt their previously acquired skills and knowledge in new environments. These environments—the schools—have an extremely important effect on the beliefs, knowledge, and skills that new teachers will draw on. It is the difficult transition, in Lee Shulman's (1986) terms, from expert learner to novice teacher. (p. 203)

When Holly at Deer Crossing was unexpectedly confronted with lack of support and differences in teaching beliefs, she chose to seek support from other teachers and peers. This choice indicates that part of the explanation provided to future lesson study participants should include forewarning to this possibility and address ways to overcome such obstacles. As Bransford et al. (2000) claim and as was evidenced in the Lolash Middle school participants' experiences,

> In particular, the dissonance between what is taught in college courses and what happens in classrooms can lead to later rejection of educational research and theory by teachers. This is due, in part, to the ways in which they have been taught in the disciplines and how their colleagues teach. Although teachers are urged to use student-centered, constructivist, depth-versus-breadth approaches in their education classes, new teachers often see traditional teaching approaches in use at the college level and in the classroom next door. Beginning teachers are especially influenced by the nature of the schools in which they begin their teaching. (p. 204)

A relationship existed between the three participants at Lolash Middle School and their supervising teachers' beliefs about teaching NOS and the type of support that was provided. According to the participants, these supervising teachers held little to no value in teaching NOS. During the course of structuring the logistics of the lesson study the participants had to justify their use of class time to conduct a lesson study, look for other classrooms to conduct the lesson study because of lack of support, and were afforded no opportunity to observe teaching practices consistent with what was advocated by the university. These experiences led to overall feelings of an unsupportive environment and much uncertainty in the way the lesson study would unfold. These experiences also clearly identify constraints associated with both teaching NOS and conducting a lesson study. A most undesirable outcome of conducting this study would be for participants to reject educational research and theory. Sharing these experiences accompanied with dialogue about the very different outcomes of Holly's lesson study would be important in a future study.

Holly's experiences were much different than the participants at Lolash Middle school. While Holly did focus on aspects of teaching outside of NOS, such as setting up materials and student behaviors, she was still able to focus on NOS and transformed her teaching perspective as a result. For Holly and the participants at Muddy Banks where support played an integral role in their teaching practices during the lesson study, attempts to teach NOS even occurred after the lesson study. However, for Holly the supervising teachers' continued lack of support in teaching NOS and differences in teaching beliefs resulted in her eventually giving up. Nonetheless, this provides evidence that the lesson study framework does offer some medium of support for teaching NOS, but that similar teaching beliefs must also exist in order for preservice teachers to feel supported in their attempts to integrate NOS. As evidence, while Holly's attempts ceased, the participants' at Muddy Banks continued to test ways to integrate NOS even after the lesson study. Therefore it can be asserted that a direct relationship exists in long term, successful teaching of NOS and the presence of supportive supervising teachers with similar teaching beliefs.

Conducting Research

Less desirable outcomes of this study, such as focus outside of NOS, lack of supervising teacher support, or failure to collect and later analyze data during the delivery phase contributes to our ability to anticipate and circumvent additional obstacles in using lesson study in alternative certification programs. The participants at Lolash found data collection during delivery to be overwhelming and were comparatively unsuccessful in the data collection component of conducting research. Fernandez et al. (2003) forewarned of such obstacles. As a result of these participants' inability to use a "researcher lens" during the lesson study cycle their experiences with lesson study also functioned at lower levels of reflection within the inquiry dimension as defined by the criteria in Ward and McCotter (2004). This lack of researcher lenses "tainted the validity of their teaching experiment" (Fernandez et al., 2003, p. 175). Fernandez et al. (2003) assert that in order for the ideals of Japanese Lesson Study to be evidenced in the

United States, the need for particular lens to be present and a natural part of the disposition of those participating in lesson study is necessary.

Reasons for the participants inability to adequately switch lens during the lesson study could be attributed to the idea “that experts recognize features and patterns that are not noticed by novices,” an aspect of conducting research in lesson study that must be mastered in order to improve instruction(Bransford et al., 2000, p. 36). Ensuring the support of the supervising teachers at the participants’ schools is one way that this obstacle could be negotiated. Bransford et al. (2000) explain that what is noticed by expert teachers is much different than what novices observe. The authors deduce from findings in research that “One dimension of acquiring greater competence appears to be the increased ability to segment the perceptual field (learning how to see).” (p. 36) The authors emphasize research “on expertise suggests the importance of providing students with learning experiences that specifically enhance their abilities to recognize meaningful patterns of information (e.g., Simon, 1980; Bransford et al., 1989)” (p.36). Essentially this indicates that the role of the supervising teacher as a model for conducting research is critical to its usefulness in a lesson study. This assertion is also supported by those three participants who were successful in using a researcher lens. Model mentors, either the supervising teachers or I, provided observed data during delivery; as well as, additional suggestions for improving student learning of the NOS goals as a result of what was observed during delivery. During reflection this expert perspective guided analysis for these three participants.

Furthermore, from the final interview we find that all six participants’ learned about teaching as a result of completing the lesson study cycle. While some participants focused more on student learning of the intended NOS focus than others, all participants still learned general aspects of student behavior, expectations, and the effects of teaching on these things. This supports conclusions drawn in Fernandez and Cannon (2005), where conclusions provided evidence to substantiate the claim that lesson study does in fact provide an entry point for improving pedagogical content knowledge. This also tells us that the core features of the lesson study framework where teachers observe live classroom lessons while collecting and analyzing data on teaching and learning (Lewis, Perry, & Murata, 2006) was perhaps no longer an abstract strategy for these participants, but an understood approach to teaching. Bransford et al. (2000) explain, “We know that increasing experience and knowledge in a specific field… has the effect that things… which, at earlier stages, had to be abstracted…are apt to be immediately perceived at later stages. To a rather large extent, abstraction is replaced by perception…” (p. 32).

Reflection

The effectiveness of this case is additionally asserted in the way it contributes to the call for research which explicates successful approaches for teacher preparation programs to support preservice teachers with practical experiences that promote professional growth through reflection (Hiebert, Morris, Berk, & Jansen, 2007). By the participants’ own account the modified lesson study framework used in this case assisted them in developing knowledge, skills, and dispositions which could contribute to the their abilities to study and improve their teaching over time (p. 49). From conclusions drawn in this study as to the relationships between levels of reflection and improving teaching practices or perspectives about NOS, the framework of lesson study is validated as a means for doing just this. While analysis maintains higher levels of reflection where participants focused in the intended ways of teaching and learning NOS, even those lower levels of reflection that occurred supported the professional growth of the participants in other ways. While these conclusions were less desirable; this does not take away from the overall effectiveness of using lesson study to support preservice teachers in reflective practices. The participants themselves best explained this as they reflected upon each of the phases of the modified lesson study framework in their final interviews and portfolio reflections. In these reflections, the time for structured reflections about the deliveries of the research lessons was highlighted not only as a positive learning experience by all of the participants, but also as meaningful in terms of developing skills and knowledge to become lifetime reflective practitioners.

While a greater degree of effectiveness of this case could be established if all of the participants had reflected on how their teaching had impacted student learning of NOS, this does not take away from the way the case contributes to the body of NOS literature which seeks to identify factors that support explicit NOS teaching (Abd-El-Khalick & Lederman, 2000b; Lederman et al., 2007). The earlier established conclusions indicate that lesson study supported reflection about teaching NOS for three of the six participants. While these conclusions highlight inconsistencies between the imposed focus on NOS curriculum goals for K-12 students and the participants' actual teaching practices, it also addresses a larger theoretical proposition relating to the transfer of learned content knowledge. Bransford et al. (2000) discuss elements that support learning and that transfer of that learning. Elements include such things as an initial level of understanding of content (versus memorization), time to explore meanings, process, and make connections, deliberation about understandings through feedback and metacognitive approaches, motivational factors, and the contexts used to support transfer.

One aspect of this research design that would have resulted in more consistent, desirable outcomes would have been to take a metacognitive approach to teaching and learning NOS in the fall semester. "A metacognitive approach to teaching can increase transfer by helping students learn about themselves as learners are in the context of acquiring" pedagogical content knowledge (Bransford et al., 2000, p. 78). One seemingly ineffective measure for the case was in the VNOS-b instrument used at the conclusion of the fall semester to assess the participants NOS understandings. From the lack of responses on the questionnaire and in final interviews it became apparent that participants did not realize that the VNOS-b was an additional reflection instrument for deepening their NOS understandings nor did they make a connection between their own NOS understandings and the reflection about teaching NOS required in lesson study. When asked in the final interview about the lack of responses, each of the participants eluded to a degree of confusion as to why they were being asked to answer these questions again. Holly said, "NOS wasn't really part of the semester…" Josie commented that she just "didn't really know how she would make her answers any different." The participants' reaction to the VNOS-b at this point in the semester indicates a need for changes in the case design. As suggested earlier, a metacognitive approach would "increase the degree to which students will transfer (learning) to new situations" (Bransford et al., 2000, p. 67). Brasnford et al. (2000) suggest that this include time and opportunity for the preservice to "become more aware of themselves as learners who actively monitor their learning strategies and resources and assess their readiness" (p. 67). At minimum, this would mean a difference in the way the VNOS-b is presented at the beginning of the fall, the inclusion of additional NOS activities that aimed to initiate reflection on those more naïve NOS views (e.g., social and cultural values of science, empirical NOS), and open discussion about the obstacles being faced during the practicum.

Implications in Science Teacher Preparation Programs

This research explored how the lesson study framework might support graduate level preservice science teachers' transition of contemporary NOS understandings into classroom practice. The outcomes of this study contribute significant data to the knowledge base of how science teacher preparation programs can both promote the teaching of NOS tenets and foster reflection about student learning when using lesson study. Implications of this research will be addressed in two ways. First in the instructional decisions associated with the planned NOS experiences and what this means for science teacher preparation programs. Second in the instructional decisions associated with the modified lesson study framework and the subsequent course requirement for completing a lesson study cycle. Within these sub-sections, discussion of possible modifications in future research is intertwined.

NOS in Science Teacher Preparation Programs

Data analysis of NOS understandings from the beginning and end of the summer course showed growth in the participants NOS understandings of specific tenets. This implies that these instructional decisions were successful approaches to improving preservice teachers' understandings of some NOS. However, gaps remained in the participants' NOS understandings at the end of the summer semester, especially in the tenets associated with the empirical NOS, the impact of social and cultural values associated with scientists' work, and the scientific community as a whole. Social dimensions of science associated with these NOS tenets are ironically the "weakest, least well developed and most confused, and in which most teachers are most reluctant to teach…" (Hodson, 2009, p. 86). This conjoined with the participants' failure to recognize how the lesson study conducted in the fall served to support additional reflection upon their NOS understandings indicates a need for additional explicit, reflective NOS instruction. The addition of such lessons during the fall semester could have allowed the participants an opportunity to continue growing in the ways they understood NOS and further contextualize their experiences through the lesson study.

These additional lessons could have been accomplished in several ways during the following fall semester. One such way might be by following models of conceptual change. This would mean sharing with the participants their summer analysis from the VNOS-b and discussing patterns seen in the class as a whole. By doing so, participants might be more motivated to continue exploring NOS through some of the classic activities (Abd-El-Khalick & Lederman, 1998) or some other performance based contexts (e.g., gestalt imagaes, transforming cookbook labs, critiquing curriculum). Exploration of the concepts could include such activities coupled with opportunities to reflect on how they perceive their NOS understandings to be shifting. These suggestions are discussed at more length below.

Another way might include using the actual experiences of the participants as a springboard for discussion during structured class time. Basis for this implication originated during the fall semester data collection. Linda wrote in one of her web based forum postings about the misleading structure of textbooks. This was a missed opportunity to address NOS issues that arise in actual teaching practices. Linda had written that textbooks, “really and truly give a false sense of how these things were really discovered and what science really is….” In situations such as these that arise in the reality of classroom practice, Hodson (2009) proposes to address “NOS issues as the need arises, and we should seek to confront students with a range of alternative views, provide the necessary support and guidance for them to engage in critical debate and argument…” (p. 77). In specific counter to the reality that these participants struggled most with the social dimensions of science, Hodson (2009) argues that the discussions which would ensue as a result of such opportunity would

> provide a powerful counterpoint to traditional textbook accounts of theoretical developments that pay scant attention to the personal and social dimensions of scientific practice, neglect to consider the ways in which the decisions and actions of scientists are influenced by their worldviews, feelings, attitudes and prejudices, and fail to acknowledge how science is subject to a wide range of sociocultural and economic influences. (p. 86)

Clough and Olson (2004, 2006) might also suggest targeting the pervasive naïve views about NOS by using an instructional sequence that allowed participants to confront naive conceptions, and then participate in metacognitive activities. Clough and Olson (2004, 2006) suggest NOS instruction to include such things as gestalt switches to guide conversations about the relevance of prior knowledge on observations, preservice teachers engaged in tracking changes of their NOS views, and conducting peer interviews. Clough & Olson (2004) also suggest contextualizing NOS instruction in science content, meaning the application of an informed NOS understanding in modifying a cookbook lab or illustrating how science works in historical and contemporary examples connected to fundamental science ideas. Holly's decision to transform her cookbook lab and the related experiences in developing her research lesson was again a missed opportunity for all of the participants. By simply sharing and discussing these experiences with the entire class, others could have possibly have benefited.

While this is just a few suggestions for modifying the NOS experience afforded future participants in a similar case study, it also stands to reason the depth at which participants were able to address NOS curriculum in their teaching practices during the lesson study would also change as a result of such additional NOS instruction. These type lessons would also provide participants additional mediums for support in their preparations and planning for a lesson study, a known factor restricting the success for some of these participants.

Lesson Study in Science Teacher Preparation Programs

With the exception of teacher initiated curriculum at the focus of improvement, the modified framework of lesson study used in this course maintained core features consistent with Japanese Lesson Study. This modification was considered critical in the setup of this case study, as it was understood through prior research that preservice teachers struggle with higher levels of reflection focused on improving their own teaching as measured by way of student learning (Abd-El-Khalick et al., 1998; Bell et al., 2000; Lederman & Zeidler, 2001; Smith & Scharmann, 1999). Transformation of the preservice teachers' students' conceptions of NOS were highlighted rationales in imposing this curriculum focus in the participants' lesson study. I wanted to determine if preservice teachers could be pushed to reflect upon curriculum issues, specifically NOS, and if lesson study could support this. All of the participants were able to maintain aspects of collaboration, delivery, and reflection in their lesson studies. This gives hopes to the potential for lesson study in alternative teacher certification programs. However, only two of the three lesson study teams were also able to focus data collection on analysis of NOS in their reflections and subsequent instructional decisions. The more desired outcome was continuous focus on teaching and learning NOS.

