EXPLORING THE COMPONENTS OF CONCEPTUAL ECOLOGY MEDIATING THE
DEVELOPMENT OF NATURE OF SCIENCE VIEWS

Hasan Deniz

Submitted to the faculty of the University Graduate School
in partial fulfillment of the requirements
for the degree
Doctor of Philosophy
in the School of Education
Indiana University
December 2007
Accepted by the Graduate Faculty, Indiana University, in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

Doctoral Committee

_________________________
Valarie L. Akerson, Ph.D.

_________________________
Fouad Abd-El-Khalick, Ph.D.

_________________________
Gayle A. Buck, Ph.D.

_________________________
Troy D. Sadler, Ph.D.

_________________________
George M. Malacinski, Ph.D.

August 13, 2007
To my family
EXPLORING THE COMPONENTS OF CONCEPTUAL ECOLOGY MEDIATING THE DEVELOPMENT OF NATURE OF SCIENCE VIEWS

The purpose of this study was to examine the impact of an explicit-reflective instruction involving the portrayal of non-controversial nature of science aspects on prospective elementary teachers’ nature of science views and epistemological beliefs about science, and the factors mediating the development of nature of science views and epistemological beliefs about science in an introductory science course context. Using a mixed methods approach, this study examined the impact of the explicit-reflective instruction by doing pre- and post-instruction assessments of nature of science views and epistemological beliefs about science. This study also examined to what extent the factors such as prior nature of science views, metacognitive awareness, thinking dispositions, science self-efficacy beliefs, and motivation are related to post-instruction nature of science views and epistemological beliefs about science. The findings suggested that the explicit-reflective nature of science instruction was effective in improving nature of science views and epistemological beliefs about science. However, a holistic examination of post-instruction nature of science views indicated that post-instruction nature of science views reflected a “naïve relativistic” position. The findings also suggested that prior nature of science views and epistemological beliefs about science were related to post-instruction nature of science views and
epistemological beliefs about science, and none of the other factors with one exception was found to be related to post-instruction nature of science views and epistemological beliefs about science. Thinking dispositions measured at the beginning of the study was found to be related to post-instruction epistemological beliefs about science. Interesting relationships between nature of science views and epistemological beliefs about science were also found.
# TABLE OF CONTENTS

Chapter I: Introduction........................................................................................................ 1

Chapter II: Theoretical Framework.....................................................................................13

Chapter III: Review of the Literature..................................................................................20

  The Implicit Approach to Improve NOS Views...............................................................20
  Summary............................................................................................................................32

  The Explicit-Reflective Approach to Improve NOS Views..............................................33
  Summary............................................................................................................................43

  The Studies Exploring the Factors Mediating the Development of NOS Views......43
  Summary............................................................................................................................50

Identification of Factors Related to the Development of NOS Views and Epistemological Beliefs about Science.................................................................51

  Prior Conceptions..........................................................................................................51

  Metacognitive Awareness.................................................................................................52

  Thinking Dispositions....................................................................................................52

  Science Self-efficacy Beliefs............................................................................................53

  Motivational Factors.......................................................................................................53

  Summary............................................................................................................................54

Relationships between Factors Possibly Related to NOS Views and Student Achievement..................................................................................................................54

  Summary............................................................................................................................73
Chapter I

Introduction

Much has been written about nature of science (NOS) in science education literature in the second half of the twentieth century. This emphasis underscores the importance of NOS as a major research agenda in science education. The importance of NOS is also recognized by major science education policy documents by putting NOS at the center of scientific literacy (American Association for the Advancement of Science [AAAS], 1993; National Research Council [NRC], 1996).

It was acknowledged that there is no agreed-upon single NOS, but certain aspects of NOS are unproblematic and relevant to K-16 education (e.g., Abd-El-Khalick & Akerson, 2004; Schwartz & Lederman, 2002; Schwartz, Lederman, & Crawford, 2004). Schwartz et. al. (2004) described the nature of science aspects as follows:

1. Tentativeness: Scientific knowledge is tentative, but durable. It is subject to change with new observations and with interpretations of new observations.
2. Empirical basis: Scientific knowledge is based on evidence and observations of nature.
3. Subjectivity: Science is theory-laden. Scientific evidence is filtered through the lenses of scientific theories. This makes science unavoidably subjective. Personal subjectivity of scientists is also unavoidable.
4. Creativity: Human imagination and logical reasoning play an important role in the development of science.
5. Socio-cultural embeddeness: Science is a human activity and it is influenced by social and cultural factors.
6. Observation and inference: Science is depended on both observation and inference. Observations are made through human senses and scientific tools.
Observations are neutral statements about the nature. Inferences are interpretations of those observations.

(7) Laws and theories: Theories and laws are different kinds of scientific knowledge. Laws explain relationships in nature through mathematical formulas. Theories are inferred explanations of natural phenomena. Theories do not become laws with the time. (p.613)

The importance of adequate understanding of NOS can be argued on three grounds: curricular, democratic, and pedagogical. The curricular argument suggests that it is difficult for students to have mastery level content knowledge in one area of science let alone in all science subjects. Adequate understanding of NOS will enable students to have a general background for scientifically-based knowledge. This curricular argument is connected to the democratic argument. The democratic argument claims that in the future, students as citizens in a democratic society will have to make decisions involving controversial issues in science. The nature of these controversial issues requires scientifically literate citizens to make informed decisions. It was assumed that informed NOS views provide people an insight about how scientific knowledge is produced and an insight about values and assumptions of science. On this basis, it can be argued that lack of NOS understanding may cause people to make uninformed decisions. As for the pedagogical argument, students’ NOS views can be related to learning certain science content. It was found that having adequate understanding of NOS can facilitate the learning of certain science content such as evolution (Dagher & BouJaoude, 1997; Rutledge & Warden, 2000).

Lederman (1992) in his extensive review of the literature divided NOS literature into four distinct, but related categories. Reviewing the previous NOS research by using
Lederman’s (1992) categorization is helpful in terms of putting the state of current research on NOS into perspective. Lederman’s (1992) categorization of NOS research is as follows:

(a) Assessment of student conceptions of the nature of science;

(b) Development, use, and assessment of curricula designed to “improve” student conceptions of the nature of science;

(c) Assessment of, and attempts to improve, teachers’ conceptions of the nature of science;

(d) Identification of the relationship among teachers’ conceptions, classroom practice, and students’ conceptions (p.332).

I will summarize Lederman’s (1992) review of the NOS literature using his categories below. For the detailed analysis and the original references, the reader is referred to Lederman (1992).

(a) Assessment of students’ conceptions of NOS: Studies that investigated students’ conceptions of NOS during late 1950s, 1960s, and early 1970s reached the same conclusion that students did not possess adequate conceptions of NOS.

(b) Development, use, and assessment of curricula designed to “improve” student conceptions of NOS: During the 1960s and early 1970s some studies compared the effects of an inquiry-oriented curriculum on students’ conceptions of NOS to the effects of traditional curriculum. These studies resulted in mixed results. They showed that effects of inquiry-oriented curriculum on students’ conceptions of NOS were neutral or somewhat positive. These studies also showed that students’ ability to understand the nature of science varied when they were taught by different teachers.
(c) Assessment of, and attempts to improve, teachers’ conceptions of NOS: Various studies on this area during 1960s and early 1970s showed that even most science teachers did not possess adequate conceptions of NOS. After realizing this disheartening fact, some researchers directed their attention to finding ways to improve teachers’ NOS conceptions. It was found that addressing the historical aspects of scientific knowledge and teaching NOS aspects directly could have some level of success in improving NOS views. Studies conducted during the 1980s and the early 1990s corroborated with the studies conducted in the 1960s and 1970s. They reached the same conclusion that teachers did not have adequate NOS conceptions. Improving teachers NOS conceptions were intuitively seen as a step towards improving students’ NOS conceptions.

(d) Identification of the relationship among teachers’ conceptions, classroom practice, and students’ conceptions: Various studies conducted during the late 1980s indicated that teachers’ adequate conceptions of NOS and their classroom practices were not significantly correlated.

It was asserted that many factors such as curriculum constraints, administrative decisions, and materials can affect the translation of teachers’ informed views of NOS in actual classroom settings (Lederman, 1999). Studies conducted during the late 1990s and early 2000 also reached the same conclusion that teachers’ adequate conceptions of NOS and their classroom practices were not significantly correlated (Abd-El-Khalick, Bell, & Lederman, 1998; Akerson & Abd-El-Khalick, 2003; Lederman, 1999).

Nowadays, science education researchers are still concerned with assessing students’ and teachers’ NOS views, and they still attempt to improve students’ and teachers’ NOS views through various interventions. Based on the recent literature on NOS two distinct
approaches can be identified for improving NOS views: (a) the implicit approach and (b) the explicit-reflective approach.

Some researchers attempted to examine the impact of the implicit approach on students’ NOS views by engaging them in doing science in authentic laboratory settings. These studies revealed that engaging a large number of students in doing science in an authentic lab environment was not an easy task to achieve and students’ conceptions of NOS were not found to be significantly improved by their short-term involvement in authentic science settings (e.g., Bell, Blair, Crawford, and Lederman, 2003). The implicit approach to teach NOS was also undermined by some studies indicating that even the scientists do not necessarily hold contemporary NOS views (e.g., Glasson & Bently, 2000; Pomeroy, 1993).