Consistency between qualities of high level of reflection and Japanese Lesson Study support the use of the Ward and McCotter (2004) instrument to analyze levels of reflection. For the two lesson study teams able to function beyond the routine and technical levels of reflection there was a greater sense of professional growth and continuous gain from the lesson study experience. For example, the understandings associated with teaching NOS that resulted from their experiences allowed these three participants to continue integrating NOS in future lessons. This additionally supports Fernandez and Cannon's (2005) claims that lesson study opens the door for improving pedagogical content knowledge. These participants were also able to switch critical lens in their lesson study, an aspect Fernandez et al. (2003) asserted was necessary for the success of lesson study. For example, these three participants used evidence from student artifacts, data collection, and observations to support the process and decisions made with the modifications to the research lesson. For the lesson study team that functioned at lower levels of reflection, data collection and analysis did not drive discussions or reflections. Fernandez et al. (2003) argue that this must be a natural part of the disposition of those participating in lesson study or, consequently, the lesson study experience is tarnished. These differences in experiences contribute to how we understand the potential for lesson study in teacher preparation programs and inform the following suggestions for modifications in future research.

If considering a future study I propose four modifications to the way the lesson study experiences might occur. These modifications would be in the presentations of lesson study itself, specific training in data collection, and the availability of resources for the development of the research lesson. These modifications have been considered as a result of the participants' experiences and research based suggestions (e.g., Lewis, 2002a).

In the presentations of lesson study I would add three specific components. First, additional reading assignments would be included that shed light on others' experiences with lesson study. These reading assignments would be more recent versions of publications such as that in *The Northwest Teacher* (2001) or from the National Science Foundation (NSF) through http://www2.edc.org/lessonstudy, where teachers talk about how conducting lesson studies have contributed to their ongoing professional growth. These reading assignments would correspond to the presentation of the "Can You Lift a 100kg?" video. The video would still be stopped for discussion points as suggested in Lewis (2002a), but would also include discussion that compared the experiences in Japan to those in the United States.

Another addition to these presentations would include troubleshooting sessions, where participants would begin to share some of the logistical issues that arise in their practicum experiences. This modification was inspired as a result of the several missed opportunities to address issues and provide support for participants in this study while they were in their practicum schools. Therefore, it is expected that these sessions would need to be structured once the practicum experiences have begun and be structured such that preservice teachers are comfortable openly discussing their experiences. By simply having the opportunities for discussion built into class time once the practicum experiences have begun, missed opportunities for learning are avoided. In considering how to initiate conversations in these troubleshooting sessions I might begin by sharing a past participants' struggle that would hopefully generate conversation about possible resolutions. As preservice teachers became comfortable sharing their own experiences, specific suggestions offered by peers and supervising professors would offer an additional medium for support. This would potentially circumvent the initial frustrations and resolve feelings of isolation, differences in teaching beliefs, and any dissonance that may be developing between the practicum schools and the university.

A third modification I would make in the lesson study experiences provided for a future study would be to include an observation training session that modeled the "conducting research" phase of lesson study. Observation training is highly recommended by Lewis (2002a). In this observation training session participants would essentially practice using critical lens (Fernandez et al., 2003) in the context of observing video footage of others' teaching. A guided inquiry approach would be taken in this observation training. Prior to viewing the video, preservice teachers would be expected to read a provided outline of the related research lesson with explicit emphasis on the NOS pedagogy being employed and the specific data collection that emulated NOS teaching concerns for the research lesson. Class would begin by checking for understanding of the NOS teaching and learning that was the focus of inquiry in the research lesson. This would be followed by a practice session of "conducting research" and whole class discussion about the preservice teachers' observations. Based on the preservice teachers' comments, additional guidance as to how modifications are determined, how focus is narrowed, etc. will presumably ensue.

As a final modification to the lesson study experiences the accessibility of curriculum resources would be improved. The development of a repertoire of resources that included prior lesson studies, unit plans previously created by the cohort, etc. would be made easily accessible for a future group of preservice teachers. From my own observations I noticed that the development of the research lesson took a significant amount of time for participants to develop. This was partially due to the minimal number of resources available and participants' familiarity with the middle school curriculums. One option would have been to have participants share each of their units of instruction that had been developed at the end of the summer semester as a starting space for resources for the research lesson in the lesson study. This unit of instruction was seen as a rigorous, but worthwhile task by the participants. It pushed the participants to plan for explicit NOS instruction in ways consistent with problem based learning. Adding value to this end-product could have been accomplished by encouraging participants to use these developed plans for consideration or modification in their lesson study. Another option would be to collect prior lesson studies, state supported middle school curriculum, and a list of online databases so that some class time could be used in gathering sources, working through NOS instructional decisions, and collaborating with the larger group of peers.

Future Research

This study attempted to explore preservice teachers experiences as they completed a modified lesson study cycle focused on NOS tenets. Participants in this study demonstrated informed views on NOS in dimensions such as the tentative NOS, function of theories and laws, and the creativity in science. However, participants did not demonstrate informed views on social dimensions of science. In addition, all of the participants did not use explicit NOS instruction in their teaching practices during the fall practicum experience, nor focused on the intended student NOS learning goals in their lesson study cycles. The results of this research study demonstrate a need for additional research into both preservice teachers' understandings of NOS, how to teach NOS, and their capacity to use various critical lenses within a lesson study.

The unique nature of case study would first indicate that a longitudinal study of these particular participants would be useful in several capacities. Following these six participants into their teaching internship and exploring how or if they integrated NOS in explicit ways in their classroom would provide unprecedented data to the science teacher preparation community about how effective the lesson study experience was at transforming teachers teaching and perspectives of NOS. Although each of the participants believes NOS is a necessary component of science teaching, it would be enlightening to know if they teach NOS in explicit ways. If they do teach NOS explicitly, it would also be interesting to examine which tenets were highlighted, how they were integrated, and how their own understandings of NOS were influenced as a result of these experiences. If the participants did not teach NOS in explicit ways, it would be additionally beneficial to identify factors that prevented this from occurring.

Continued research into this subject would also include repeating this experience with another larger group of preservice science teachers. In this future study the modifications described above would be used. Knowing how these modifications impacted the outcome of a larger group of participants' experiences in terms of pedagogical content knowledge, disposition, and levels of reflection could have a profound impact on future participants' understandings of NOS, reflective teaching practices, and ability to use critical lenses within their teaching.

A final suggestion for future research is to use these same NOS and lesson study experiences with in-service teachers who volunteered to participate in professional growth of this nature. This research approach would actually be more consistent with Japanese Lesson Study as a teacher initiated, teacher driven approach to professional growth aimed at improving student learning of historically difficult concepts. Some of the participants in this study expressed their frustrations with differences in pedagogy proposed by the university and those practiced within their fall practicum placements. If in-service teachers volunteered to participate and transformed their perspectives and teaching practices associated with NOS, these experiences would further explain the potential of lesson study in the United States.

Limitations of the Study

This case study explored at depth the experiences of six preservice science teachers and their reflections upon teaching and learning NOS. A premise of the study was that the reflection that occurred in lesson study would yield data that would contribute to how we understand the potential of lesson study to support shifts in NOS understandings and explicit NOS teaching. The participants in this case study completed a lesson study cycle with research lessons that included explicit teaching of NOS, yet inconsistently reflected on student learning of NOS with only three of the six teaching NOS explicitly. The planning of NOS within the research lessons and the higher levels of reflection that did occur are confirmation of the research design. Nonetheless as is typical of qualitative methodologies, particularly case study, certain limitations of the study need to be presented.

The participants chosen in this case study unintentionally represented a “revelatory case…regarded as discovery and to provide an opportunity for doing an exemplary case study” (Yin, 2003, p. 162). The discovery nature of this case study later revealed that the participants’ experiences could be represented on a continuum which might provide the initial data that could lead to a breakthrough in theory development of the relationship between levels of reflection supported in the lesson study framework and transformation of understanding and teaching NOS. In practical terms this potential cannot be ignored in efforts to promote critical scientific literacy among both students and future teachers. Because of this, one limitation in this case study is in the few sites that were included in data collection and analysis. While these selections were purposeful in ensuring that all participants had the same NOS and lesson study experiences, this limited the number of sites where replication across sites could be established. Instead, data revealed three quite unique experiences that were represented on a continuum of varying experiences.

In addition to the site limitations in this case study, the researcher role within these sites had a direct impact on the outcome of these participants’ experiences. While establishing rapport with the participants during the summer NOS experiences and continuing to earn their trust and respect during the fall lesson study experiences, accuracy in the data collected is achieved. At the same time, field notes served to document these casual and formal sources of observational evidence. While these measures were taken to ensure reliability of the data collected, this data also speaks directly to the way my relationships with the participants and specific biases impacted collaboration, reflections, and modifications during the lesson study cycle. While my roles as instructor and researcher were clear to each of the participants, the additional role of participant-observer was assumed when observing participants at their middle schools during the fall practicum placements.

Yin (2003) identifies several problems associated with the role of participant-observation, all of which present limitations in this case study. Most of these problems are associated with potential biases. Yin (2003) states that the researcher has "less ability to work as an external observer and may, at times, have to assume positions or advocacy roles contrary to the interests of good scientific practice" (p. 94). The participants considered me one of the contributing members of their lesson study team, therefore including me in the development of their research lesson, data collection during their deliveries, reflections between deliveries, and in final reflections. While again, this led to significant and accurate observational evidence with which to explore their experiences, it also resulted in my contributions to the way these events unfolded. My contributions were influenced by (a) my beliefs in the importance of teaching and understanding contemporary views of NOS, and (b) my pre-conceived notion that by encouraging higher levels of reflection during the lesson study, the participants would be successful in teaching NOS in explicit ways.

Summary

In this research study, data collection and analysis indicated that preservice science teachers can transform contemporary NOS tenets into their classroom practice supported by the modified framework of lesson study. When participants engaged in high levels of reflection according to the Ward and McCotter (2004) reflection rubric, dialogic inquiry ensued leading to changes in teaching practices or perspectives. This provides significant evidence to the potential of the modified lesson study framework in supporting the development of knowledge, skills, and disposition necessary for preparing science teachers to be reflective practitioners. While all participants were not successful in teaching NOS in explicit ways, during final interviews all expressed understanding in the way the lesson study intended to support this reflection about students' learning. Participants also expressed willingness to participate in similar reflective structures in their futures. Participants did not demonstrate shifts in their NOS understandings as a result of the lesson study experience, indicating disconnect at the time when the VNOS-b questionnaire was administered. Instead, some participants demonstrated growth in their pedagogical content knowledge. This was evidenced in the way they understood the potential space for teaching NOS in explicit ways in their actual classroom practice. This also indicates that in lieu of some participants' lack of success in teaching NOS, their pedagogical content knowledge associated with NOS did change over the course of the study, a critical aspect in the transfer of NOS into classroom practice.

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APPENDIXES

APPENDIX A

NOS ACTIVITIES

As described in Chapter 2 and 3, “classic” natures of science activities include such things as “Tricky Tracks” and “The Tube” (Lederman & Abd-El-Khalcik, 1998). The framework for using these explicit, reflective NOS activities is outlined in Lederman & Abd-El-Khalick (1998), as well as, copied here as Appendix A. As described in Chapter 3, these activities were part of the instructional approaches used in the Introduction to NOS course in summer 2009. After the NOS activities, contextualized, or content based lessons, were used to complement the related NOS concepts explicitly reflected in the “classic” NOS activity. These activities are have additionally been included in Appendix A and are presented in the order with which it was delivered.

“Tricky Tracks !”

This activity can be typically used to introduce students to the NOS. You can use the activity to establish an atmosphere that supports your students' active participation in classroom discussion. This atmosphere is crucial if you are to derive the most of this activity. `Tricky Tracks!’ conveys to students the message that every single idea of theirs counts irrespective of it being the `correct' answer.

The activity aims to help students:

1. Distinguish between *observation* and *inference.*
2. Realize that, based on the *same* set of evidence (observations, or data), several answers to the same question may be equally valid.

Possible Scenario

1. Place Figure 7 on the overhead projector. Ask students to write down an account of what they think might have happened as indicated by what they see. A typical story line is that "two birds approached each other over the snow, had a fight, and the big bird ate the smaller one and went on its way." Make sure that each student writes his/her own account. This written record will render students' dissatisfaction with their accounts greater and facilitate their attending to the ideas being presented.
2. Place Figure 5 on overhead. Ask students: "What do you observe?" Typically students would answer: "Bird (or any other animal) tracks" or "Tracks left by birds (or other

animals) as they walked toward the same spot," etc. Accept *all* answers at this point and avoid passing any judgment. You can list those answers on the board.

3. To continue with the bird scenario, at this point you may ask: "Can you see the birds?" or "How can you tell that these tracks are left by birds?" The fact that we cannot see birds makes the statement "bird tracks" an inference rather than an observation. A possible observation would be: "Two sets of black marks of different shapes and sizes left on a transparency!" It is the case that based on this observation and probably on our familiarity with the kind of tracks that some animals leave behind we inferred that birds made those tracks. The marks or tracks may equally well be those of dinosaurs: Two different species of dinosaurs, or a mother (or father) and a baby dinosaur of the same species. The tracks may as well be those of two different kinds of birds, or a large and a small bird of the same species. Even our claim that larger tracks are left by the larger animal is an inference.

4. The important point to emphasize is that student statements similar to the above ones are inferences as contrasted to observations.

5. You may ask your students: "Why were the two animals heading toward the same spot?" Again the answers may vary: Aiming for a common prey, or moving toward a source of water. One animal may have been attacking the other, or the two had to move to the same spot by virtue of the nature of the terrain, etc. It is important to point out that all of these statements are inferences and that all those inferences are equally plausible. Emphasize that based on the same set of observations or evidence, you and your students were able to come up with several, but equally plausible answers (inferences) to the same question: "What has happened?"

6. Place Figure 6 on overhead. Ask your students: "What do you observe?" Some may answer: "The two sets of marks now appear to be close and randomly mingled," which is a possible observation. Others may say: "The two birds are having a fight," which is an inference. Point out to students the difference between the two. Again note that many inferences are possible: The two animals are fighting, or engaged in a mating ritual, or battling over a prey that one of them has captured, etc.

7. Now place Figure 7 on overhead and ask students what they observe. By now the answer should typically be: "The set of the larger marks is left on the transparency. The smaller marks are not visible anymore." Ask them: "What do you infer?" Again the possibilities are many: One animal may have eaten the other, one may have grabbed the other and moved on, one animal may have flown while the other kept walking, etc. Again stress the point that all these inferences are equally justified by the evidence available.

8. Now ask each pair of students to compare their written accounts and what they think of them after the class discussion. (You can ask younger students to write in their journals whether and how the discussion made them change their mind about their own accounts). Next, ask students whether we can ever know, based on the evidence available, what has "really" happened?