As for the explicit-reflective instruction, a considerable number of studies showed that explicit-reflective NOS instruction modeled after constructivist teaching and learning principles can substantially improve NOS views (e.g., Akerson, Abd-El-Khalick, & Lederman, 2000; Schwartz & Lederman, 2002). We now know that explicit-reflective NOS instruction is effective in improving NOS views. However, even in the studies which employed the explicit-reflective nature of science instruction participants’ post-instruction NOS views were found to be fragmented. Most participants did not show growth in all NOS aspects and some participants did not show substantial growth in most NOS aspects. Substantial numbers of studies examining the impact of explicit-reflective NOS instruction did not consider the factors mediating the development of NOS views, rather they only documented the changes in NOS views doing pre- and post NOS
assessments. The common modus operandi in these studies was to assess NOS views before and after the explicit-reflective instruction.

In the late 1990s personal epistemology literature (e.g., Hofer, 1997; Hofer and Pintrich, 1997) provided alternative measures of students’ epistemological beliefs about science. These theorists envisioned epistemological beliefs as a domain-specific multidimensional construct. They separated themselves from theorists (e.g., Baxter Magolda, 1992; King & Kitchener, 1994; Perry, 1970) who were concerned with students’ personal epistemologies rather than their epistemological beliefs about science. These theorists envisioned personal epistemology as a domain-general unidimensional developmental construct. They all assumed a continuum from a dualistic objectivist view of knowledge to a more subjective relativistic view, and finally to a contextual, constructivist view (Hofer & Pintrich, 1997). Schommer (1990) challenged the view that epistemological beliefs are unidimensional and they are developed following a certain trajectory of stages. Schommer (1990) contemplated that five related but independent dimensions constitute personal epistemology. Schommer’s (1990) original five dimensions are as follows: (a) seek single answers and avoid integration (simple knowledge); (b) avoid ambiguity and knowledge is certain (certain knowledge); (c) don’t criticize authority and depend on authority (omniscent authority); (d) can’t learn how to learn, success is unrelated to hard work, and ability to learn is innate (innate ability); (e) learning is quick, learn the first time, and concentrated effort is a waste of time (quick learning). Later, Hofer (1997) proposed that epistemological beliefs are composed of four dimensions: (a) certainty/simplicity knowledge, (b) justification for knowing, (c) source of knowledge, and (d) attainability of truth. Hofer (1997) provided evidence that her
proposed four dimensions cut across disciplinary domains (e.g., science and psychology) and students hold different epistemological beliefs depending on the domain (e.g., science and psychology).

Considering that NOS refers to the epistemology of science (Lederman, 1992) it is appropriate to draw a parallel between students’ NOS views and epistemological beliefs about science. It can be thought that certain dimensions of Hofer’s (1997) epistemological beliefs scale are related to certain NOS aspects. For example, certainty of knowledge dimension is related to what extent students think that scientific knowledge is subject to change. For this reason, certainty of knowledge dimension is similar to tentative NOS aspect. Attainability of truth dimension is related to what extent students think that scientists can ultimately get to truth. Therefore, it is possible that students who think that attainability of absolute truth is not possible in science are more likely to think that scientific knowledge is subjective because of theoretical and personal bias of scientists. Based on these assumptions it can be argued that if students’ epistemological beliefs about science improve as a result of the explicit-reflective NOS instruction this can be used as further evidence with regard to the effectiveness of the explicit-reflective NOS instruction.

Recently, some researchers started to investigate the factors mediating the development of NOS views. For instance, Abd-El-Khalick and Akerson (2004) provided empirical evidence that gains in students’ NOS views are related to their motivation level to learn NOS, the metacognitive awareness and the global worldviews encompassing epistemological beliefs and religious orientation. Akerson, Morrison and McDuffie (2006) found that the retention of informed NOS views is related to students’
epistemological beliefs. Southerland, Johnston and Sowell (2006) identified a considerable number of factors which can facilitate or hinder one’s development of NOS views. These factors are as follows: thinking dispositions, beliefs about learning and learners, and view of science as an enterprise (product, process, or blended), affect for science, past science experiences, and learning goals.

NOS research is in transition to a new phase in which the researchers will devote their time and energy to determine what factors mediate the development of NOS views and epistemological beliefs about science. The current study explored various factors that can possibly mediate the development of NOS views and epistemological beliefs about science. The current study aims to be a step towards determining the components of a conceptual ecology that facilitate or hinder the development of NOS views and epistemological beliefs about science.

A careful analysis of the recent NOS literature, the conceptual change literature, and the literature on personal epistemology enabled the author to identify the factors that may be related to the improvement of NOS views and epistemological beliefs about science. These factors can be grouped under five categories: (a) prior conceptions, (b) metacognitive factors, (c) science self-efficacy beliefs, (d) motivational factors, and (e) thinking dispositions.
Figure 1. Conceptual model showing hypothesized relationships among motivational factors, metacognitive strategy use, science self-efficacy, and nature of science views/epistemological beliefs about science.

There is a consensus among researchers that teaching NOS should be treated like other cognitive learning outcomes (e.g., Schwartz & Lederman, 2002). The literature suggests that students’ motivational beliefs, metacognitive strategy use, and science self-efficacy beliefs are related to students’ performance in science and mathematics (e.g., Elliot, McGregor, & Gable, 1999; Hayden & Roeser, 2002; Wolters, 2004). Therefore, it can be inferred that these factors should also be related to students’ nature of science views and epistemological beliefs about science.

Southerland et al. (2006) suggested a positive relationship between thinking dispositions and nature of science views without providing much empirical support. Sinatra et al. (2003) and Deniz, Donnelly, and Yilmaz (in press) found a positive
relationship between thinking dispositions and acceptance of evolutionary theory. Thinking dispositions are included in this study because of exploratory purposes.

First, I hypothesized that prior NOS views and epistemological beliefs about science should play an important role in determining one’s ability to acquire more informed NOS views and epistemological beliefs about science. The importance of prior conceptions was underscored by many (e.g., Ausubel 1978; Bransford et al., 1999; Chinn & Brever, 1993; Pintrich et al., 1993). Pintrich et al. (1993) also underscored the importance of students’ confidence in their pre-existing beliefs as they might interfere with the process of conceptual change. I hypothesized that students’ confidence in their pre-existing NOS views might impact the learning process in two different ways. For instance, on one hand students’ confidence in their uninformed NOS conceptions may hinder the learning process, on the other hand students’ confidence in their informed NOS conceptions may facilitate the learning process by making the integration of newly presented conceptions to their already informed NOS conceptions optimal.

Second, I hypothesized that metacognitive awareness of students would facilitate their ability to acquire more informed NOS views and epistemological beliefs about science. Abd-El-Khalick and Akerson (2004) found that the learners with deep orientation to learning improved their NOS views substantially more than their peers with surface orientation to learning.

Third, I hypothesized that students’ self-reported confidence in understanding science and using science in their lives would facilitate their ability to acquire more informed NOS views and epistemological beliefs about science. Self-efficacy beliefs have been
defined as a domain-specific construct about individuals’ self-reported performance capabilities in a particular domain (Bandura, 1986).

Fourth, I hypothesized that motivational factors should play a role in learning about NOS aspects and in improving one’s epistemological beliefs about science. Abd-El-Khalick and Akerson (2004) also found that internalizing the importance of NOS or being motivated to learn about NOS helped the learners to improve their NOS views. Pintrich et al. (1993) also underscored the importance of motivational factors during the learning process.

Fifth, I hypothesized that students with more sophisticated thinking dispositions would be more likely to revise and improve their NOS views and epistemological beliefs about science. Southerland et al. (2006) suggested that thinking dispositions such as actively open-minded thinking are related to learners’ NOS conceptual frameworks. It was assumed that learners with such thinking dispositions would show more growth in their NOS views because of their tendency to consider alternative opinions and evidence, and to search and process information that goes against their beliefs.

This study addressed the following research questions:

1. To what extent will an explicit-reflective NOS instruction that satisfies the conditions for learning as conceptual change as described by Abd-El-Khalick and Akerson (2004) and Hewson, Beeth, and Thorley (1998) improve students’ NOS views and epistemological beliefs about science?

2. Are there any correlations within and between students’ pre- and post-instruction NOS views, and pre- and post-instruction epistemological beliefs about science?
3. Are students’ post-instruction NOS views related to their metacognitive awareness, thinking dispositions, science self-efficacy beliefs, and motivation measured at the beginning of the intervention?

4. Are students’ post-instruction epistemological beliefs about science related to their metacognitive awareness, thinking dispositions, science self-efficacy beliefs, and motivation measured at the beginning of the intervention?
Chapter II

Theoretical Framework

Trying to explain how students assimilate scientific information into their existing conceptual framework and how their conceptual framework is adjusted in order to accommodate scientific knowledge was a focus of extensive research during almost last three decades in science education. This line of research was appealing to many science educators. This gave rise to the various accounts of conceptual change in the literature (e.g., Chi, Slotta, & de Leeuw, 1994; Posner, Strike, Hewson, & Gertzog, 1982; Vosniadou, 1994).