9. Conclude by making explicit the two main points: a) the difference between observation and inference, and b) based on the same set of evidence many equally warranted answers to the same question can be inferred. Continue that scientists make similar inferences as they attempt to derive answers to questions about natural phenomena. And even though their answers are consistent with the evidence available to them, no single answer (or story) may solely account for that evidence. Several answers

are often plausible. And similar to the case of our tracks, scientists may simply never find the answer as to what has really happened.

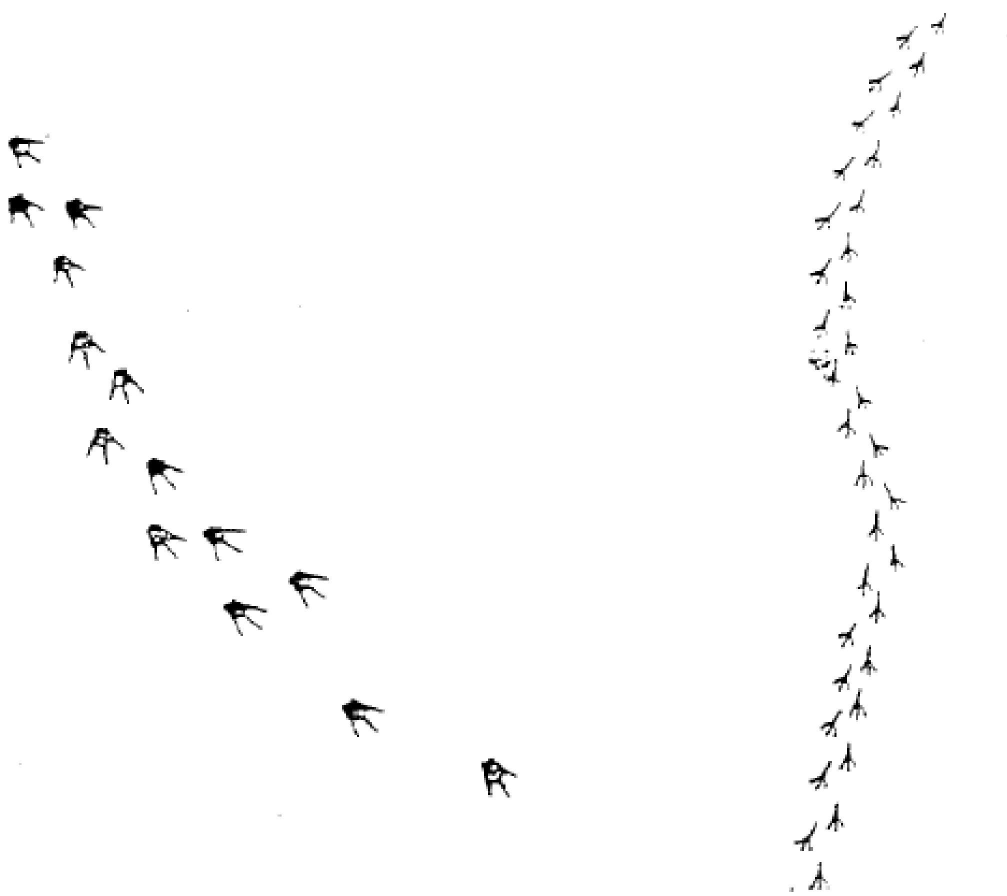


Figure A1. Figure 5 in Lederman & Abd-El-Khalick (1998, p. 47)

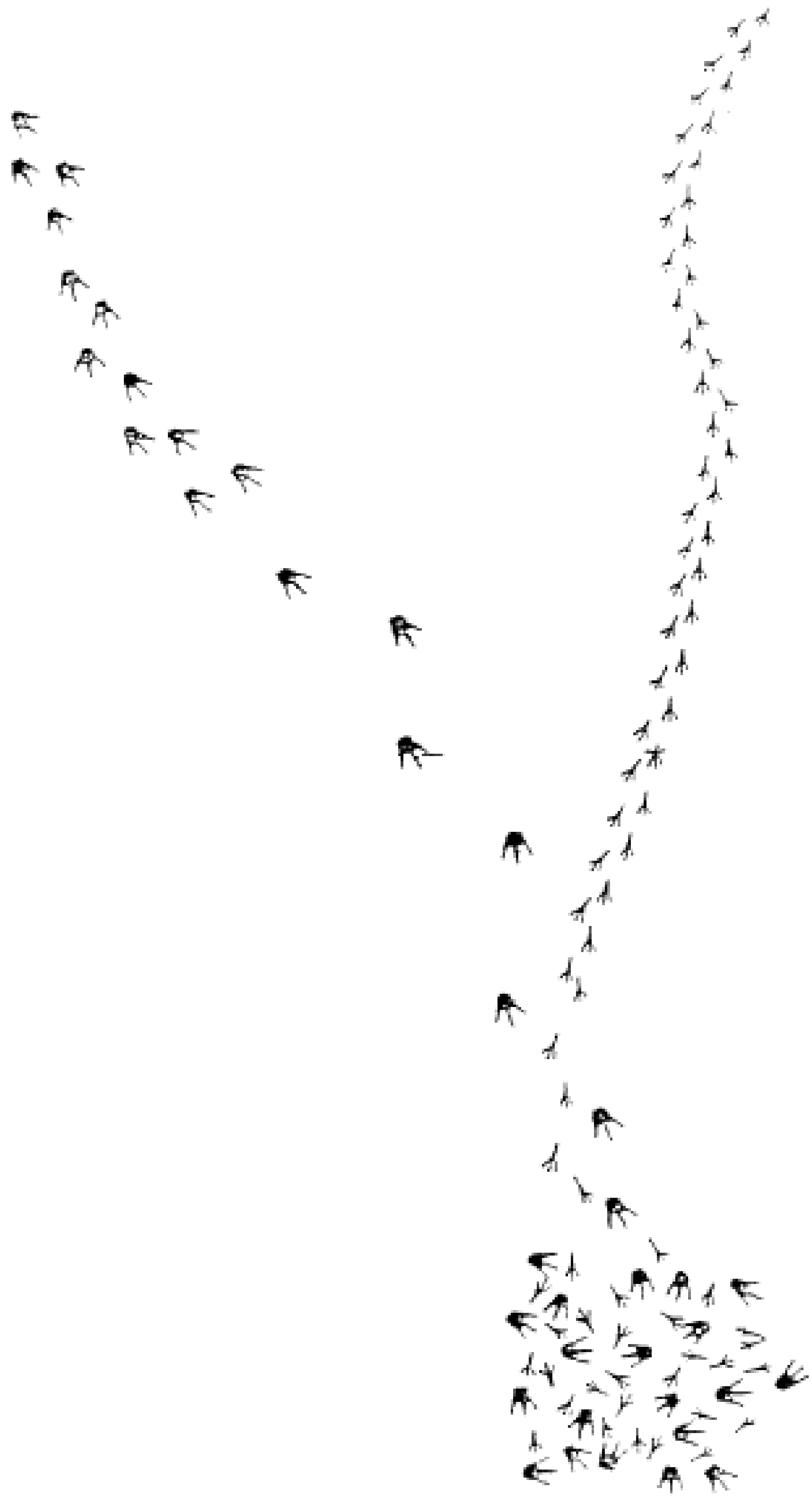


Figure A2. Figure 6 in Abd-El-Khalick (1998, p. 48).

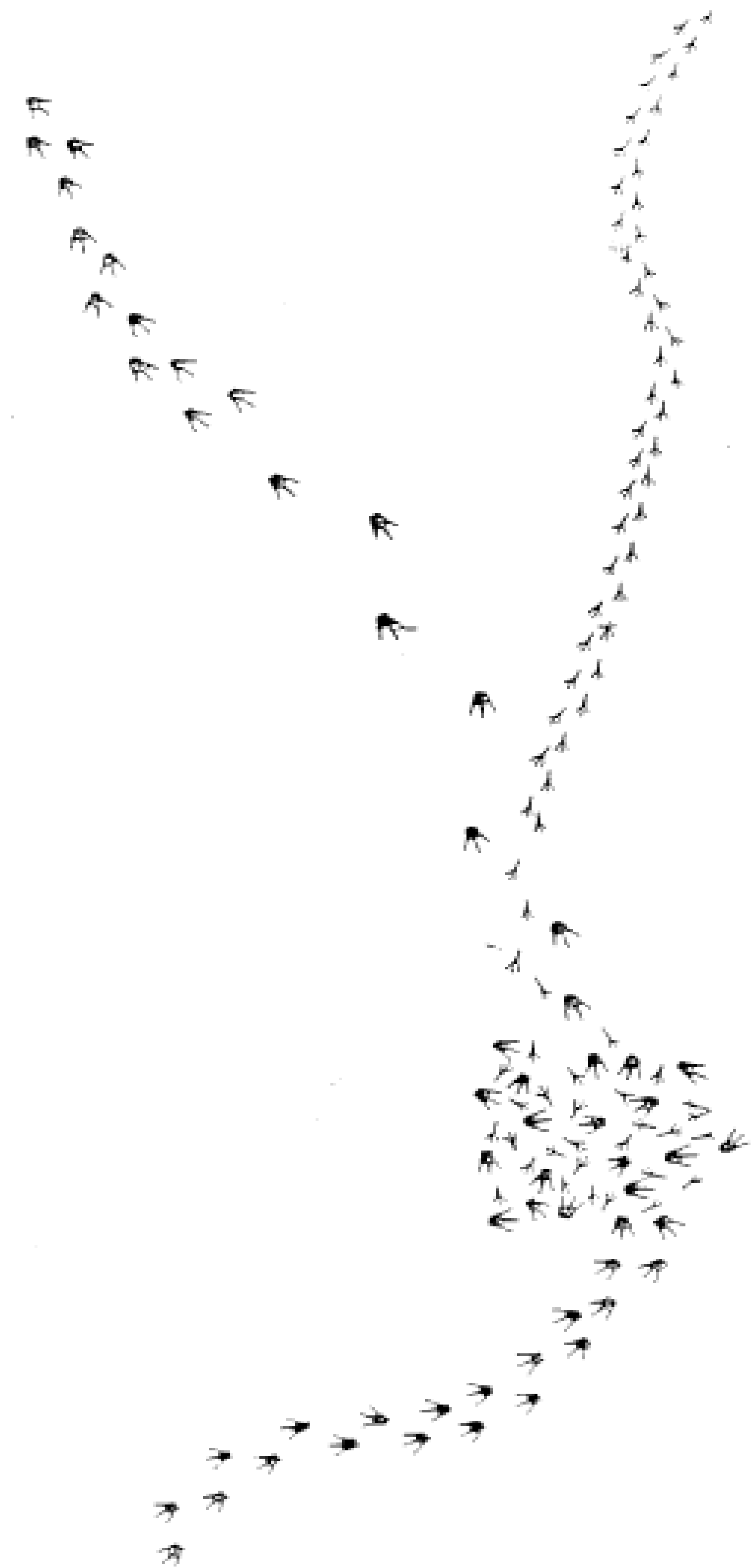


Figure A3. Figure 7 in Abd-El-Khalick (1998, p. 49).

Nature of Science, Activity 1 – Participant Handout page 1
From Figure 7, Provide a thorough explanation of what you think has occurred?

Figure 5 Observations	Figure 6 Observations	Figure 7 Observations

"Tricky Tracks" Activity (Abd-El-Khalick & Lederman, 1998) – Participant Handout page 2

Connections to "Project 2061: Benchmarks for Science Literacy" (AAAS, 1990)	Connections to Georgia Performance Standards, Characteristics of Science co-requisite standards	Connections to Georgia Performance Standards, co-requisite Content Standards	Other Comments/Points for Discussion

Final Reflection: After doing this activity, how clearly do you think you now understand this (these) particular tenet(s) of the nature of science? Put a circle on the continuum to indicate how well you understand the tenet(s) in relation to the way it has been explained?

Understand & Could Apply ←——————— Unclear ———————→ Understand

Does this go against or with your initial understandings of the nature of science? Please explain.____

The Tube

"The Tube" is categorized as a black box activity by Lederman & Abd-El-Khalick (1998). Table 1 found on the subsequent page is only an excerpt, excluding information about other black-box activities that are not intended to be part of this introductory NOS course.

Black-box activities provide students with experiences similar to those of scientists. Students examine `phenomena' and attempt to explain how they work. They make observations, collect data, draw inferences, and suggest hypotheses in order to explain their data. Next, based on those hypotheses, students make predictions and devise `ways' to test them (these `ways' need not be limited to controlled experiments). Based on their tests, they judge whether their hypotheses are appropriate or not. Students finally construct models to explain the `phenomena' investigated and test whether their models `work'. Black-box activities can be used to convey to students appropriate conceptions of many aspects of the NOS.

Students can be helped to understand:
1. The distinction between observation and inference.
2. That scientific knowledge is partly a product of human inference, imagination, and creativity.
3. That scientific knowledge is, eventually, empirically based (i.e., based on and/or derived from experiment and observation).
4. That scientific knowledge (both theories and laws) is tentative and subject to change.
5. That scientific models (e.g., atom, gene) are not copies of reality. Rather, these models are theoretical entities used to explain natural phenomena.

In addition, these activities provide students with opportunities to practice some science process skills. Among these are:
1. Observing and collecting data.
2. Inferring, hypothesizing and devising `ways' to test those hypotheses (or inferences).
3. Constructing models.

Activity	The Hypothesis Box	The Tube
Level	Upper-elementary & Middle	Elementary & Middle
Pre-requisite knowledge	None	None
Construction Materials	I cardboard box (approx. 70 x 50 x 30 cm) with back open, 1 plywood sheet (approx. 50 x 30 cm), 4 plastic funnels, rubber tubing, 2 three-way rubber tube connectors, 2 filter-paper cones soaked with 2 different food colorings, 300 mL beakers.	I tube (mailing tube or PVC pipe, approx. 30 cm), I plastic ring (optional, you can simply loop the lower rope over the upper rope), rubber stoppers or tape (to seal tube ends), 1 roll of clbthesline rope (for whole class), 1 toilet paper roll core (each student can get his/hers)
Set up	see Figure 19	see Figure 21
Idea (the phenomenon)	Ss can only see the front of the box with top funnel and outlet tube. T can pour clear water from top funnel and re-collect it from outlet. By changing the position of tubing inside the box to funnels with food coloring soaked paper-cones, the T can pour clear water but collect solutions of different colors !	The way the ropes are set inside the tube will cause a seemingly complex and amazing movement pattern of the ropes. When T pulls on end of the rope, another end will be pulled in with a seemingly random pattern. T can pull on rope ends clockwise at one time, then across the tube at another.

Table A1. Excerpt from Table 1 (Lederman & Abd-El-Khalick, 1998, p. 37).

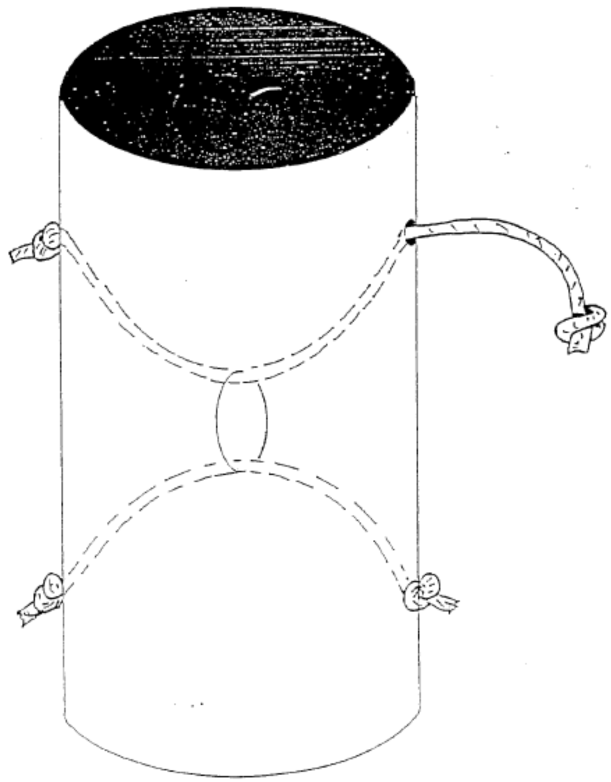


Figure A8. Figure 21 in Lederman & Abd-El-Khalick (1998, p. 71)

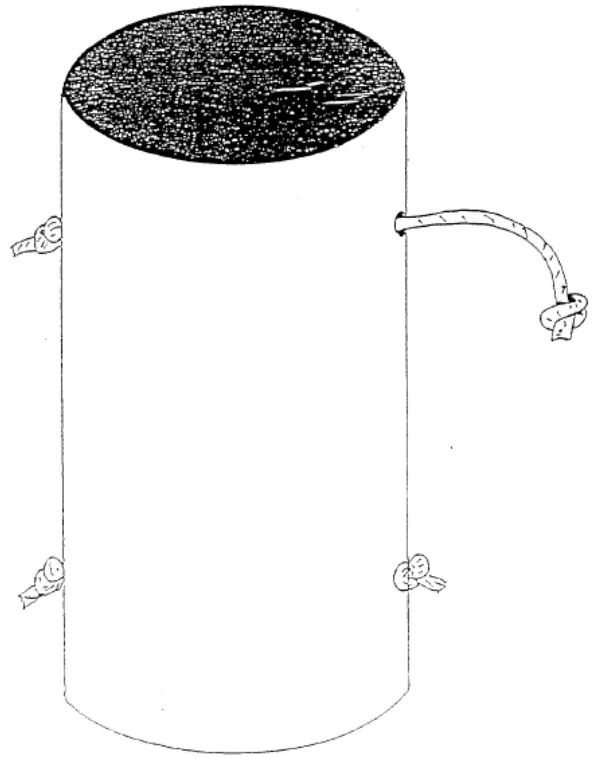


Figure A9. Figure 22 in Lederman & Abd-El-Khalick (1998, p. 72)

Nature of Science Activity 2 – Participant Handout page 1

What is the nature of science?	The Tube	What is the nature of science?
Why would you want students to do science?	Explain the how/why of the phenomena. Use diagrams. How could you further engage students in this activity?	

Nature of Science Activity 2 – Participant Handout page 2

How is this relevant? How can this be included in a learning unit? Where do you see the application?	Reflection: Prior to doing this activity, how did you understand the particular nature of science understandings explicitly addressed? How is it now different, or the same?

	Why do you think understanding the nature of science might be considered important?

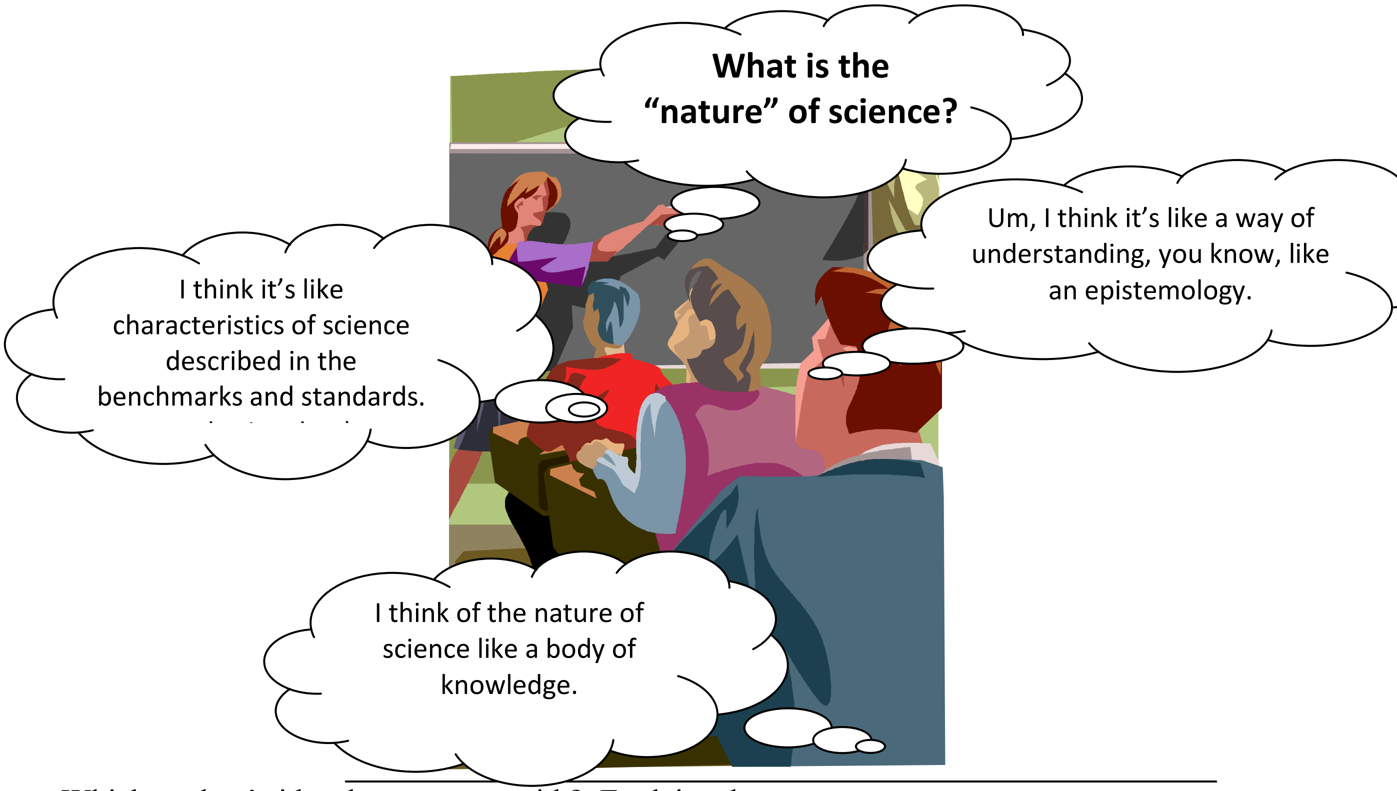
Thursday, June 25, 2009 Agenda

Nature of Science

Explore: Concept Cartoon (Keeley, 2008, p. 72)
Engage: Mythos of NOS (McComas, 1998)
Explain: Concept Cartoon
Elaborate: Carousal Walk
Evaluate: Ticket Out the Door

Assessment

Explore: First Word-Last Word (Keeley, 2008, p. 88)
Engage: Role Play
Explain: Concept Card Sort (Keeley, 2008, p. 56)
Backwards Design (Covey, 1994; Wiggins, 1998)
Elaborate: Balanced Assessment Template (http://www.georgiastandards.org)
Evaluate: First Word – Last Word



Which student's idea do you agree with? Explain why.

APPENDIX B

OUTLINES OF CLASS DISCUSSIONS

As described in chapter 3, in the fall of 2009 participants explored features of lesson study through discussion, video, and modeling. Outlines of class discussion guides are provided as evidence of the type of lesson study experiences included in the course. Additional lesson study training suggestions are found in Lewis (2002b).

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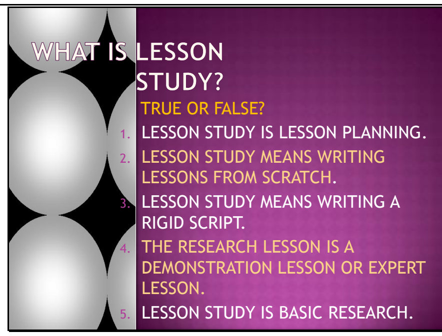
<td>
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<td>Use this slide to prompt discussion from the assigned reading….Then lead into formal presentation of LS.
As you have read, lesson study is a cycle where teachers work together to consider long term goals for students, bring those goals to life in actual research lessons, and collaboratively observe, reflect, and refine the lessons.</td>
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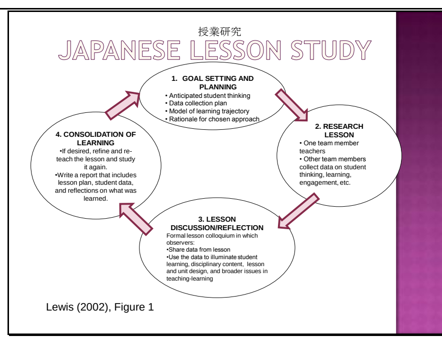
<td>
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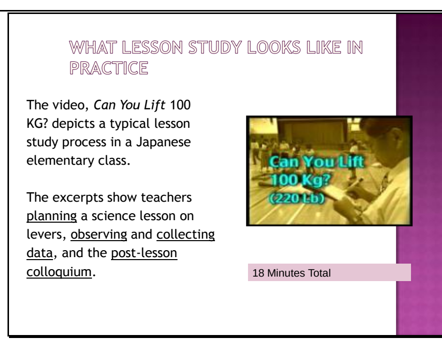
<td>
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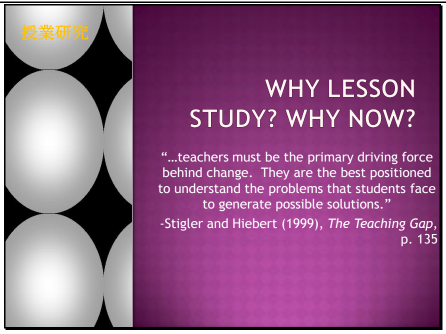
<td>
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<td>As you have read, lesson study is a cycle where teachers work together to consider long term goals for students, bring those goals to life in actual research lessons, and collaboratively observe, reflect, and refine the lessons.</td>
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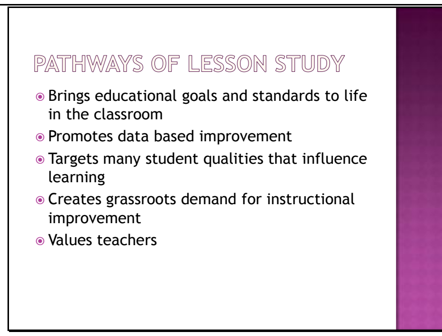
<td>
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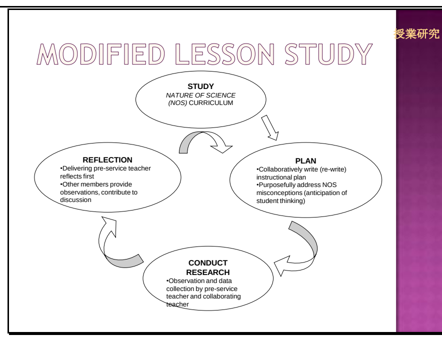
<td>
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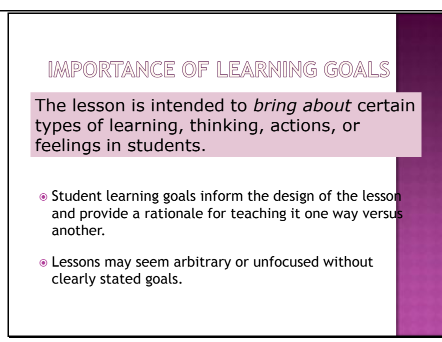
<td>
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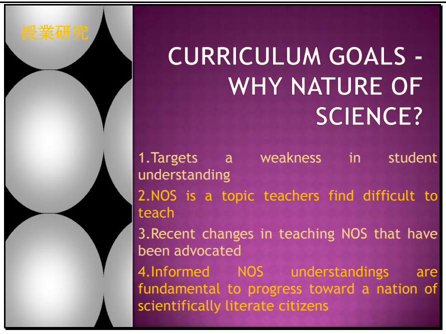
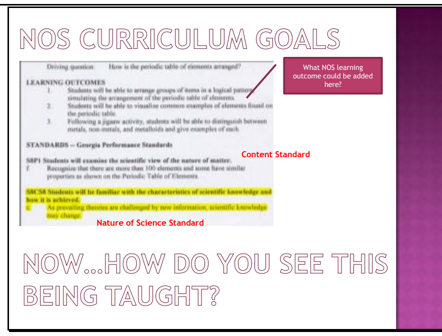
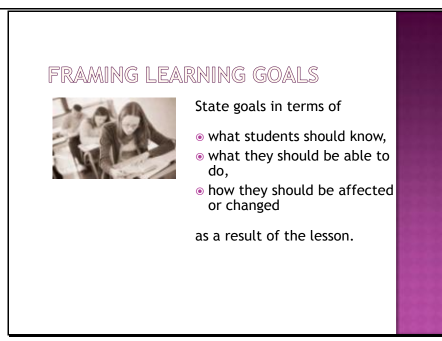
Slide 8		As you have read, lesson study is a cycle where teachers work together to consider long term goals for students, bring those goals to life in actual research lessons, and collaboratively observe, reflect, and refine the lessons. In choosing the subject and topic for lesson study teachers often target weaknesses in student learning or development, choose a topic teachers find difficult to teach, choose a subject where teaching approaches have been advocated/changed, and/or choose topics that can be fundamental in other areas
Slide 9		Below the learning goals in your LP is kind of an obvious space to document where the NOS goals are being connected to the content standard. More importantly is to think and collaborate with your team about how these NOS learning outcomes are going to be taught explicitly for your research lesson. This will allow you to think deeply about the long term NOS goals as it relates to scientific literacy, and will also deepen your subject matter knowledge for both NOS and the related science content.
Slide 10		