The most famous and influential of all these various accounts of conceptual change is the conceptual change model developed by Posner et al. (1982). This conceptual change model draws heavily from the history and philosophy of science. The central phenomenon in this model is how students change their conceptions based on new and conflicting evidence. The influence of ideas articulated by Kuhn (1970) and Lakatos (1970) can easily be seen in the conceptual change model developed by Posner et al. (1982). Posner et al. (1982) stated that science learning involves conceptual changes comparable to a “scientific revolution” and replacement of “research programs” in science itself.

In the initial formulation of the conceptual change model, Posner et al. (1982) sequentially provided the list of conditions required for conceptual change. The first condition-*dissatisfaction* is met when the learner is dissatisfied with the existing conception. The learner fails to rationally explain some event with his/her current understanding. The second condition-*intelligibility* necessitates that the learner has at
least some understanding of the newly presented conception. The third condition- 
*plausibility* is met when the new conception seems valid to the learner. If the new 
conception does not show any degree of fitness into the learner’s existing conceptual 
ecology, it is likely to be rejected. The fourth condition- *fruitfulness* is that the learner 
should be able to utilize the new concept to explain the phenomena that the old 
conception accounted for and new events that formerly could not be explained.

Although the conditions articulated by Posner et al. (1982) are helpful to understand 
the process of conceptual change they do not suggest a mechanism for conceptual 
change. Piagetian theory offers a mechanism to explain the process of conceptual change. 
According to Piaget (1964) learning occurs through *cognitive disequilibrium*. *Cognitive 
disequilibrium* has two main components: *assimilation* and *accommodation*. Individuals 
either fit new experiences within existing cognitive frameworks (*assimilation*) or 
individuals modify existing cognitive frameworks to account for new experiences 
(*accommodation*). In the conceptual change model the emphasis was placed on 
*accommodation*.

A collection of epistemological commitments called the learner’s “conceptual 
ecology” (Toulmin, 1972) was an important construct that was used by Posner et al. 
(1982) in the initial formulation of the conceptual change model. Conceptual ecology in 
the initial conceptual change model was primarily restricted to the cognitive domain. 
Although Posner et al. (1982) was aware that affective and motivational factors are also 
influential on the learning process they chose to focus on cognitive aspects of the learning 
process (Abd-El-Khalick & Akerson, 2006; Tyson, Venville, & Harrison, 1997). For this 
reason, the initial model was found overly rationalistic and criticized by many (e.g., Pines
& West, 1986; Solomon, 1987; West & Pines, 1983). Later, in response to criticisms of “conceptual ecology” in the initial formulation of the conceptual change model was broadened by Strike and Posner (1992). Strike and Posner (1992) modified the model in a way that a wider range of factors were considered to describe a learner’s conceptual ecology as well as cognitive factors. The revised conceptual change model was called a “revisionist theory of conceptual change” and the importance of the roles of intuition, emotion, motives, and social factors was made explicit in this revised model (Strike & Posner, 1992).

Even the revised conceptual change model was subject to severe criticism (Alsop & Watts, 1997; Caravita & Halldén, 1994; Cobern, 1996). Alsop and Watts (1997) criticized the revised model for remaining largely cognitive in emphasis. They suggested the inclusion of three dimensions such as affect, conation, and self-esteem in the model. The affective domain included three elements (salient, germane and palatable) and emphasized the learners’ interest on learning. The conative domain also included three elements (trust, control, and action) and focused on the practicality and applicability of knowledge. Just like affective and conative domains, self-esteem, also included three elements (image, confidence, and autonomy). Self-esteem emphasized the importance of learners’ perception have of themselves in relation to science and their perseverance in the face of incomprehension.

Another severe criticism came from worldview theory of Cobern (1996). Cobern (1996) formulized worldview as a combination of a number of components such as religion, gender, ethnicity, and science views. According to worldview theory these components form a unified and coherent worldview unique for each person and some of
these components are more dominant than others. Cobern (1996) criticized the conceptual change model because it assumed that learners subscribe to “scientific” world view by not considering that scientific views are only one component among many competing components in one’s worldview. For this reason, Cobern (1996) stated that it is not surprising to see some students fail to develop orthodox scientific conceptions even after carefully designed instruction because of the interference of other components of the worldview. Abd-El-Khalick and Akerson (2004) found Cobern’s (1996) criticism of the conceptual model pessimistic and they stated that Cobern (1996) did not provide an alternative functional model.

Caravita and Halldén (1994) questioned the epistemological foundations of the original conceptual change model (Posner et al., 1982) and the revised conceptual change model (Strike & Posner, 1992). They claimed that comparing children to scientists and borrowing heavily from the history and philosophy of science literature (e.g., Kuhn 1970; Lakatos, 1970; Toulmin, 1972) limit our understanding of the learning process rather than empowering it. They suggested caution in drawing a parallel between the development of scientific ideas and the learning process. They stated that science as an enterprise is epistemologically different from school science. They also criticized that using the cognitive disequilibrium in Piaget’s theory of cognitive development as a mechanism for the conceptual change. They suggested that there is a distinction between the process of individual development and the process of learning by stating that even Piaget himself acknowledged this distinction. They also did not offer an alternative model.

Chi, Slotta, and deLeeuw (1994) approached the process of conceptual change from ontological perspective. This approach was based on the assumption that our brains
classify different entities into different ontological categories which may or may not be compatible with the scientifically accepted categories. According to this approach, if there is mismatch between learners’ original categorization and scientifically accepted categorization the learning process would be hindered. Chi et al., (1994) conceptualized conceptual change in terms of the reassignment of the ontological category to which the concept is originally assigned.

Vosniadou (1994) articulated her own version of the conceptual change model. She claimed that mental models are created by learner right on the spot to deal with specific problem-solving situations. She argued that mental models are the points where assimilation of new information is realized to the existing conceptual framework. She further argued that mental models can facilitate or hinder the learning of formal scientific knowledge. Vosniadou (1994) suggested that assimilation of new information into an existing conceptual framework, and revision of a mental model on a particular subject are easier than revising long held and deeply entrenched alternative frameworks. Vosniadou (1994) stated that conceptual change is difficult to realize and it is more likely to cause misconceptions when it requires fundamental revisions in the existing conceptual framework (entrenched presuppositions). Vosniadou (1994) pointed out that students may store inconsistent information in isolated conceptual structure in a way that it does not cause any cognitive conflict with other existing presuppositions.

Vosniadou, Ioannides, Dimitrakopoulou, and Papademetriou (2001) further articulated Vosniadou’s (1994) model. They stated that conceptual change does not require the abandonment of learners’ initial conceptions in favor of scientific conceptions. In their view, the conceptual change is a slow revision of existing
conceptions through incremental incorporation of scientific conceptions. They are not particularly concerned whether the prior conceptions are retained or abandoned as a result of instruction. They suggested that the aim of instruction is to enhance the new and qualitatively different knowledge representations not annihilating the previous conceptions. For this reason, their characterization of the conceptual change process stand in sharp contrast with the characterization of the conceptual change process of Posner et al. (1982). However, in terms of their gradual approach to the conceptual change process there are similarities between Vosniadou et al. (2001) and Posner et al. (1982). Posner et al. (1982) also stated that accommodation is a gradual adjustment of conceptions, but the end result is a major reorganization of learners’ conceptual framework.

Science education literature and cognitive psychology literature on conceptual change have long been segregated. The research on one domain made little reference to the other and vice versa (Duit & Treagust, 2003). However, Sinatra and Pintrich (2003) acknowledged the contributions of both science education and cognitive psychology on the conceptual change literature. Sinatra and Pintrich (2003) emphasized the role of learner’s intentions in the conceptual change process. The researchers working from this intentional conceptual change perspective started to investigate the role of affective constructs such as epistemological beliefs and thinking dispositions on the process of conceptual change (e.g., Sinatra & Pintrich, 2003; Sinatra, Southerland, McCounaughy, & Demastes, 2003; Southerland, Johnston, & Sowell, 2006). Pintrich, Marx, and Boyle (1993) suggested that four general motivational constructs such as goals, values, self-efficacy, and control beliefs should be considered as mediators of the process of
conceptual change and classroom contextual factors as moderators of the relations between student motivation and conceptual change.

It is now clear that the conceptual change model which is strictly restricted to the cognitive domain fell short in explaining the complexity of the learning process. Prior conceptions and learners’ confidence in their prior conceptions, affective, motivational, and ontological factors as well as cognitive factors should be taken into consideration simultaneously when explaining the complexity of the learning process. Theoretically, it makes sense that above factors can mediate the cognitive process. Furthermore, it is theoretically possible that the contextual factors can also play important roles in the cognitive learning process through their connection to affective and motivational factors. However, these theoretical assumptions need to be supported with empirical evidence. Pintrich et al. (1993) called for such empirical studies linking affective and cognitive domains. This study is an attempt to respond to such an important call.
Chapter III

Review of the Literature

The 22 studies reviewed below are organized into four sections: (a) the implicit approach to teach NOS, (b) the explicit-reflective approach to teach NOS and (c) studies exploring the factors mediating the improvement of NOS views, (d) studies exploring relationships between factors possibly related to the development of NOS views and student achievement.