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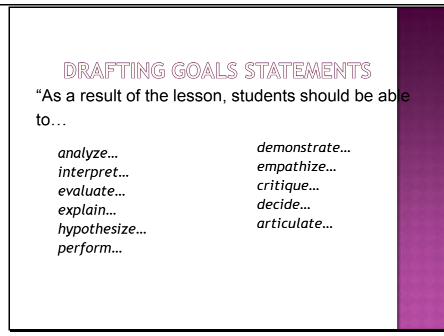
<tr><td>Slide 11</td><td>
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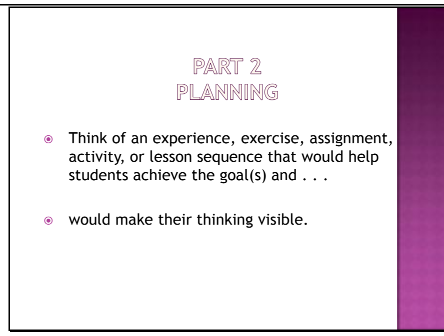
<tr><td>Slide 12</td><td>
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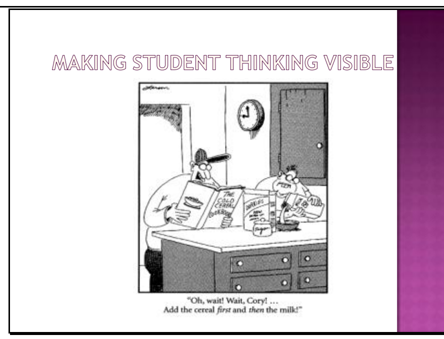
<tr><td>Slide 13</td><td>
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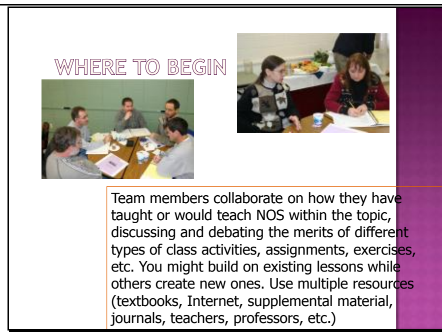
<td>
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<td>I want to end today with this in mind. I think it's important for you to begin thinking about the upcoming content and how you can integrate NOS into this content. You need time to collaborate with the other teachers in your schools, work through the planning of how to do this assignment, etc. In our next class session I will pick up with the process of collecting data/conducting research, but also help you in developing research lessons if you need this as well.</td>
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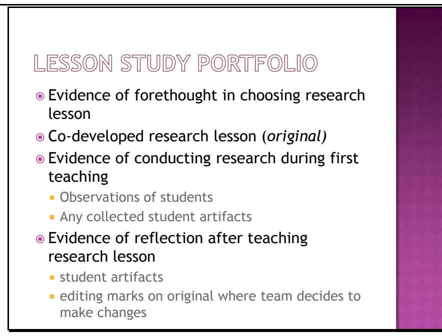
<td>
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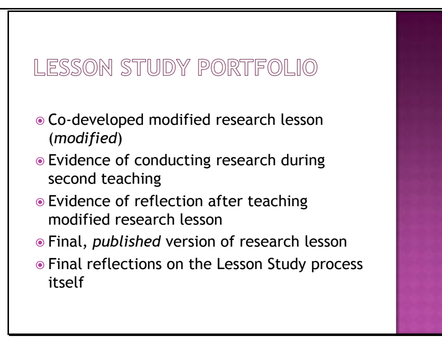
<td>
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APPENDIX C

LESSON STUDY PORTFOLIO

A handout was provided to participants that explained the specific requirements for the Lesson Study Portfolio. This handout overviews features of the modified lesson study framework, provides a guide for data collection, and details the assignment requirements.

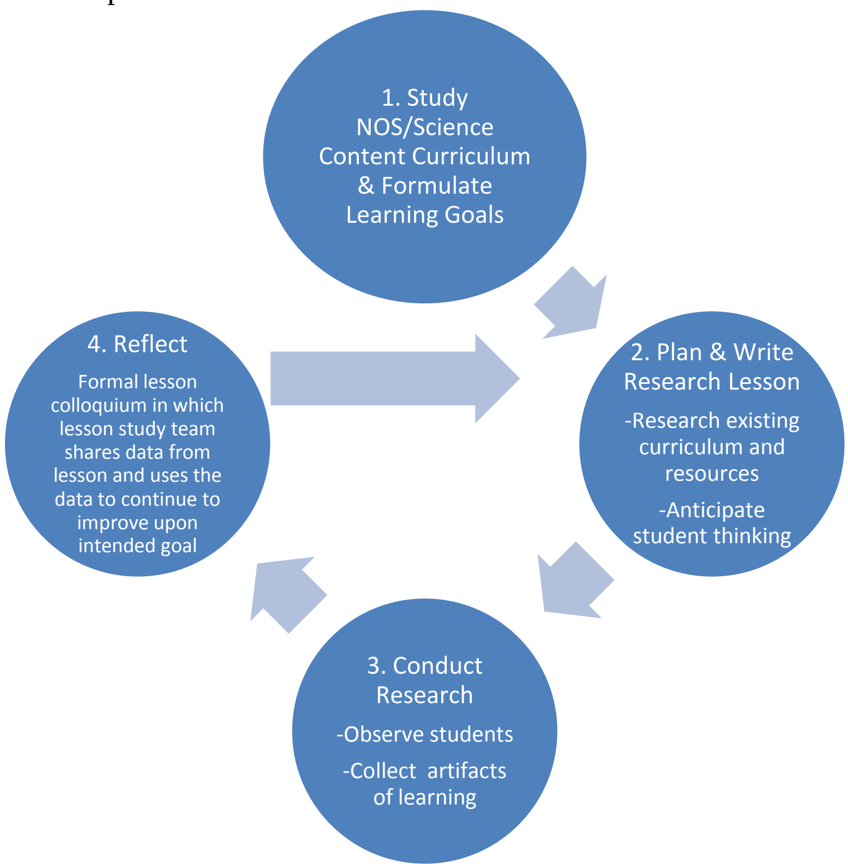
TEEMS Lesson Study

Lesson Study will allow for opportunity to meet portions of the following INTASC Goals:

CONTENT	The teacher of science understands the central concepts, tools of inquiry, applications, structure of science and of the science disciplines he or she teaches and can create learning activities that make these aspects of content meaningful to students.
STUDENT LEARNING & DEVELOPMENT	The teacher of science understands how students learn and develop; and can provide learning opportunities that support students' intellectual, social, and personal development.
STUDENT DIVERSITY	The teacher of science understands how students differ in their approaches to learning and creates instructional opportunities that are adapted to diverse learners.
INSTRUCTIONAL VARIETY	The teacher of science understands and uses a variety of instructional strategies to encourage students' development of critical thinking, problem solving, and performance skills.
LEARNING ENVIRONMENT	The teacher of science uses an understanding of group and individual motivation and behavior to create a learning environment that encourages positive social interaction, active engagement in learning, and self-motivation.
COMMUNICATION	The teacher of science uses knowledge of effective verbal, nonverbal and media communication techniques to foster active inquiry, collaboration, and supportive interaction in the classroom.
CURRICULUM DECISIONS	The teacher of science plans instruction based upon knowledge of subject matter, students, the community, and curriculum goals.
ASSESSMENT	The teacher of science understands and uses formal and informal assessment strategies to evaluate and ensure the continuous intellectual, social, and physical development of the student.

Overview of Lesson Study

For this assignment you will collaborate to create, teach, and reflect upon an inquiry based lesson that is designed to interweave nature of science curriculum and science content. A visual representation is below.



Details of Lesson Study

Part One: Formulate Learning Goals

- From what you know about students' misconceptions about how they understand nature of science AND the science content you are responsible for teaching, determine an appropriate student learning goal that you will work collaboratively to improve upon. From here forward this will be referred to as the research lesson.
- This research lesson needs to represent a true learning need of the students. In this research lesson, a rationale for the collaborative choice must be provided. (see reflection guide)

Part Two: Plan & Write Research Lesson

- Once the research lesson has been determined, members of the lesson study team work together to develop a research lesson where all team members contribute to instructional decisions, ensuring that the learning goal is being met.
- Remember: a portion of the content and a nature of science concept must be part of the intended learning goal.

- In planning and writing the research lesson, use multiple resources, citing any of these resources using APA. In addition, provide copies of any related assessments, handouts, etc.

Part Three: Conduct Research

- One member of the lesson study team should volunteer to teach the research lesson.
- The other members of the lesson study team will be observing the students' actions, collecting evidence of the students' learning, and recording any related observations.
- This data collection needs to be very specific to the pre-determined research lesson goal.
- Please remember that observations are to be directed toward students and in relation to the particular NOS and science concepts being integrated. Data will need to be recorded using the following "Observation and Reflection Guidelines" (Martin-Hansen, 2007).

Part Four: Reflection

- Once the research lesson is complete, the volunteer teacher should be allowed the first opportunity to reflect on the research lesson learning goal. In this open reflection, conversation revolves around how the students' actions indicate successful learning outcomes, or the need for a modification in the instructional decisions.
- This will be somewhat of a think aloud and requires the other team members contribute data to support the volunteer teacher's initial perspective.
- Once the volunteer teacher reflects, all other lesson study members should contribute any collected evidence as it relates to the research lesson learning goal.
- As reflection is occurring, evidence of these conversations should be indicated on the research lesson. (See the example below.)

- A volunteer in the lesson study team will now volunteer to teach the modified research lesson. This volunteer can be the same person as in Part One, or different.

- The lesson study team will again conduct research as the volunteer teaches the research lesson with the agreed upon modifications in place.

- Final reflections on the research lesson's learning goal will follow the same structure as before. However, in this last phase of your requirements you will also need to reflect on the entire experience itself. This reflection is guided by questions in the "Observation and Reflection Guidelines" (Martin-Hansen, 2007)

The cyclical process of Lesson Study is now unfolding.

An Example of a Research Lesson with Evidence of Reflection:

1	Phase puzzle (collection of 28 squares with one phase of the moon on each).	1 per group
1	Moon phase calendar (28 day calendar showing phase of moon on each day)	1 per student
1	Index cards with a picture of one of the 28 phases of the moon on each card	28
1	Lamp and globe	1 each
1	Moon phases formative assessment (see Appendix)	1 per student
2	Styrofoam balls	1 per group
2	Lamp and globe	1 each
2	Moon phases worksheet (see Appendix)	1 per student
3	Balloons	2 per group

5#'S IMPLEMENTATION: LESSON ACTIVITIES (Procedures)

Assessment Strategies

* Pre-Assessment
  - Day 1: some free-response written answers about the moon and eclipses (see Appendix)
* Formative Assessment
  - Day 1: Standup class demo: looking for students to find correct location of their phase of the moon
  - Day 1: Ticket out the door: did the student draw correctly the phase of the moon?
  - Day 2: KWL Chart – looking for prior knowledge of moon and informed questions
* Summative Assessment
  - At the end of the lesson, what will students do that tell you they successfully learned the main concepts of the lessons? If there is an application of ideas, that fits here. What is the culminating activity/task that demonstrates the student's understandings? Again, IF this is a discussion state exactly what you want to hear from the student. If this is a task or worksheet, include it. If it is a test, include it.

Day One

1. Introduction/Engage – Day 1 (1.5 hrs) EQ: What do the phases of the moon look like and do they go in order?
   a. Correction of Seasons Unit assessment
   b. Pre-assessment – 10 min Students try to prove their ideas for the different phases
      i. See Appendix for pre-assessment
      ii. Not for grade, only for GSU class
   c. Phase puzzle (prediction, in pairs)– 30 min
      i. Distribute squares that show pictures of the moon on each day
      ii. Put the squares in the correct order
   d. Compare puzzle to moon phase calendar
      i. Allow kids to put their phase squares in the correct order
   e. Ticket out of the door - Fill in the missing moon phase
      i. Have five phases of the moon on a sheet, with one missing.
      ii. Ask the students to draw the missing phase.

Reasons
1. Earth's shadow on moon
2. Illumination of moon as viewed from earth
3. moon is in southern hemisphere during half moon
4. Clouds
5. Phases depend on seasons
6. Indirect vs direct light on the moon

Day Two

2. Explore & Explain Phases – Day 2 (55 min); EQ: Why do we see phases of the moon a~~nd what are their names?~~
   a. Moon Conference – 40 min Task: Explain the phases of the moon + convince
      i. Take ideas from the pre-assessment and break the kids into groups with similar explanations. They are going to a scientific conference and they must convince their fellow scientists that their hypothesis is correct. Tell each group they have 15 min to figure out how to convince their fellow scientists. Then give presentations. NOS: must prove your ideas
   b. KWL Chart

Before presentation, ask each group to state their original belief then show why its right or wrong

Page 2

Guide for Conducting Research:

The purpose in providing this guide serves dual purposes: (1) to remind you that your observations during the teaching and reteaching of the lesson study should be focused on the students, and (2) that your learning goals should be connected to some component of nature of science understandings**.**

This is a guide, and does not have to be adhered to strictly. Any way that you can **provide evidence of conducting research** in a way consistent with Lesson Study will be acceptable. (Note: The space provided in this guide will be spaced using an entire page, rather than in this condensed version.)

<u>Observations and Reflections Guidelines</u> (Martin-Hansen, 2007)

Observation Guidelines:
Who should be observed?
What should be observed?
How should data be collected?

Students' Actions or Behaviors	Teachers' Actions or Behaviors (refer to research lesson, or specific instructions/actions)	Points for Discussion

FINAL REFLECTIONS

After the second delivery of the research lesson, as a team discuss some of your final reflections on both teaching NOS and being part of a lesson study team. Guiding questions follow:

1) Were NOS concepts taught explicitly (not just modeled, but also discussed)? If so, which ones and how?
2) What evidence is there that the focus of the lesson study improved student's learning goals (include NOS concept(s)) from the original to the modified research lesson?
3) How did being part of a lesson study team help you in thinking about students? Instructional decisions?
4) What frustrations did you have as you were going through the lesson study process?

Appendix D

The VNOS-b was used in this dissertation to gain insight to participants' NOS understandings. The questions as they appear in Lederman et al., 2002, p. 505) are found in Figure 1. Analysis of these questionnaire responses is guided by the rubric outlined in the subsequent Figure 2. Figure 2 is Table 2 from Lederman et al. (2002), representing illustrative examples of responses to VNOS-b that will guide analysis.

Figure 1
Figure of Views on nature of science questionnaire, Form B

VNOS–Form B

1. After scientists have developed a theory (e.g., atomic theory), does the theory ever change? If you believe that theories do change, explain why we bother to teach scientific theories. Defend your answer with examples.

2. What does an atom look like? How certain are scientists about the structure of the atom? What specific evidence do you think scientists used to determine what an atom looks like?