The Implicit Approach to Improve NOS Views

This section includes 5 studies. The following 5 studies examine the impact of students’ research experiences on their NOS conceptions.

Bell, Blair, Crawford, and Lederman (2003) reported a study in which ten high-ability students (6 females, 4 males) from grades 10-11 participated as apprentices at a Northwest University. These ten students worked in different laboratories full time for 8 weeks during the summer. The purpose of the study was to explain the impact of the 8-week participation on students’ understanding of NOS and scientific inquiry. At the beginning of the 8-week program, the students were given a modified version of the Views of Nature of Science, Form B (VNOS-B) to assess their views nature of science and scientific inquiry. The researchers used six open-ended questions from VNOS-B and they developed two questions to assess the students’ knowledge of scientific inquiry and abilities to do scientific inquiry. They used the same questions at the end of the 8-week apprenticeship program. The researchers asked a panel of three science educators to evaluate the content and face validity of these questions. The researchers used a semi-structured interview protocol to further examine the nature of students’ apprenticeship
experiences. These interviews took place at the end of the 8-week program. The researchers aimed to probe the students’ conceptions of nature of science and scientific inquiry. The researchers also conducted semi-structured interviews with the scientists who served as mentors or masters at the end of the 8-week program. The interviews provided additional information about the apprenticeship experience and the degree of instruction that was provided by scientists related to NOS and scientific inquiry. The researchers also collected notes from the laboratories and fields in which the apprenticeships were conducted. Before analyzing the entire data set, the researchers randomly selected three identical samples of each of the data sources and analyzed the data. They reached more than 95% agreement in the data analysis. The researcher used Bogdan and Biklen’s (1992) model of analytic induction in the analysis of the entire data set. They focused on generating categories of students’ understanding of NOS and scientific inquiry before and after the apprenticeship experience.

The researchers pointed out that one of the most important aspects of the scientific inquiry, which is developing research questions, was missing in many of the apprenticeships. The researchers reported that mentors believed that the students mostly learned about specific process skills and aspects of experimental design. Interactions between mentors and students were related to immediate problem solving and little time was spent on explicitly discussing general attributes of science.

The researchers reported that the students’ understanding of NOS were similar to the understandings of NOS reported in previous studies and inconsistent with the contemporary interpretations of NOS at the beginning of the apprenticeship program. The researchers reported that the students saw subjectivity in science as inevitable but
something to be avoided, none of the students made a connection between the subjectivity and creativity, they did not seem to understand the theory-laden nature of data interpretation, and social and cultural context in which scientific investigations are conducted were totally overlooked. The researchers came to the conclusion that little change in students’ understanding of NOS occurred and none of the students were found to have adequate understanding of the nature of science. The researchers reported that the students gained increased level of experience in doing science, but few students demonstrated increased understanding about the nature of scientific inquiry and 7 out of 10 students referred to a single scientific method in both pre- and post-questionnaires.

Richmond and Kurth (1999) reported a study in which they investigated how research apprenticeships shaped students’ view of the culture and practice of science. Twenty-seven (14 female, 13 male) 11th and 12th graders from across the United States and American Samoa were selected from a national pool of applicants based on their interest and past performance in science to participate in a 7-week summer research program in which the students were matched with a research mentor based on their preference for a particular project. The researchers frequently asked the students to reflect in journal writing and orally in individual interviews on a large number of issues regarding their views of science and scientists, their prior experiences in and out of school, and their own interest in pursuing a science-related career. They stated that application essays, interviews, journals and researcher field notes were the data sources that were used in the study. They interviewed the students at the beginning, in the middle and at the end of the apprenticeship program. They chose 7 students out of 27 students as a focus group on the basis that they were representative of the group with respect to race, ethnicity, gender,
social class, initial views about science, and research topic. They described the background of each student clearly, but they failed to report the nature of the project in which the students were involved. They just reported that particular student’s research project was in astronomy, biology, chemistry, or physics.

The researchers used an ethnographic approach in data collection and analysis suggested by Glaser and Strauss (1967), and Hammersley and Atkinson (1983). They adjusted the content of the instruments based on weekly conversations about the students’ experiences and students’ journal writings. They revised interview questions, probes, and journal writing assignments to be sensitive to the issues the students were dealing with in the apprenticeship program. They did not provide any version of interview protocols and structure of journal writing assignments. Based on the data analysis, they came up with four dimensions of the culture and practice of science: (a) technical language, (b) collaboration, (c) uncertainty, and (d) inquiry.

The researchers reported that the students were immersed in the literature early in the program and much of vocabulary within the readings was unfamiliar, but all the students used the language associated with their research project correctly and efficiently and had solid understanding of the research problem towards the end of the program. The researchers reported that the students thought of individual scientists working on research questions alone and this view changed dramatically because of the apprenticeship program settings in which students worked for 7-weeks. The researchers reported that the students’ experiences with science in school had made them believe that most questions had unambiguous answers that were reachable in a short amount of time and uncertainty was stemming from the experimenter error, rather than being natural part of the research
process. They pointed out that the students learned, to some degree, that uncertainty was an integral part of science encouraging scientists to ask additional questions and to find creative ways of answering them. The researchers reported that the students held an incorrect view of scientific inquiry at the beginning of the apprenticeship program in the sense that they thought that the emergence of issues and their resolution took place in a short period of time. They pointed out that the students started to see science as a cumulative body of work with ideas building upon each other in a fairly long amount of time towards the end of the apprenticeship program. The researchers identified three different communities in which students participated during the apprenticeship program: (a) the laboratory-centered community, (b) peer-centered community, and (c) program-centered community. They described the experiences of students in each community. The students learned that the labs in which they worked were quite different from the sterile and isolated environment that they associated with scientific enterprise, and dynamics of the lab contributed to the way scientific understanding developed. The researchers reported that the peer interactions during the apprenticeship program gave the students an opportunity to share their experiences in an environment in which the students felt less threatening. The students were part of different programmed activities continuing during the apprenticeship program such as speakers, watching science related movies, and discussions regarding how research questions are generated and tested, the politics of science, gender and race issues in science. This study illuminated what and how students learned about the culture and practice of science as they developed a sense of identity of a scientist. The researchers reported that the students’ ideas about what it means to do science became more complex, more realistic, and richer as they moved from the
periphery of the scientific community toward the center. They stated that they did not expect that a 7-week experience would bring about a level of understanding about how science is done and how scientific ideas are developed that is as advanced as someone who spent years in the field. However, they reported that the change in the understanding of most of the students were remarkable over only 7 weeks.

Barab and Hay (2001) reported a study in which they summarized the characteristics of apprenticeship learning based on the literature and used these characteristics to evaluate 6 different apprenticeship programs in which 24 middle school students (11 girls 13 boys) coming from 13 different schools were matched with scientists in the School of Sciences at a large Midwestern university. The researcher described the characteristics of each program in detail. For instance, the students analyzed the effects of various insecticides for inhibiting the growth of the Juvenile Hormone in moths in one of the programs. The students applied topical assays of the treatment insecticide or controls to worm larvae and then observed the differences in growth of the worms. The students performed dissections, weighed worms, collected, analyzed, and interpreted data. The students worked in groups of four for ten days as they conducted scientific research and prepared scientific presentations under the tutelage of a scientist and with the guidance of their teachers. The students came from different economic backgrounds and various academic abilities. How these students were selected was not clear in the study, but all the students submitted an essay stating which groups they wanted to participate in and why. Six middle school science teachers (3 male and 3 female) who had taught at least 5 years were selected and some of these teachers had some kind of connection with the director of the apprenticeship program before the study began. The researcher sent an
invitation letter to the associate dean of the College of Arts and Sciences, six scientists (1 female and 5 male) agreed to participate in the study. They reported that the teachers participated in a 2-day workshop in which they learned about the characteristics of the program, met with the scientists before the program started, they discussed the nature of the projects and learning challenges that might face during the program.

They reported that an evaluator was present for ten days and for the final presentation day. The two researchers also collected field notes, videotaped students while they were working in the laboratory, and conducted interviews. The researchers also asked the students to keep an electronic research notebook in which they kept track of their field notes and data collection techniques, etc. This electronic notebook also provided an opportunity for students to chat with other students, their teacher and scientists, to check their schedule, and to visit related links.

The researcher stated that they collected naturalistic data to provide the holistic vision of the apprenticeship program. But they pointed out that their data collection focused on certain predetermined characteristics of the apprenticeship program. They stated that their interpretations of the data were emergent and data analyses were consistent with the constant-comparison method suggested by Glaser and Strauss (1967). The researchers discussed field notes, students’ interviews, and teacher observations during their daily meetings. They refined their interpretations during fieldwork, group meetings, and data collection and analysis. They also triangulated the data through multiple methods of data collections including interviews, field notes, videotape analysis, learner debriefing, and referential materials.
The researchers reported that the students were engaged in doing science and there was no separation between doing science and learning science. They stated that the students analyzed data on the final 2 days of the program and the scientists helped them to draw inferences from the data. The students made presentations at the end of the apprenticeship program. These presentations served as an indicator whether the students understood the scientific process occurring in laboratory. The students were taught didactically how to make a presentation, but they decided what content to present as well as order and means of presentation. The researchers found that the students continually engaged in discussions similar to the discussions that practicing scientists engaged in. The students engaged in hypothesizing about explanations that they believed to fit the available evidence, defended their hypothesis, and debated with the scientists. The researchers pointed out that the scientists shared their previous research experience with the students, the students learned science under the expert guidance, and learning was seamless part of the environment. The students were lectured on two occasions outside of the laboratory context, however the scientists engaged in brief less than 5-minute lectures in response to students questions on numerous occasions in the laboratory. The researchers acknowledged that the students had little control over primary research questions, basic goals and assumptions of the research, and they entered the ongoing practice of science by conducting experiments that were part of the scientist’s research agenda. However, the researchers reported that the students frequently perceived their actions as authentic and they believed that the scientists valued their contributions in the laboratory. The teachers served as liaisons between the students and scientists. When the scientists explained concepts and asked questions the students did not understand, the
teacher paraphrased the scientist for the students. The teachers also encouraged the students to reflect on what they had learned during the day and to ask questions to the scientists using the electronic notebook. The researchers acknowledged that the amount of time that the students spent in the apprenticeship program was limited. However, the researchers pointed out that the students were able to engage in many of the key principles of doing authentic science, including doing domain-related practices in response to domain-related dilemmas, negotiating scientific and technical meanings, and learning “at the elbows” of more knowledgeable others. The methods that were used to conduct this study were appropriate, but limited amount of time that the scientists spent with the students called the conclusions of this study into question. Although, the researchers reported that the apprenticeship program lasted for 10 days, later they explained that the scientists worked with the students for only 6 days and actual contact time between the students and scientists was only 2 hours per day. They reported that many of the participants were able to gain an appreciation of situated nature of science. But they did not use any formal NOS questionnaire to measure participants’ NOS views.

Ritchie and Rigano (1996) reported a study in which they discussed the viability of cognitive apprenticeship for learning science in school in relation to findings from an investigation of a research project involving high school students working in a university chemical engineering laboratory under the mentorship of a scientist. There were 2 students participating in this study. The study took place in Australia. Both students were senior secondary students (years 11 and 12) and they were both received As in their science and mathematics classes. The students were released from their normal school classes one afternoon once a week for up to 6 months to complete the project. They
worked in a chemical engineering lab used by three chemical engineering staffs and
graduate students. One of the researchers observed all the laboratory sessions and took
field notes which focused on context, discursive interactions and the students’ actions. They stated that these field notes became the primary data source and they used these field notes to prepare interview questions. The researcher used stimulated recall technique suggested by Marland (1984) where video recordings of students were used to stimulate students thought process during the interviews. The researchers also used additional data sources such as student journals and concept maps. They stated that they analyzed the data in an interpretive way and they followed a hermeneutic style where they developed assertions in a continuous cycle of data gathering. They did not cite any interpretive data analyzing reference, but they cited Guba and Lincoln (1989) as a reference supporting that they did member checks to improve the credibility of the results. The researcher acknowledged that their own experiences and beliefs affected the data analysis and they gave detailed descriptions of their backgrounds. One of the researchers was holding a doctoral degree in science education and the other researcher was a scientist holding a doctoral degree in biochemistry. The researchers came up with three assertions based on the data analysis: (a) laboratory skill development preceded conceptual development, (b) challenges provided opportunities to practice skills, but increased frustrations and revived memories of fudging in school cookbook labs, (c) students developed into independent researchers during the project.

The researchers reported that the students had to learn how to use new pieces of apparatus and techniques at the beginning of the project. They pointed out that the students’ understanding increased as they became more competent in using the apparatus
and techniques. The researchers reported that the students became frustrated on several occasions during the project when a time consuming procedure needed to be repeated. The students expressed the opinion that these occasions would be the fudge time, if they were in the school cookbook laboratory session. In other words, students would alter their findings according to the expected results to avoid frustration and receive good grades in their school cookbook laboratory sessions. The researchers reported that the students did not think of doing fudging in this project because the students owned the project, and fudging would mean that they were cheating themselves. The researchers reported that the project was not based on the student questions however the students became independent researchers just like the other researchers within the laboratory community as their confidence grew. The researchers expressed their doubts with regard to the general effectiveness of apprenticeship models in school. They stated that the teachers with limited disciplinary background might not be able to serve as expert mentors and some teachers might have a blind commitment to the science content, national curricula, and textbooks. The researchers did not clearly describe the nature of the project and the research questions that were provided to the students by their mentor were not mentioned in the study. The researchers reported that students developed into independent researchers, but they did not claim that students did have adequate views of NOS at the end of the cognitive apprenticeship program.

Ryder, Leach and Driver (1999) reported a study in which they investigated the images of science of 11 undergraduate students (7 female and 4 male) working on final-year undergraduate research projects including various science disciplines such as chemistry, biochemistry, earth science, and genetics at the University of Leeds. Students
worked alone under the supervision of a science lecturer within an authentic science laboratory up to 8 months. Students worked on original research questions which were not pursued previously. As a result of this authentic research experience the researchers hypothesized that students were likely to develop social representations about NOS. The researchers did not administer paper and pencil NOS questionnaire. They explored students NOS views through interview-based case study approach. The researchers stated that this study was part of a larger study in which students were interviewed three times, but they only used first and third interviews to investigate students’ NOS views. The researcher used the same 5-question interview protocol during both first and third interviews. The researchers analyzed students’ responses for each question and they created a framework which addressed three aspects of NOS after analyzing the data as a whole. Their framework included the following aspects of NOS: (a) the relationship between scientific knowledge claims and data, (b) the extent to which scientists were seen as following a coherent line of inquiry, (c) the social dimensions of science.

The researchers reported that all the participants made statements indicating that knowledge claims could be proved absolutely, but 4 participants also made statements that knowledge claims go beyond the data and the proof is problematic. Seven participants who stated that knowledge claims could be proved absolutely during the first interviews stated the same understanding during the third interviews with the exception of one participant. Four participants who made no statements about the absolute knowledge claims made such statements during the third interview. Five participants who made statements about the extent to which scientist were following a coherent line of inquiry made the same kind of statements during both first and third interviews.
participants who made no statements about the extent to which scientists were following a coherent line of inquiry made statements about the extent to which scientists were following a coherent line of inquiry with exception of one participant. Participants recognized that scientists do not work in isolation, but a few of them were able to elaborate on the social dimensions of science. They also reported that students whose projects required relating data to knowledge claims tended to show development in their epistemological reasoning and students whose projects whose project involved making experimental techniques work tended to show limited development.

Summary. Barab and Hay (2001) and Richmond and Kurth (1999) reported gains in students’ conceptions of NOS as a result of 8 to 10-week research experience without doing formal NOS assessments. Although Ritchie and Rigano (1996) reported that participants developed into independent researchers they did not comment on gains in students’ conceptions of NOS as a result of the research experience. Ryder et al. (1999) reported limited gains in understanding of undergraduates’ understanding of NOS as a result of 8-month authentic research experience. In contrary to the findings of Barab and Hay (2001) and Richmond and Kurth (1999), Bell et al. (2003) reported that 8-week research experience did not make any difference in students’ conceptions of NOS based on formal NOS assessments. Only Bell et al. (2003) used formal NOS assessments. Except the study of Ryder et al. (1999) all of these studies suffer from similar shortcomings. Students were placed into an apprenticeship program under the mentorship of a scientist for 7 to 10-week period in all of these studies. Students became part of a research team and engaged in different aspects of the scientific inquiry. Students found themselves in the midst of an on-going research project and they tried to keep up with the
pace of the project. They had an extremely limited amount of control over the research agenda. In general, the actual contact time between the students and their mentor was not mentioned or this contact time was short (e.g., 5 hours a week). Learning the culture and practice of science through participation in scientific communities of practice takes time and it is unreasonable to expect major gains in students’ understanding of culture and practice of science within 7 to 10-week periods.

The critical review of these studies suggests that students’ NOS views without deliberately teaching the target NOS aspects will be likely to remain naïve and will not be suffice to qualify as informed even if the amount of time spent in authentic research settings is increased.

*The Explicit-Reflective Approach to Improve NOS Views*

This section includes 5 studies. The following 5 studies examine the impact of explicit-reflective NOS instruction on students’ NOS views across various contexts such as an introductory physics course, elementary and secondary science teaching methods courses, 6th grade elementary science class, and an authentic research experience.