3. Is there a difference between a scientific theory and a scientific law? Give an example to illustrate your answer.

4. How are science and art similar? How are they different?

5. Scientists perform experiments/investigations when trying to solve problems. Other than the planning and design of these experiments/investigations, do scientists use their creativity and imagination during and after data collection? Please explain your answer and provide examples if appropriate.

6. Is there a difference between scientific knowledge and opinion? Give an example to illustrate your answer.

7. Some astronomers believe that the universe is expanding while others believe that it is shrinking; still others believe that the universe is in a static state without any expansion or shrinkage. How are these different conclusions possible if all of these scientists are looking at the same experiments and data?

Figure 2

Table 2 from Lederman et al. (2002) Illustrative Examples of VNOS Responses

NOS Aspect	More Naive Views	More Informed Views
Empirical NOS	Science is something that is straightforward and isn't a field of study that allows a lot of opinions, personal bias, or individual views—it is fact based. (Form C: Item 1) Science is concerned with facts. We use observed facts to prove that theories are true. (Form B: Item 6)	Much of the development of scientific knowledge depends on observation. . . . [But] I think what we observe is a function of convention. I don't believe that the goal of science is (or should be) the accumulation of observable facts. Rather . . . science involves abstraction, one step of abstraction after another. (Interview follow-up on Form C: Item 1)
The scientific method	Science deals with using an exact method. . . . That way we know we have the right answer. (Form B: Item 4) Science has a particular method of going about things, the scientific method. (Form C: Item 1)	When you are in sixth grade you learn that here is the scientific method and the first thing you do this, and the second thing you do that and so on . . . That's how we may say we do science, but [it is different from] . . . the way that we actually do science. (Interview follow-up on Form C: Item 1)
General structure and aim of experiments	An experiment is a sequence of steps performed to prove a proposed theory. (Form C: Item 2) Experiment is everything that involves the act of collecting data and not necessarily manipulation. (Interview follow-up on Form C: Item 2)	An experiment cannot prove a theory or a hypothesis. It just discredits or adds validity to them. (Form C: Item 2) An experiment is a controlled way to test and manipulate the objects of interest while keeping all other factors the same. (Form C: Item 2)
Role of prior expectations in experiments	You usually have some sort of idea about the outcome. But I think that to have a scientific and valid experiment you should not have any bias or ideas in advance. (Interview follow-up on Form C: Item 2)	To organize an experiment you need to know what is going to come out of it or it wouldn't really be a test method. I don't know how you would organize a test . . . if you don't have a general idea about what you are looking for. (Interview, follow-up on Form C: Item 2)
Validity of observationally based theories and disciplines	Science would not exist without scientific procedure which is solely based on experiments. . . . The development of knowledge can only be attained through precise experiments. (Form C: Item 3)	Experiments are not always crucial . . . Darwin's theory of evolution . . . cannot be directly tested experimentally. Yet, because of observed data . . . it has become virtually the lynchpin of modern biology. (Form C: Item 3)

APPENDIX E

VNOS INTERVIEW TRANSCRIPT TRANSCRIPTION

Participant: Holly Date of Interview: July 17, 2009 Time of Interview: 12:05 p.m.

I: This is ----- and it is Friday, July uh…(H interjects with 17th) 17th and it's about 12:00 and this is our first interview.

I: Let's talk about the VNOS. The first question is about theories and whether or not they can change and what, if any, the importance of teaching them is.

H: Okay.

H: The first time I was very much under the impression of theories could change until they became law. But after our little discussion of theories and laws and clarifying all that. Um, now I know that both theories and laws can change with the new technology and new information all that kind of stuff. And that if we didn't teach them, we'd be missing out on most of science. Cause most of science is in some way a theory or based on a theory. So… my big change was the fact that you can always change a theory. You can also change a law.

I: Now were you also when you that um that linear relationship. Hypothesis, law, or hypothesis theories, laws, (H: m, hmm – yeah. affirmation of understanding what was said) were you also …that misconception that we talked about. Did you have that misconception going into class as well?

H: yeah. I had been taught that misconception. Even through a uh basically a nature of science class I had had here as an undergrad.

I: Really?

H: Yeah. It was still taught incorrectly. SO.

I: So..even with that experience and this one course I hear you to say that you are definitely understanding the distinction between the two now.(H: yeah..) I: Ok. Well, talk to me a little bit about how you distinguish between the two now. Laws mean (this) to you now. Theories mean (this) to you now.

H: Now, theories are I understand them as basically explanations of things. Um, how things work and how um the science behind a big concept. Where as law, can predict. It doesn't as much explain what's going to happen and how it's happening but how it will happen under certain conditions.

I: More like a prediction?

H: Right.

I: Ok, so…um, let's go back to the idea of theories. (H: um, hm) How are theories developed? You know, what kind of… you mentioned 'stuff', you mentioned technology and that kind of "stuff" contributes. Talk more about how theories are developed.

H: Um, my understanding is that through observations, experimentation, data collection, all different kinds of things…that that information is um put together and then interpreted and through those interpretations a theory can develop. But it doesn't have to be technology related because things like plate tectonics…or whatever…are just observations. So…

I: Ok, um… the second question …um…was about models,the atoms…the structure of the atom and how models are created in science.

H: Ok.
I: The first time you answered it.
H: I just basically tried to answer with what the structure of the atom. I didn't even think about the idea of models. I thought it was a content question.
(Both chuckle.)
I: So, then you answered it the second time differently.
H: Definitely differently. Um, I said that basically it's one of those situations where we don't know because we can't exactly see an atom. So we use uh what we know to build a model and from that model we can project what we think. So it's kind of like a theory type thing but it's based on information but we don't have enough information about it. Maybe because we don't see it, or maybe we're missing a piece of information, so we can get only what we think is correct.
I: Is what we think is correct, um, pretty spot on?
H: Usually, but it's up for change. I mean, the atoms changed, or, the model of the atoms changed a lot.
I: I like that you clarified that. because the atom you're assuming has not changed but the model or the way we (H: interjects…the way we view it) I: Yeah, definitely has changed.
H: Yeah.
I: Um, the second (third) one was along the same lines as theories. I think that you um kind of addressed how you changed your answer. But I notice that your first answer here is pretty lengthy.
H: Yeah.
I: Did you spend a significant amount of time talking about how theories become laws?
H: Yeah (chuckles.)
H: Yeah I wrote about a linear relationship in that one. (first survey) where as, my re explanation of everything was were more of a , "they are separated entities."
I: Do you see some overlap of the two of them?
H: Definitely.
I: You do?
I: I think that I heard you say earlier that they're tentative. So that would be one way they overlap. Are there any other ways they overlap?
H: Um, I mentioned in my explanation that they also overlap in that they are very content specific. Uh, that a theory can only pertain to a certain area uh that can't be overlapping all of biology or all of biology and chemistry. And the same thing goes for a law. They have to be pretty specific.
I: Um, so let's take gravity. Gravity is a law. Not a theory?
H: Yeah. Well, technically. (pause)
I: Yeah, so let's address this one. This gravity thing throws us for a loop.
H: Right.
I: Especially if we're coming from a lifetime's experiences of misconceptions.
H: Yeah.
I: Application of these ideas you know into content…something like gravity. What does that look like?
H: Yeah. I think that's why we have all these misconceptions. Because it is extremely confusing cause the law of gravity we can see it and we can explain and predict what's gonna happen but the explanation part is the theory and the prediction is the law. In the

case of gravity it seems you can't have one without the other. But there's other times where you can definitely have a law without a theory. Or a theory without a law. So. (page turning)
I: It's something you're going to be working on in the classroom as well, so, what as you see as one really important thing when it comes to talking about this stuff in your classroom?
H: Just trying to clear up the misconception of that linear relationship. I think it's where that's where uh where uh where I don't want to say lots of people go wrong but that's basically what it is. (chuckles) but they're taught that it's a linear relationship, so they automatically think hypothesis, theory, law, and then that means the law can't change. Which means there's a whole lot of misconceptions that come out of that one.
I: Did you , when you were planning your learning cycle unit, did you see um, some misconceptions that could be in your topic? Yours was inheritance right?
H: Yeah.
I: Genetics and inheritance, right?
H: Yeah,
I: So, did you see some misconceptions content wise that could have more of a foundation in nature of science?
H: Um, I don't know if it was as much misconceptions as it was the nature of science that was easiest to incorporate was that science explains and predicts.
I: um, hm
H: Um, and so that was weaved throughout my whole learning cycle unit and then I also included a very explicit portion of describing that that was what Mendel did. Used experiments to explain what was happening and then he could predict from there.
I: Ah, so when you say that was an explicit portion, what do you mean by that…explicit?
H: Um, I created a section that was me basically going over with the students um like asking them "what did Mendel do?"

I: like guiding questions?
H: Yeah, and then from there after getting their answers, it was, well this is what science does, it doesn't give us an answer but it can explain our answers for us and predict future answers for us.
I: and so in your lesson planning you wrote that out as um…I hate to say your script….but you know, that's kind of, you know when we're first starting to teach, that's kind of what we rely on, is a script. Because we have to really think those things through before we get in there.
H: Yeah, and I incorporated it into a PowerPoint section, and so there was a slide that included questions that was uh, um, that would be asked of the students. So that it was kind of a reminder for me but also a visual for them. So..
I: Your learning cycle unit, did you find it easy to put nature of science in there?
H: Um, implicitly? Yes. The explicit part was, it took a little bit more tweaking to make it actually relate back to the lesson in the end so then it was not just like I was going off on a tangent. So, right, it worked.
I: Well, I was going to ask, "Do you feel like it worked?"

H: It worked, yeah.

I: it just required another step thinking wise (H: Yeah). Alright, so, let's go back to your questions. Art and science.
(H Laughs)
H: The first time I thought I got a lot out of it because I understand the creative aspect. When I went back I added some to it saying that there's even more similarities between the two in the creative process of coming up with the ideas, um taking what you have and kind of messing with it. (I: right, right) Um, cause the first time I just basically said there's the creativity aspect in both and both can be interpreted (I: right) and that kind of stuff. But in the second time I went back and said you know I still agree with most of what I said but I'd like to add that there's more creativity in the whole scientific process than I'd even considered before.
I: Yeah, well, ok, so you've brought up scientific process. Do you, have you, always called it a scientific process?
H: Yes, but with different meanings.
I: Ok, talk to me about that.
H: That in, earlier in my, like, I guess you would call it my scientific career. Like, middle school high school years, it was very rigid structure process. Um. The whole you get up, get your idea, you hypothesize, you create your experimental plan. The traditional what's taught. (I: um, hm) but then going throughout my college career, while it's still a process, that process was a lot less rigid. In that…
I: Talk about that, what do you mean?
H: Um, best example I have is my 400 level biology class. We had to um create our own experiment from scratch and then execute it. (pause) well a lot of people followed that rigid structure but what we did is we went and said well we know this happens when you add these chemicals together (I: um, hm), what if we were to change it? So we started with, basically we already knew an answer, and then went back and created a design and based off our design we created our hypothesis. It was kind of like all flip flopped of what you would normally tell a student to do. But it worked out really well except we didn't get results and instead of just giving up and that we reject our hypothesis as you would normally be taught to do, we (I: um, hm) said well, maybe it's because of this. And we went back and changed things and changed our hypothesis and everything and it was kind of an everchanging thing instead of this is step 1, this is step 2, this is step 3 kind of thing.
I: Ok, well, which one do you think um represents the field of science more accurately?
H: Definitely the less rigid aspect. For the most part I should say.
I: Yea, because I think both have their place. (H: Yeah) So, let's speak to that. There's a place for both.
H: Teaching like introductory science and the science methods and how the sciences work, I think its important to include that rigid structure to give the students something to build off of. Cause if you just kind of throw them in there then it's like "Here..it's like big mess" (I: open inquiry?) Yeah, then there might be a lot more misunderstandings and misconceptions in how everything works…
I: Or chaos in your classroom?
H: Yeah, that too. (chuckling) Cause if you start with the more rigid structure and then go and explain well this is how it works in a classroom and in a very controlled

environment…but most of science is not very controlled. Then you can go more into the "it's not exactly as rigid as we've perceived it to be…"
I: So you think it's more the um, would you say it's almost developmental?
H: Definitely, cause uh, what was his name? I think it was Piaget that we were talking about in this class (I: um, hm.) saying that the different levels that students could think at. The concept, or the concrete versus the abstract, no it started with an f but I can't remember the name. I think (I: an F? hmm.) but going from that concrete level to the next level. The concrete level is what I think a lot of middle school and earlier high schoolers would be at. And I don't think they could mentally understand the non rigid at that point because they're not developmentally there.
I: Yeah, Well see, I'm not sure I agree with you. Well, I should say I agree with you on some level. Well I agree that it occurs at earlier ages. Well, its hard to say. At earlier ages you can almost envision them being inquisitive um and being open to doing anything and just wanting to just try stuff and not necessarily needing or wanting to be "scientific" in their process. Which you know is an exploration in the process in itself.
H: Definitely. I just don't think they would understand as much as if they were just doing it.
I: And I don't even know, even if that age, they would even understand if you said, "Oh this is the scientific way and blah blah blah. I don't know. But that's from my total lack of experience with younger kids.
H: And I have had some experience cause I did science fair all throughout high school and my mom working in an elementary school, I was constantly asked to go work with her 4th and 5th graders. And seeing her 4th and 5th graders trying it with the way I was doing it in a lab, at a university they were completely confused and frustrated to the point that they were shutting down. But if I sat there and was like, "Ok, let's come up with a question. How can we answer this question? What do you think the answer to this question? " They were okay.
I: So even older elementary would need that? Not even the younger?
H: Yeah
I: I think I might agree, but…even in my experience teaching 7th and 8th, it depends on their training. If they've had some experience with guided inquiry then they're more comfortable doing inquiry themselves.
H: Right, they're not going to get to that frustration level. Yeah,
I: So, I think it's a very individual or even class kind of thing. But I think it's very interesting to think about this now. You know cause when I first started teaching, this would not even be part of conversation.
H: Yeah
I: Which is probably very true for you too? Wait, how old are you?
H: 22
I: Oh geez, I'm old. Wow, I'm really old. Alright so, let's not talk about age anymore. Let's go to number 5. Scientists perform investigations when trying to solve problems. Other than planning and designing, how do you see creativity um during and after data collection?