Abd-El-Khalick (2001) conducted a study of 30 female elementary education majors who were enrolled in a semester-long physics course for elementary teachers at the Department of Education at an American University in a Middle Eastern Country. Participants’ age ranged between 17 and 22, with an average of 19.8 years. Ten participants were sophomores, 12 participants were juniors, and 7 participants were seniors. Twenty seven participants had very limited science background. The course was taught by the author and it included the atomic structure of matter; the physical characteristics of solids, liquids, gases, and plasmas; heat, temperature, heat transfer; and
basic thermodynamics. During the first five hours of the course, the author used five content free NOS activities (Lederman & Abd-El-Khalick, 1998) to explicitly introduce participants to the following target NOS aspects: tentative, inferential, empirical, creative, theory-laden NOS, and the functions and relationships between theories and laws. Each activity was followed by either small group or whole-class discussions. The explicit NOS instruction was also supported with several examples of from history of science and complementary readings. The NOS framework developed at the beginning of the course was later used as a theoretical lens to interpret participants’ science content and inquiry skills learning. An eight-item open-ended NOS questionnaire was used to assess participants’ NOS views. Participants filled NOS questionnaire before and after the course. Two of the questions were content-specific. One of the questions was related to a familiar content (atomic structure) which was covered in the course and the other question was related to an unfamiliar content which was not covered in the course. The rest of the questions were generic. Twelve randomly selected participants (six at the beginning of the study and six at the end of the study) were interviewed to avoid misinterpreting the questionnaire responses. The author analyzed the data and a graduate student in science education performed a blind round of analysis. The correspondence between two analyses was about 87%. First of all, the author analyzed the pre-instruction questionnaires of the six randomly chosen participants and the graduate student analyzed these participants’ interview transcripts. Then the same procedure was repeated with the post-instruction questionnaires and interviews. This helped the author to establish the validity of his interpretations of students’ written responses. Later, all NOS questionnaires were independently analyzed by the author and graduate student to
generate pre- and post-instruction profiles of participants’ NOS views. Pre- and post-profiles were compared to evaluate changes in participants’ NOS views. The author reported that 18 (60%) participants’ pre-instruction NOS views seemed to fit into a “scientistic” worldview, but other participants’ NOS views were fragmented. These participants held informed views of three or four of the six target NOS aspects, but expressed uninformed views of the rest of the aspects. At the beginning of the instruction, 8 participants (27%) expressed a belief in the existence of a universal “Scientific Method”, 19 participants (63%) stated that science relies on observations of the natural world by ignoring the role of subjective and creative human elements in the construction of scientific knowledge, 18 participants (60%) stated that laws are fixed and more reliable than theories and they cannot be changed under any circumstances, 18 participants (60%) stated that scientists are hundred percent sure about the structure of the atom because they see atoms under the microscope, 20 participants (67%) with regard to the dinosaur extinction controversy did not seem to believe that scientists look beyond the empirical data using inference, creativity and imagination, and 23 participants (76%) stated that theories change not because they held genuine informed conceptions of tentative NOS, but because they held uninformed conceptions about the functions and relationships between theories and laws.

At the end of the instruction, participants held more informed views about the target NOS aspects. Compared to 18 (60%) at the beginning of the study, 5 participants (17%) noted that scientific laws are fixed at the end of the study. Twenty participants (67%) noted that both scientific theories and laws are tentative. Compared to 18 (60%) at the beginning of the study, only 4 participants stated that scientists were certain or hundred
percent sure about the structure of the atom. Similarly, compared to 5 (17%) at the beginning of the study, 13 participants (43%) supported the inferential and internally consistent nature of scientific theories at the end of the study. Compared to 23 (76%) at the beginning of the study, only 4 participants (13%) stated that there is a hierarchy between theories and laws. Participants expressed more informed ideas about creative and imaginative NOS. Compared to 4 at the beginning of the study, 20 participants (67%) expressed more informed views of creative and imaginative NOS. Lastly, 13 participants (43%) expressed informed conceptions of the inferential, creative and imaginative NOS in their responses with regard to atomic structure. The author reported that participants were more successful in explaining the NOS aspects in a familiar context (atomic structure) as compared to unfamiliar context (dinosaur extinction). The author reported that many of the participants were not comfortable with the idea of ambiguity in science and they shifted from “believing” in science to viewing science as “someone’s opinion about what is going on.”

Akerson, Abd-El-Khalick and Lederman (2000) conducted a study of 25 undergraduate students (23 female and 2 male) and 25 graduate students who were enrolled in two different sections of an elementary science methods course in a midsized Western university. The undergraduates’ age ranged between 23 and 43, with a median of 28 years and the graduates age ranged between 25 and 52, with a median of 32 years. Undergraduate students were pursuing a Bachelor’s degree in elementary education and graduate students were working towards a Master’s degree in elementary education. The first author taught both sections of the elementary methods course. Both of the sections
were similar in structure. Both sections met once a week for 3 hours. Both sections were subjected to the same readings, activities, and assignments during the semester.

An open-ended NOS questionnaire was used to assess participants’ NOS views. Participants in both sections filled NOS questionnaire before and after the course. A total of 40 participants (20 from each section) were chosen for interviewing. Half of the participants from each section were interviewed at the beginning of the semester and the other half of the participants from each section were interviewed at the end of the semester. Interviews were important to establish the validity of the questionnaire and not to misinterpret the students’ responses during data analysis.

NOS aspects were explicitly addressed through generic NOS activities as described in Lederman and Abd-El-Khalick (1998). Participants were encouraged to relate science content and pedagogy to NOS during the NOS instruction.

The second and third authors analyzed the data qualitatively according to Strauss and Corbin (1990). The questionnaires and interview transcripts were separately analyzed and then interview transcripts were used to establish the validity of the NOS questionnaire. As a result of data analysis pre- and post-profiles were produced for each participant. The pre- and post-profiles for each participants across the two sections were compared to assess changes in participants’ NOS views.

The majority of the participants in both sections held unsatisfactory views of one or more of the seven intended aspects of NOS at the beginning of the semester. Participants’ NOS views were not consistent across all the seven intended aspects of NOS. More than 60 percent of participants held unsatisfactory views on the seven aspects of NOS except social and cultural aspect of NOS in both sections.
More participants held satisfactory views of NOS at the end of the semester. Both groups showed comparable gains in their NOS views across seven aspects of NOS. More than 50 percent of undergraduate students showed gains in their NOS views across all the seven intended aspects other than empirical and the relationship between theories and laws aspects of NOS. More than 50 percent of graduate students showed gains in their NOS views across all the seven aspects of NOS except creative and imaginative aspect of NOS. Undergraduate and graduate participants’ NOS views on the seven intended aspects were not substantially different. The researchers concluded that explicit-reflective NOS instruction was effective to improve participants’ view of NOS within the context of an elementary science methods course. However, the researchers also reported that the improvements on participant’s views of NOS were not consistent across all the seven intended aspects of NOS.

Khishfe and Abd-El-Khalick (2002) sought to study the impact of explicit reflective inquiry-oriented NOS instruction and implicit inquiry-oriented NOS instruction on 62 sixth graders’ understanding of NOS. Participants were enrolled in two intact sections in a private school in Lebanon. The first section, the explicit section, consisted of 33 students (16 female and 17 male) and the second section, the implicit group, consisted of 29 students (12 female and 17 male). The school science achievement of the students in these two groups was not significantly different (p > .05).

Participants in both groups were taught for two 50-minute sessions per week over the course of 10 weeks. They engaged in the same inquiry activities. Topics of the inquiry activities included structure of matter (atomic structure), properties of matter (mixtures, phase changes), energy transformations (heat and heat transfer), combustion, earth
science (fossils). These topics were taught using a guided inquiry instruction. In the explicit section, all or some of the intended NOS aspects were mentioned and students are led to discuss and reflect on the intended NOS aspects. The researchers defined explicit-reflective NOS instruction as students’ awareness of NOS aspects in relation to the science activities and student reflection on these activities. The researcher cautioned readers not to equate explicit-reflective NOS instruction with didactic teaching strategies and they stated that the explicit-reflective NOS instruction was compatible with constructivist teaching principles.

A six-item open-ended NOS questionnaire was used to assess participants’ NOS views. The questions in the open-ended questionnaire were designed to tap the tentative, empirical, inferential, and imaginative and creative NOS. Participants in both sections filled NOS questionnaire before and after the intervention. A purposeful sample of 16 students (8 from each section) was chosen for interview both before and after the intervention. The students interviewed at the end of the intervention were different from those chosen for pre-intervention interviews. Interviews were used to establish the validity of the questionnaire and to avoid misinterpreting the students’ responses during the data analysis. Both researchers analyzed the data qualitatively. They found that views of intended NOS aspects of students in both groups were not different at the beginning of the study. They also found that views of intended NOS aspects of students in the implicit group at the end of instruction were not different from their pre-instruction views. They reported that post-instruction views of students in the explicit group were substantially different from their pre-instruction views in the expected direction. They concluded that explicit and reflective inquiry-oriented NOS instruction is more effective than an implicit
inquiry-oriented NOS instruction. However, they acknowledged that the explicit-reflective NOS instruction was effective to some degree. They reported that only 24% of the explicit section students showed improvement with regard to all the intended aspects of NOS. Students in the explicit group had informed views of tentative (52%), inferential (40%), empirical (48%), and creative and imaginative (34%) NOS at the end of the intervention.

Palmquist and Finley (1997) reported a study in which 15 postbaccalaureate students who were enrolled in two consecutive secondary school science teaching methods course at the University of Minnesota participated. Participants ranged between 23 and 45 years. Sixty percent of the participants had worked in a science lab at least for 6 months. The researchers stated that two methods courses followed a different approach in teaching about NOS, but a careful reading of how they dealt with teaching NOS in both methods courses suggested that substantial direct NOS instruction were provided in both methods courses. Pre- and post-intervention data were collected through a NOS survey followed by semi-structured interviews. A sample of lesson plans, curricular materials, and journal entries were collected from participants for analysis. The same 8 participants were also interviewed to illuminate how they incorporated NOS into their lesson plans after both first and second methods courses. Data were analyzed qualitatively according to a predetermined scheme. The scheme included three categories (traditional, mixed, and contemporary NOS views). The researchers stated that they validated the scheme through extensive discussions with two experts in the philosophy of science. They reported that they were able to classify more than 90% of NOS aspects highlighted in interview and survey transcripts using these three predetermined categories.
The researchers reported that 3 participants had traditional NOS views, 1 participant had contemporary NOS views and the great majority of the participants (11 participants) had mixed NOS views at the beginning of the intervention. The majority of participants’ views on the “Scientific Method” and laws were traditional, but the vast majority of participants’ views on scientific theories, the role of scientists and the tentativeness of scientific knowledge were contemporary.

They reported that teachers’ views were more contemporary after the methods courses meaning that fewer teachers held traditional views. But there were two exceptions. Teachers’ views on the “Scientific Method” and laws did not change from traditional to contemporary as a result of intervention. This was not surprising in that the “Scientific Method” and laws were not taught explicitly in methods courses. More teachers had contemporary NOS views on scientific theories, the role of scientists, and the tentativeness of scientific knowledge at the end of the intervention and all these NOS aspects were taught explicitly. Nine of the 15 participants’ NOS views changed from traditional view to a mixed view or from mixed view to a contemporary view.

Schwartz, Lederman, and Crawford (2004) examined 13 preservice secondary science teachers’ NOS views before and after a 10-week research internship. All of the participants were seeking a master’s degree in teaching in a mid-sized Western university. Participants’ NOS views were assessed through a formal NOS questionnaire (VNOS-C) coupled with semi-structured interviews both before and after the research internship. The research internship included seminars and journal assignments in addition to research component. All the participants were matched with a practicing scientist at the University. They spent an average of 5 hours a week in the research settings for 10
weeks. The researchers reported research experiences of preservice secondary science teachers did not involve components of higher level authentic scientific inquiry. NOS aspects were taught using an explicit-reflective approach during five 2-hour seminars. Journal assignments gave participants an opportunity to keep detailed records of their research experience much like a practicing scientist and to make connections between their research experiences and NOS aspects. The first author performed the qualitative data analysis and the second author reviewed the analysis and interpretations. Data generated by each participant were analyzed separately and comparisons between the participants’ profiles were made to describe generalities across the participants. They reported that participants showed substantial development in their NOS knowledge. Eleven of these 13 participants demonstrated progress in their NOS views at the end of the research internship. Two participants did not show any progress in their NOS views. The researchers reported that the participants attributed their improved NOS views to their journal writings and the participants stated that the seminars were the most beneficial component of the research internship. The researchers also reported that none of the participants stated that their research experiences directly impacted their NOS views. On the other hand, the researchers acknowledged that the research experience provided a context for reflection on NOS aspects. The researchers reported that prior research experience did not seem to make a difference on NOS learning. They also reported that the research experience on its own had little impact on interns’ understanding of NOS. This study invests on the notion that if NOS aspects are explicitly taught within the framework of an authentic research experience participants can better contextualize abstract NOS ideas in terms of concrete experiences.
Summary. The 5 studies reported above came to the same conclusion that the explicit-reflective approach was effective in improving NOS views across different contexts. The explicit approach was effective within the context of a physics course designed for elementary teachers (Abd-El-Khalick, 2001), an elementary science teaching methods courses (Akerson et al., 2000), a 6th grade science class (Khishfe & Abd-El-Khalick, 2002), a secondary science methods course (Palmquist & Finley, 1997), and an authentic research experience (Schwartz et al., 2004). However, participants’ post-instruction NOS views were found to be fragmented. A substantial number of participants did not show growth in all NOS aspects and some participants did not show substantial growth in most NOS aspects.

The Studies Exploring the Factors Mediating the Development of NOS Views

This section includes 3 studies. The following 3 studies explored the factors related to the development of NOS views in the context of elementary science teaching methods courses and a graduate level NOS course.

Abd-El-Khalick and Akerson (2004) conducted a study in which they examined the effectiveness of explicit-reflective NOS instruction that met the conditions for learning as conceptual change and they identified factors that mediated the improvement of NOS views. Participants were 28 preservice elementary teachers (25 female, 3 male) enrolled in an elementary science teaching methods course at a mid-sized Western state university. Participants’ age ranged from 23 to 44 years. Participants’ pre- and post-instruction NOS views were assessed by an open-ended NOS questionnaire (VNOS-B) coupled with semi-structured interviews. Ten participants were randomly selected to be interviewed both at the beginning and at the end of the study. A total of 17 participants
were interviewed because three of the participants were interviewed both at the beginning
and at the end of the instruction.

Participants received explicit-reflective NOS instruction which satisfied the
conditions for learning as conceptual change as described by Hewson, Beeth, and Thorley
(1998). Participants’ pre-instruction NOS views were used as a discussion point and they
were revisited several times during the study. Then, participants were assigned to two
readings which presented the science education community’s perspective on NOS
aspects. Participants were engaged in 11 NOS activities coupled with small group and
whole class discussions during the weeks 3-5 of the semester. Participants were also
provided with opportunities to reflect both orally and in writing on NOS aspects
throughout the semester. After the third week of class participants were assigned to a
series of readings addressing NOS aspects and they were asked to write a reflection paper
on each reading. The researchers reported that quality of participants’ reflection papers
improved over the semester. The instructor of the course kept a detailed log of her
teaching prompts and interplay of ideas between herself and participants. At the end of
the fifth week the researchers purposefully selected 6 participants as a focus group. These
6 participants showed similar NOS views at the beginning of the study and showed
greater variance in terms of their improvement of NOS views on target NOS aspects.
Members of this focus group were closely followed throughout the rest of the semester
and all their reflection papers were collected for data analysis. These 6 participants were
also interviewed at the end of the instruction and they were specifically asked to
comment on whether their views on target NOS aspects changed as a result of NOS
activities.
The data were analyzed by the first author and the second author performed a round blind of analysis. Participants’ pre-VNOS-B responses were used to generate a summary their NOS views: empirical, inferential, tentative, theory-laden, and creative NOS, the myth of “scientific method,” and functions and relationship between theories and laws. The researchers analyzed the summaries to search for categories. The categories were then checked against the data and the necessary modifications were made. The process of category formation, confirmation and modification was repeated several times. These categories were used to create a profile of participants’ NOS views. Then, these categories were compared to the profiles generated from separate analysis of VNOS-B responses and corresponding interviews. The researchers reported that there was 95 percent or better agreement between the categories initially formed and the profiles generated from separate analysis of VNOS-B responses and corresponding interviews. This meant that the first authors’ interpretations of participants’ written NOS views in VNOS-B were not different from participants’ NOS views as articulated during the interviews. Participants’ post instruction NOS views were analyzed in a similar fashion. As a result, the researchers obtained pre- and post-instruction profiles for each participant’s NOS views. Then, the researchers compared and contrasted the two profiles to assess the impact of the intervention.

The researchers used the focus group data to explore the factors mediating the improvement of NOS views. Because the 6 focus group participants had similar pre-instruction NOS views, the researchers analyzed the post-instruction VNOS-B responses and associated interview transcripts to determine the expected differences between focus group participants’ NOS views. As it was anticipated, three of the participants showed
substantial growth in their NOS views and other three participants showed minimal growth. Then, the focus group participants’ reaction papers, interview transcripts, and contributions to class discussions were critically analyzed to determine the factors that facilitated and hindered the development of informed NOS views.

The researchers reported that only a small number of students had informed views of NOS at the beginning of the study. Less than 30% of the participants had informed NOS views across empirical, tentative, theory-laden, inferential, creative NOS, the myth of the scientific method, and the distinction between the theory and law. They reported that participants improved their NOS views with regard to all the aforementioned NOS aspects. Participants had informed views of empirical (71%), tentative (64%), theory-laden (82%), inferential (75%), creative (86%) NOS, myth of the scientific method (68%), and the distinction between the theory and law (75%). This meant that the explicit-reflective NOS instructions which satisfied the conditions for learning as conceptual change was effective in helping participants improve their NOS views on all target NOS aspects. Based on the close examination of the focus group data, the researchers identified three factors that mediated the development of informed NOS views: internalizing the importance of NOS, the global worldviews encompassing participants’ religious orientation and epistemological beliefs, and deep versus surface orientation to learning.

Akerson, Morrison, and McDuffie (2006) conducted a study in which 19 preservice elementary science teachers (16 females and 3 males) participated at a midsized Western state university. Participants’ age ranged from 25 to 49 years, with a median of 32 years. All the participants were seeking to obtain Master’s degree in elementary education. The
first author taught the class. The participants received an intensive 6 hours of NOS instruction which addressed NOS aspects explicitly in the context of elementary science methods course. Most of the activities that were chosen for NOS instruction were generic activities (Lederman & Abd-El-Khalick, 1998). Only one activity, Rutherford’s Enlarged (Abd-El-Khalick, 2002), embedded within the science content was used to highlight NOS aspects. Students participated in oral and written activities that led them to reflect on NOS aspects.