H: I think the first time I was talking very rigidly, talking about well there's creativity in the interpretation. That kind of thing where as um after going through some of the

discussions for class and thinking back on my own experiences, I see there's creativity throughout the whole process. That you can't exclude creativity because if you did it would just be following directions and that's not really scientific inquiry investigations that's just doing an experiment to do an experiment.
I: validation labs?
H: Yeah,
I: Um, so (pause – major distraction - guy with Pabst blue ribbon beer in a 50 galloon bag walks by) alright, number 6 – knowledge and opinion. Ah, this is a good one.
H: Yeah, so if I remember correctly I basically said that my opinion stayed the same because I thought I was pretty much spot on for what I thought before hand. In that, their I think they were asking if they're different (I: Yeah) and saying that they're very different. That sometimes they can overlap but for the most part, at least in science, there's not much room for overlapping. Except for the exception of explanation of data
I: interpretation?
H: Right, um, cause uh, the knowledge is based on what I would like to consider rigid facts. Like observations or um you know data from experiments or different technologies that tell us different things. That kind of stuff that's more of a rigid you know 2+2=4 type thing. Where as, opinion comes into more of the creating and taking that knowledge and what you're doing with it. Like, creating a theory or you know trying to create a law based on the knowledge. But if you're not using the knowledge like you're opinion. You have to validate your opinion basically.
I: Can you validate your opinion with scientific knowledge?

H: Yes. Definitely, you just have to be careful in how you validate it. I've seen people try to take knowledge and twist it to their preconceived notions and their already made opinions instead of taking that knowledge and creating an opinion.
I: So, perspective is what you're thinking is important?
H: Yeah, and trying to get rid of bias. I think that's very important, too.
I: Do you think that's possible?
H: To a certain extent, yes. But you have to be aware of the biases. Which I think there lies a problem. Knowing what your biases are.
I: what else do you think might influence the biases that you make? I think specifically about tricky tracks. You know, the point of that exercise was to get some first hand exploration into this notion of observations and how they influence your inferences or your interpretations, big time. So…(phone rings close by) I think that…it's important to…maybe talk about what influences your observations.
H: Alright, um. Uh, I would say that one thing that your background would influence your observations cause if you're used to the word observation meaning what do you think this means instead of strictly I see this…then that's definitely going to change it…and also, you know what you could see out of something. Even if it's just strictly an observation you might miss see that your lab partner might that might be the first thing they see. Um, because of your background or your biases even. You know, I know, the tricky tracks experiment, I saw two tracks going together and then one coming out. That automatically meant to me that one ate the other. Where someone else in the classroom, sitting right next to me, looking at the same exact things, saw two tracks going in, jumbling up, coming out, but that meant somebody flew away. And that didn't even

occur to me until they brought it up. So, that right there shows how your preconceived notions and that kind of stuff can definitely influence you, where your observations even take you, and even where you're willing to see in a more complex situation.
I: Yeah, I think that's a really important point what you brought up..even what you're willing to see. Um, (H: Yeah), I want to go back to something else you said. It's kind of like 2+2 is always 4. (H: Yeah) Well, no. I'm just going to counter you. ok, let's just pretend. No, 2+2 does not always equal 4. If I have 2 grapes and I have 2 apples, that does not equal 4.
H: That's true. (giggling)
I: So, that's where I really want you to talk about. That notion of something being absolute. A fact. It's a very classic example…2+2=4. But…
H: Ok, but change but it can change if like if the situation changes. Like in my head, I'm thinking 2+2 of the same thing =4, but you bring up a different situation of 2 things of one type and 2 of another type, that's not going to equal 4, so the actual situation something is occurring in can change the facts and also I think the way the facts are presented based on the knowledge that backs up those facts. You know, if that background knowledge (phone vibrates in background) changes you know then the fact can change.
I: well…do you think…with all this notion of scientific knowledge, do you think that what we accept as knowledge that we basically accept it as true, lower case t, true, but we recognize some change may happen..blah blah. Can the same be true for my colleagues I have hear from India?
H: Not necessarily. (I:ok) I should say, yes and no. I think it depends on where they got their education. (I: okay) um, because a lot of what we accept or are taught as knowledge can change regionally as what is accepted in those areas. Um, like I know, from my experiences I came from just very southern Baptist background when it came to evolution. I was taught creationism period.
I: Ah, at your school? Or?
H: At home and uh…cause we basically didn't even touch it at school. It was kind of a don't talk about it, or we talked about it for a day and then it was micro not macro evolution. Uh, you know natural selection and the very small genetic changes, not genetic as the whole. Where as, I go to college and I am in a classroom with someone who is from California and they were brought up completely ignoring creationism and going with the more what I guess is considered the more scientific route of evolution that would be presented in a textbook as evolution of you know man came from a primitive ancestor type thing. And there – my - what I considered knowledge or facts - they weren't even willing to consider as facts, where as a lot of their facts I wasn't willing to consider at the time. Now I mean I was able to sit down and wade through stuff as a science minded person but somebody who is an English minded person might not be willing to accept those things as facts or knowledge based on their backgrounds.
I: So, how does all that influence how you handle all that influence? How you, how you view all this nature of science stuff we did in this course?

H: Um, I think that made me think of the nature of science as kind of like a mediator between different backgrounds or knowledge bases or however you want to approach it.

Cause the nature of science was, or is, I should say, it's not telling us facts or figures or anything like that. but it's more of a how to approach …
I: It's not telling us what to think? (H: yeah), is that what you mean? (H: yeah, yeah) what content? (H: yeah)
H: Yeah, but maybe how to think about that kind of stuff to wade through it and look at it through these things. Um, the I forget how it was phrased, maybe it was in the Benchmarks (I: um, hm) we read where there's no one answer and um things like that, that tells us not to take what we think as absolute truths or create them as absolutes because there could be evidence backing up something else. And they could be equally valid in the eyes of the evidence, which is what we really have to look at. So…
I: Uh, which kind of speaks to the tube activity. There were a couple of explanations from the tube activity that were put on the board in terms of how that worked. (H: Correct.) And um, no/all were valued. They were all equally plausible. And um, so some of you were okay with that and others of you were not. You wanted to open that tube up and see 'for real'.
H: Yeah, I was one of the ones who wanted to open it. –both chuckle –
I: So, that's kind of an example that supports what you were saying. Um, but it also supports other things. Content, you know? Um, and maybe you could just speak to that. What else does that tube, while it's a very isolated/abstract nature of science activity, how could it support content or be used in a classroom to support content?
H: Right, ok, um, the tube could represent, uh, I guess you could say a law or theory. It's actually like content or a knowledge base. but we can't look inside the tube, you could say that's like looking at plate tectonics or evolution or something where you can't look inside you know figuratively and get the answer to that kind of stuff. You have to make knowledgeable inferences based on what you can see now. And what your background knowledge might be, like, we knew just from experience, you pull on one string and the other gets shorter. But if you had a string outside the box, just in a linear fashion that wouldn't happen, so we had to make some inferences as to how they're connected and stuff based on, you know, background stuff.
I: Would you, or what did you think of that activity?
H: I like it a lot. (I: Did you?) Yeah, while it frustrated me, when I stepped back and looked at it from the aspect of taking it back to the classroom and how it could be part of content, I thought it was very applicable to a lot of because I'm a biology background person, a lot of biology content that can't be looked inside of the past and see because all of that evidence is gone. We only have what we can see now. So you can only explain to a certain degree. {This portion of the recording was very loud and the voices were muffled in various points, making some of the transcription impossible.}
I: So, um, the only activity that we have not spoken to is the concept cartoons.
H: ok
I: and the misconceptions article. You guys read the McComas article outside of class and then in class randomly drew one of the misconceptions and then were asked to draw or represent it though what's called a concept cartoon. Right? Are you um, do you like learning in that way?
H: Personally, no.
I: Right? Was there someone in your group who did?

H: Uh, um, in my group I would not say that. Uh, based on their frustrations with it. But then it may have just been the misconception that we had. That we all got frustrated to the point that, “we don’t like this,” but we eventually came up with something that worked really well for a lot of other members of the class.
I: Which was your misconception?
H: uh, the scientific process I think it was. I can’t think of the actual rule, but we used the “following the rigid process, or the creative uh…”

I: So it was frustrating for you because no one really cared to draw?
H: basically
I: And also frustrating to you because coming up with the others or the answer choices was tough…or what was the frustrating part I guess?
H: A lot of the frustration came from trying to get a situation that would apply to a cartoon setting that would be understandable to a mass that didn’t have to have a scientific background in order to get across that misconception and not something else. In order to get to that point, we were all over the place. So, I think that’s where the frustration was because we were very wanting to get to the content instead of the misconception and so
I: Do you think as a result of that that you probably..will you or will you not use that um concept cartoons for misconceptions – in your classroom?
H: Um, in one way I think I will use them. But in another aspect I don’t think I’ll use them. Cause I liked how you used one to present to us a misconception when you showed one up on the board and we had to pick the correct answer if there was one and then explain why the others were still valid but one was more correct. I liked that a lot. Because that involved…more…there was a visual aspect and auditory but there wasn’t any tactile to stop someone from enjoying the experience. You’re getting as much as could out of it. Um, as far as students creating one themself, I think that would have to be a class by class thing.
I: Decision?
H: Right. Because if I had a lot of pretty artistic students I think that would go over pretty well but if my classroom was filled with more auditory or visual learners and not tactile learners, it might pose a problem because I mean, I get frustrated with the experience, instead of pretty much what I was supposed to get out of the experience.
I: Right, so, um, that, um, uh, let’s see how do I say this? I knew going into that particular teaching strategy that I chose that there would be…I was thinking about half of you would not like it but I still wanted you to experience it because I knew that would be half that would like it. In terms of just the actual strategy itself. Not necessarily the thinking about the misconception itself but the way that they were being asked to portray their understanding. And the half that didn’t like it, I wanted you to experience because it meant that you were a different type of learner and that also means that your strategies you choose in your classroom are going to be more like what you like and that means that you are still possibly not going to get half of your class. And so I wanted to model that in the sense of getting you to think, ok, this blew for me, I hated this (both chuckle) but the good thing was that you saw how other people in your class were able to benefit from it. Even what you did not like, you used it to get something from it. So it’s that balance of instruction that is always at play and something you gotta think about. It had nothing to

do with NOS and everything to do with just instructional approach. So if you think about…well…let's just talk very briefly about instructional approach to NOS.
H: ok
I: The first was tricky tracks. How would you label that approach?
H: I guess as a more of a what I would consider maybe a more auditory, maybe verbal , which was kind of with the auditory but with the student being auditory not the teacher. Visual and tactile
I: Would you say student centered or teacher centered?
H: student centered.
I: ok, um, tube… teacher or student centered?
H: student centered still.
I: ok, so then go with learning?
H: uh, tactile experience
I: anything else?
H: to a certain extent I guess you could say visual. Because you have to look at it and everything.
I: ok, what about the drawing of the model?
H: I would still classify that as tactile, but it is a different type of tactile.
I: see in my mind, it adds visual because the people who weren't necessarily – they were pulling and pulling and pulling, they can't you know, they see that visual and it's like yeah, that's what I think.
H: looking at the stuff on the board was definitely a visual, but pulling the strings was tactile.
I: ok, um, the what was the next one? Oh, the concept cartoons which we've already talked about so the last one was … oh… um, the last one was the theories and law thing.
H: that was definitely more of an auditory/verbal type thing.
I: yes, um, I considered it a much more traditional approach to teaching. What did you think of that?
H: it worked for me to a certain extent. I am very much of an auditory/visual combination learner. So if it had been more like we know we did a Venn diagram which helped, but for the majority of the time it was very much visual/auditory based. That worked for me because I'm going to take it and process it but I know that's going to exclude a great deal of people. Cause I've seen it in family members that can not process auditory (ambulance siren blares in background)information without something to look at and write.
I: ok and that's where the resources came in, that way the resources, you know I gave about 4 or 5 resources explaining laws, theories, outside of the article that I had gotten you guys and that there was a graphic organizer on the backside of the agenda I think.
H: yeah
I: yeah, so just something to think about just in terms of you knowing how I was trying to plan for hitting those people that do need the writing or the kinesthetic aspect as well, so, just something to think about the next time you're planning a unit….which is not too far away. (smiling, nervous laughter)
I: so let's move on, so, what do you have to say about the course itself? Not necessarily NOS, though we can speak to that too but just uh, I think I hear you coming from a very traditional paradigm. So I think this might have been crazy different for you?

H: definitely, like I was very frustrated for like the first two wks of the class. And my parents are both educators and I would complain to them that I am learning nothing from this course, it's a waste of 3 hours of my day, everyday. Why am I here? And their answer was always like, you're not having to take a test so it's an easy A, just go sit. Well it ended up not being that in the end and I ended up loving the course definitely changing my whole perspective as to how a class should be run as opposed to being very teacher based, being very student based. Because in the end I didn't realize I learned, but my knowledge base has expanded drastically. And it wasn't that easy A sit back and take a huge test like a traditional test. You know there was a whole lot of thinking involved and writing involved and which seemed easy at the time which made me enjoy the assessment but I also had to be very specific and driven in how I approached my answer to those things which I had to take aspects from the course and so I liked it in the end but it was very frustrating for the first 2 weeks.
I: Do you think it was a manageable amount of frustration or were you on the cusp of quitting?
H: Me, yes.
I: We were just curious to know if anyone was just on the cusp of getting out of here, or if it was within that manageable zone?
H: it was manageable but I know from talking to people in the class there was this one person who was considering dropping out of the whole program because they could not handle this level of frustration.
They were so frustrated with the fact that they weren't learning. But again, in the end, they loved it just as much as I did, and so…It worked well.
I: since we're looking back, if your attitude or disposition had been different in those first two weeks as opposed to its an easy A, sit and listen, do you see yourself as having gotten something more or less or different out of those two weeks?
H: um
I: I know it's a hard question. Cause you don't really know. I'm only asking because if you take some teaching styles like this into your practice, you know, um, what are you going to do for your students? You know they're much younger than you (H: right), so what are you going to do to make their frustration a working frustration? As opposed to them going home making the same complaints you did and their parents go well it sounds like an easy A, cause here's what you know, that's not what their parents are going to say.
H: Right, they are going to go straight to the principal.
I: Right. That's exactly what's going to happen. So, how's it going to look different? You're going to teach different, you're going to do different, …. And we're excited to hear that but we also know there's a reality….so…
H: yeah, I think that I'll start out with …. Instead of like in this class…. Where we went head on, full inquiry, because you guys knew that we could deal with the frustration and we weren't going to go to the dean and complain because we're more adult than that. so in the classroom when I would do it, I think I would have to start out with more of a balanced mixture of the two. You know, going very traditional in some stuff but then inquiry based learning with others. So that the students felt like they were getting more…well they feel like they're learning, but not necessarily learning the whole time. Which would appease the parents and the students because if they feel like their learning

and at the same time there's that easy concept then they're not going to go complain. So then the parents aren't going to go complain, pissed off about your teaching style and go complain to the principal and you won't lose your job…so…I think that you have to start off with that very conditional aspect of you know, but then start working in inquiry and hopefully by about 3, 4 weeks in you've gotten the students accustomed to you know that inquiry based learning because you're with them every day and they get used to, get used to it, then eventually you can go full on with inquiry and get rid of a lot of the what you consider traditional stuff.

I: What made you come to realize this?

H: um, a lot of talking with fellow students and my parents and then um, also, I've got other friends that are in other education programs here and have already been through…for instance, one of them is, she's getting her masters and her certification for early childhood/special education but she's already in the classroom on a provisional. So, her students she has to approach with in a certain way or their parents will get very frustrated.

I: With their modifications, there are so many legal restrictions there that present a completely different set of issues..?

H: Right. She has changed her teaching style based on what Georgia State shows her that she can do. But she had to start off appeasing the parents, appeasing the administration, appeasing her advising teacher, and then eventually proving what she knew worked actually did work. (I: Yeah) So, talking with her, talking with other students in the program and just comparing ideas, and talking to my parents who have both been in it – my dad for 30 years, my mom for 28 – like seeing their experiences and what has worked and hasn't worked with trying to change the norm.

I: Do you see, um, when you're going home and talking to your parents about this and they hear this, I hesitate to call it a new way, but it is new to you (H: Right) and so I'll say, different, different way of teaching, How do they respond too, now that you're not the frustrated child and you're not thinking like this and now you understanding teaching to mean this, now how do your conversations go? In the sense of…is it influencing them even?

H: Um, I'd say yes and no. um, I think it's influencing them in the way that they're looking at the way content can be taught. But they're both music teachers and they're both very inquiry based anyways.

I: They teach high school?

H: My dad was middle school. He's retired now. My mom is elementary school, so she's very much inquiry, hands on all the time. And she at one of her other schools they tried to do cross curricular teaching (I: uh, huh) and so she did a lot of inquiry type things in her classroom that were never touched in the traditional classroom because of the traditional learning scheme. So she is thrilled at what I am doing and that I can actually verbalize to her what I am doing because before I didn't realize it was inquiry based learning going on, it was just 'were not being taught' (laughing); and you know that frustrated me which frustrated her…but you know…whatever. Now that I can verbalize what's going on, she is 100% for it and wishes they could apply it, but in her school, in the elementary school even more, but, which is going to be difficult cause it's a lot of 40 year old women basically is what it is at her school. Trying to get them to change their ways would be very difficult. So…

I: all it takes is a 'young whipper snapper' like you, eh? (both laughing)
H: not from what I've learned
I: well, I'm glad that you're expressing all this. We have a lot to learn from you guys. And I've learned. I think I've told you this, I think I told the class this, you guys are motivating to me. though I haven't been teaching as long as your parents, I feel like I've been teaching a long time, so you guys reignite my fire. (H:yeah) so I appreciate your participation and willingness in the end to jump those hurdles. (H laughs, yeah) Your units were fantastic, you know? It was evident in your units, speaking as a whole, that you guys had um understand what you've been empowered to do.
H: yeah, I could've never have done this, at least to the level, I think I did my unit. Because I would have done lecture the whole way, maybe thrown in what we learned as a cookbook lab, you know, and then traditional assessment at the end. You know, that would have been my lesson because that's what I've been used to and this is completely NOT what my lessons ended up being, my unit. You know.
I: no, we uh, were very proud of the outcome of those. You guys are going to have a great fall experience. You know you're going to experience some of the same frustrations because now you're going to be eager and we're going to encourage you all to try some of these things and um, you know we're gonna keep nature of science in there. We think nature of science is really important. It makes it um, I'm not sure if you understand in this way or not, but I understand nature of science to make science accessible to all students. For us, we are not looking at the 5-10% that are going to walk out and be scientists, we're looking at the nation as a whole.
H: Well, I know the nature of science is what got me into science. The experimentation aspect, understanding the idea behind science was the only reason why I went into science because I had one teacher he's here getting is doctorate now, he's a full bright scholar teacher. I mean he is definitely ahead of his game for his traditional. He's, I'd say, in his late 30s maybe by now, so he was taught in a very traditional way, very ahead of his time, and b/c of him teaching in a very inquiry based way and this is why things are the way they are that's the reason I went into. So, I wouldn't have been one of those 5-10%, so I'm definitely with you.
I: We want you to be that one teacher. Well, obviously we want more than 1…
H: all 27 of us…(laughs)
I: exactly. That would be awesome, wouldn't it? Just in terms of a final comment on nature of science. You mentioned in your unit plans that you wrote guiding questions, etc. etc. to make sure those nature of science standards were being met explicitly. So I just want to make sure that you explain to me how NOS needs to be taught in a classroom, or how we're advocating that NOS be taught in a classroom?
H: Um, what I've gathered from everything and what I think would be the best approach would be to continuously implicitly teach and then take the time to stop every once in a while, say once a unit if possible, and go into the explicit version of this is nature of science. Cause I don't think you can effectively teach the content without implicitly teaching the nature of science. And if we take that conscious step to explicitly explain or get the students to come to those conclusions on their own, like the tube experiment, or whatever. They have in the back of their hands been thinking the whole time.
I: So, to state those things outloud?

H: yeah, cause I know my whole unit, the whole time they are explaining and predicting or seeing how Mendel explained and predicted.
I: the students are explaining? Not you?
H: definitely, i was, the whole time, I was trying to get them to because I wrote out lecture notes for the whole substitute or another teacher type thing but I also think it helped me as a first time teacher. But you know, I would write it out. What is probability? (slight interruption because I looked at time, noticing that it was time for H to be in class – she commented it was fine that It was Dr. Nave, one of the most easy going professors on campus) And I allotted time for students to tell me what think probability is. I wrote in questions that students are going to come up with a definition for probability, so I wrote in an example with flipping a coin, most students have had that in math class, so what could we take from that and apply to this? Then to say…cause at that point we would have done a hands on experiment with no explanation of why just this is Punnett squares, pull these letters out of the bag, put em in this table and fill it out, what can we take from what we just learned about probability back to that and then explain and make those connections about predicting and explaining. I think that's extremely valuable because if you just tell a student it lasts until their tested on the material and then it's gone.
I: You know what's amazing me to me, you know, is to hear you talk about your unit and your teaching plans in this way versus you six weeks ago.
H: Definitely
I: you seem to have made some huge transformations.
H: Definitely
I: Wow, (laughs)
H: See I come from a very very traditional background and it didn't work for me which is why I think I've made that change so much. If you go back and look at my college transcripts, there's obviously a disconnect between my knowledge base and my grades. Um, if you look at tests, you see multiple choice doesn't work for me but if I can sit there and explain I'm making 100s. so when I'm given this other opportunity to teach students, I'm thinking that's gonna work for even multiple choice excel students if they can provide those explanations, they're going to do even better. And so I think that's why I was so willing to change my whole thought base. Well, it didn't work for and a lot of my colleagues. If it doesn't work for us, I can always go back. (laughs)
I: Well, thank you. We're really excited.

APPENDIX F

POST LESSON STUDY FOLLOW UP INTERVIEW PROTOCOL

- Tell me about what you were going through when you first started this practicum.
- Tell me about any ways that the lesson study impacted your experience.
- Could you see yourself trying another lesson study? (Why/Why not?)
- Tell me about how you see yourself reflecting on your own practices once you are teaching full time.
- Tell me some things that could help you be a reflective practitioner.
- Tell me how you feel about teaching NOS now.

APPENDIX G

DATA ANALYSIS

Data analysis of all data collected included an analysis of the levels of reflection preservice students were engaged in during the lesson study. Data sources were compiled and evidence indicating the preservice teachers' level were matched based on descriptions within the article and characteristics provided from Table 2 in Ward & McCotter (2004, p. 250).

	Levels			
	Routine Self-disengaged from change	Technical Instrumental response to specific situations without changing perspective	Dialogic Inquiry part of a process involving cycles of situated questions and action, consideration for others' perspectives, new insights	Transformative Fundamental questions and change
Focus (What is the focus of concerns about practice?)	Focus is on self-centered concerns (how does this affect me?) or on issues that do not involve a personal stake. Primary concerns may include control of students, time and workload, gaining recognition for personal success (including grades), avoiding blame for failure.	Focus is on specific teaching tasks such as planning and management, but does not consider connections between teaching issues. Uses assessment and observations to mark success or failure without evaluating specific qualities of student learning for formative purposes.	Focus is on students. Uses assessment and interactions with students to interpret how or in what ways students are learning in order to help them. Especially concerned with struggling students.	Focus is on personal involvement with fundamental pedagogical, ethical, moral, cultural, or historical concerns and how these impact students and others.
Inquiry (What is the process of inquiry?)	Questions about needed personal change are not asked or implied; often not acknowledging problems or blaming problems on others or limited time and resources. Critical questions and analysis are limited to critique of others. Analysis tends to be definitive and generalized.	Questions are asked by oneself about specific situations or are implied by frustration, unexpected results, exciting results, or analysis that indicates the issue is complex. Stops asking questions after initial problem is addressed.	Situated questions lead to new questions. Questions are asked with others, with open consideration of new ideas. Seeks the perspectives of students, peers, and others.	Long-term ongoing inquiry including engagement with model mentors, critical friends, critical texts, students, careful examination of critical incidents, and student learning. Asks hard questions that challenge personally held assumptions.
Change (How does inquiry change practice and perspective?)	Analysis of practice without personal response—as if analysis is done for its own sake or as if there is a distance between self and the situation.	Personally responds to a situation, but does not use the situation to change perspective.	Synthesizes situated inquiry to develop new insights about teaching or learners or about personal teaching strengths and weaknesses leading to improvement of practice.	A transformative reframing of perspective leading to fundamental change of practice.

APPENDIX H

COURSE SYLLABUS FOR FALL SEMESTER DUAL PRACTICUM AND

EDSC 7550 COURSE

EDSC 7550 TEEMS/TADS
Theory and Pedagogy of Science Instruction
Fall 2009

Course Focus: *Examines current issues, strategies, materials, and technology related to the teaching and learning of science at the middle and secondary school levels. Science curriculum, teaching, and research in science education are investigated.*

Expanding and augmenting the ideas constructed during the summer institute of TEEMS/TADS, preservice and inservice teachers will design instructional lessons that address misconceptions, immerse themselves in a setting within a different culture, develop a classroom management plan and explore and evaluate effective strategies in the science classroom. Helping students understand ideas about the world of science teaching through personal experience is one of the fundamental goals of training teachers for today's schools. This course will provide a variety of experiences in science education that are characterized as experiential, inquiry oriented, and reflective.

The experience will encourage a reflective and constructivist philosophy of teaching in which preservice and inservice teachers will examine their prior knowledge of teaching, and then explore science teaching experientially. To integrate the process of reflection and construction, preservice and inservice teachers will continue to work on the construction of a science teaching professional E-Portfolio.

Conceptual Framework: As part of the College of Education vision and goals in the Conceptual Framework, this course will prepare individuals who, by integrating their knowledge, skills, and attitudes, make and implement effective educational decisions and environments based on current instructional strategies and tools, including technology.

Learning Opportunities: There are required several aspects of the course. These are as follows:

The student will

- make positive and appropriate contributions during class, and actively participate on the bulletin board and online portions of the course.
- model reform-based pedagogy in peer-taught lessons.
- state appropriate, richly described, and critical self-evaluation of teaching in videotaped teaching segments.
- Complete assignments with a high degree of quality demonstrating application of concepts explored in this course (whether teaching strategies, science or nature of science concepts, and so forth)

Student Learning Outcomes	Framework Standards Addressed
1. **Knowledge:** Students will be able to discuss new curricular trends (technology, STS, etc.) and assert how they may be used in the contemporary science classroom.	Knowledge about teaching will grow and evolve with changing contexts and with improved inquiry about effective learning and teaching
2. **Knowledge:** Students will be able to discuss practical teaching strategies based on constructivist and cooperative learning models of teaching.	In teacher education programs, the learning process should be an active process.
3. **Knowledge:** Students will be able to discuss pedagogical content knowledge and the current research into the authentic practices and knowledge teachers have in their pedagogical realm	A teacher education program's knowledge base should integrate knowledge, skills, attitudes and technologies, and it should be grounded in theory and documented within current pedagogical and content literature.
4. **Knowledge:** Students will be able to increase their own scientific literacy, as well as be able to assist students in developing meaningful scientific terminology.	Demonstrates mastery of and continually pursues knowledge in the content area of the field for which he or she is prepared.
5. **Skill:** Students will be able to identify science inquiry skills and design methods of assessing these skills that are paramount in current school standardized testing.	Demonstrates mastery of and continually pursues knowledge in the content area of the field for which he or she is prepared.
6. **Skill:** Students will be able to participate with colleague design teams to develop secondary school teaching materials (student projects) based on the learning cycle, technology and cooperative learning.	Demonstrates the ability to integrate assessment, planning, instruction/intervention, and evaluation strategies.
7. **Skill:** Students will be able to synthesize concepts presented in class to complete a project involving traditional and nontraditional teaching strategies in order to constructively present a topic of social significance to culturally diverse school science learners.	A teacher education program should utilize a variety of teaching strategies to meet the needs of the learner.
8. **Attitude:** Students will be able to recognize the importance of making science real and applicable to students' everyday lives.	Knowledge about teaching will grow and evolve with changing contexts and with improved inquiry about effective learning and teaching.
9. **Attitude:** Students will be able to reflect on their own learning about science concepts so that they may acknowledge student science learning.	A teacher is a critical and independent thinker.

<u>Knowledge Base</u>

Suggested Texts

Fay, J. (1995). *Teaching with Love and Logic: Taking control of the Classroom.* Golden, CO: Love and Logic Press.

Obidah, J. & Teel, K. (year). Because of the Kids: Facing Racial and Cultural Differences in Schools. Teachers College Press.

National Academy of Sciences (2000). *Teaching about Evolution and the Nature of Science.* National Academies Press.

Rutherford, F. James, and Ahlgren, A., (1990). *Science for All Americans*. New York: Oxford University Press.

Wong, H. & Wong, R. (2001). *The First Days of School: How to Be an Effective Teacher*. Sunnyvale, CA: Harry Wong Publications.

*Additional required readings to be handed out during class or posted online

Teaching Strategies: The nature of the course will be open and informal to create a learning and supportive environment for pre service teacher collaboration. This course will provide a variety of experiences in science education that are characterized as experiential, inquiry oriented, and reflective. Various teaching strategies will be used in order to model effective teaching and practice. The online environment will be accessed for email, Bulletin Board, assignments and collaboration. Assessments will be alternative in nature, including portfolios and project based assessments.

Technology: There is strong technology integration in this course that satisfies several technology standards for teachers. Students are required to use LiveText, YahooGroups and Georgia State email for communication and collaboration.

Diversity: Addressed through individual assistance and the informal environment of the class. There is equal access to all instruction. Special attention on diversity in the science classroom will be addressed through lecture, cooperative projects, case study, and teaching diverse student populations in the practicum.