Participants’ pre- and post-instruction NOS views were assessed by an open-ended NOS questionnaire (VNOS-B) coupled with semi-structured interviews. The VNOS-B coupled with semi-structured interviews was also administered after 5 months from the conclusion of the methods course. The researchers were able to gather a complete set of data from 17 of these 19 participants.

Each participant was treated as a separate case and the data generated by each participant was analyzed qualitatively. As a result of data analysis, participants’ NOS views across tentative, creative, subjective, empirical, inferential NOS, the distinction between theory and law, and the social and cultural influences were identified as inadequate, adequate and informed views. The data generated thorough the second administration of VNOS-B coupled with semi-structured interviews were used to explore participants’ personal epistemology according to Perry’s (1970) scheme. The researchers stated that they chose to analyze this set of data because they hypothesized that their personal epistemology at the end of the intervention would influence the retention of adequate or informed NOS views.
The researchers reported that participants made substantial increase in their understanding of intended aspects of NOS. Participants’ views across all seven intended aspects of NOS increased from inadequate to adequate or informed views. The researchers found that one student at Perry position 1, no student in position 2, three students in position 3, five students at position 4, six students at position 5, and one student at one position 6. There were no students beyond position 6. Perry’s scheme contains 9 original positions. Perry’s epistemological scheme is developmental in nature and each position represents epistemologically more sophisticated position than the previous position.

Although there were substantial increases in participants’ understanding of intended NOS aspects the researchers reported that these adequate or informed views of NOS aspects were not retained by all participants and participants who were categorized below Perry position 5 reverted to their original NOS views more often than participants at positions 5 and 6.

Southerland, Johnston, and Sowell (2006) conducted a study in which participants enrolled in a graduate-level course entitled *The Nature of Science and Science Education* in the United States’ intermountain west. There were 9 students enrolled in the course, but 5 of these students were participants of the study, three of which were chosen as a focus of in-depth analysis. The course focused on the following aspects of NOS: the empirical, creative, tentative, inferential, theory-laden NOS, the socio-cultural embeddedness of science, the “scientific method,” and the bounded nature of science. All the participants were inservice teachers ranging from the primary level through the upper grades of high school science. Participants were coming from diverse backgrounds in
terms of their science content area, teaching experiences, and teaching interests. The course lasted for 6 weeks with two class sessions per week. They stated that the NOS instruction was based on explicit-reflective NOS instruction as described by Abd-El-Khalick and Akerson (2004) and Khishfe and Abd-El-Khalick (2002). However, they did not report enough information about the nature of their NOS intervention to let the readers to decide themselves whether the NOS instruction was truly explicit-reflective as described by Abd-El-Khalick and Akerson (2004) and Khishfe and Abd-El-Khalick (2002). Participants were asked to write weekly reflection papers and to prepare for classroom discussions of course readings. Students were asked to write a final paper which was prepared to assess participants’ NOS views at the end of the course. Participants were also interviewed to validate their written responses in the final paper. It was not clear, however, how and when the researchers assessed participants’ NOS views at the beginning of the course. For data collection, the researchers used selected questions from the Views of Nature of Science Version C (VNOS-C) questionnaire (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002), the scientific thinking and internet learning technologies (STILT) (Southerland, Settlage, Johnston, Scuderi, & Meadows, 2003), and an epistemological survey (Schommer, 1990). But, there was not enough information in their methodology section regarding when these surveys were administered. One of the researchers analyzed the data to identify different aspects of each participant’s conceptual ecology and a second researcher analyzed the data to assess participants’ NOS views on the target NOS aspects. Both researchers upon developing their characterization of each participant’s conceptual ecology and understanding of NOS views on target NOS aspects checked their characterizations against the data by specifically looking for negative cases.
The researchers reported that participants held various degrees of sophistication in their NOS views at the beginning of the study and they hesitantly reported that the participants held sophisticated NOS views at the end of the study. Despite the fact the researchers were aware that the explicit-reflective NOS instruction was effective in improving NOS views, the overall degree of sophistication in NOS views at the end of the course was surprising to them. The researchers reported that participants’ NOS conceptual ecology included the following components: past science experiences, affect toward science, self-efficacy for science and teaching, learning dispositions (open-minded thinking, need for cognition, comfort with ambiguity, reflective thinking), epistemological beliefs, beliefs about learning and learners, conception of science as an enterprise, religious beliefs, and goal in the course. They reported that participants’ NOS views on the target NOS aspects were primarily influenced by their learning dispositions, beliefs about learning and learners, and view of science as an enterprise (product, process, or blended). They also reported that participants’ NOS views were secondarily influenced by affect for science, past science experiences, and learning goals. They did not report how epistemological beliefs as it was measured by Schommer (1990) are related to participants’ NOS views. All their participants held strong religious beliefs and they did not find that religious orientation to be a factor in the development of NOS views.

Summary-The three studies reviewed above also suggest that explicit-reflective NOS instruction is effective in improving NOS views. The effectiveness of the explicit-reflective approach is well-documented and it is not news to science education community. It is now clear that the explicit-reflective approach is effective in improving NOS views. For this reason, the logical next step for researchers is to shift the focus of
research towards factors mediating the development of NOS views away from documenting the changes in students’ NOS views after explicit-reflective NOS instruction through pre- and post NOS assessments. I think that in the future more research will be done to explore the factors mediating the development of NOS views. I also think that the importance of situating the research within a theoretical framework and the use of multivariate research techniques will increase in this new phase.

Identification of Factors Mediating the Development of NOS Views and Epistemological Beliefs about Science

The following section identifies and describes the factors that might be related to the development of NOS views and epistemological beliefs about science.

Prior conceptions. Ausubel’s frequently quoted statement captures the importance of prior knowledge during the learning process in a dramatic way. This quote appears before the preface of the book that Ausubel co-authored with Novak and Hanesian (Ausubel, Novak, Hanesian, 1978).

If I had to reduce all of educational psychology to just one principle, it would say this:

The most important single factor influencing learning is what the learner already knows.

Ascertain this and teach him accordingly.

After decades of research on misconceptions we now know that students’ minds are not “tablula rasa” or “empty vessels.” Students do have alternative explanations (Driver, 1981). Often, students’ alternative explanations are in conflict with the scientific explanation taught in schools. This is certainly true for students’ NOS views (Lederman, 1992a). In this case, students’ alternative conceptions need reorganization in order to accommodate the scientifically accepted contemporary views. As it was mentioned in the introduction, many researchers emphasized that students’ prior conceptions might
interfere with the conceptual change (e.g., Ausubel 1978; Bransford et al., 1999; Chinn & Brever, 1993; Pintrich et al., 1993). Pintrich et al. (1993).

*Metacognitive awareness.* Metacognition refers to the ability to reflect upon, understand and control one’s one learning (Schraw & Dennison, 1994). Some studies indicate that metacognitively aware learners perform better than unaware learners (Garner & Alexander, 1989; Swanson, 1990). The importance of metacognition was emphasized during teaching for conceptual change (Gunstone, 1994; Hewson et al., 1998). It was assumed that lack of adequate metacognition can result in poor learning dispositions. Abd-El-Khalick and Akerson (2004) found that the learners with deep orientation to learning improved their NOS views substantially more than their peers with surface orientation to learning. According to Schraw and Dennison (1994) metacognitive awareness has two dimensions: knowledge of cognition and regulation of cognition. Knowledge of cognition refers to what learners know about themselves, strategies, and conditions under which strategies are most useful. Regulation of cognition refers to knowledge about the ways of learners’ planning, implementing strategies, monitoring and correcting comprehension errors, and evaluating their own learning.

*Thinking dispositions.* Southerland et al. (2006) suggested that thinking dispositions such as actively open-minded thinking are related to the development of NOS views. Thinking dispositions was measured by the actively-openminded thinking (AOT) scale (Sá, Stanovich, & West 1999). The scale is composed of five different subscales. The AOT composite score indicates openness to belief change, cognitive flexibility (reflectiveness), tendency to consider alternative opinions and evidence, and searching and processing of information that goes against one’s beliefs.

52
The AOT scale has some similarities to other epistemic measures such as Shommer’s (1990) scale (Sá, Stanovich, & West, 1999). The AOT is also connected to Perry’s (1970) developmental epistemological beliefs model. Items in one of the subscales of the AOT (absolutism) were specifically developed to tap the early stages of Perry’s (1970) epistemological beliefs model characterized by lack of reflectiveness or cognitive rigidity (Stanovich & West, 1997; Sá, Stanovich, & West, 1999).

**Science self-efficacy beliefs.** It was suggested that science self-efficacy beliefs of students might have an effect on their science learning (Pintrich et al., 1993). It was assumed that science self-efficacy beliefs are related to students’ confidence in understanding and using science in their lives. Science self-efficacy beliefs were measured by a modified version of an instrument which was specifically designed to measure biology self-efficacy of nonmajor college students (Baldwin, Ebert-May, and Burns, 1999). The instrument has three dimensions: (a) methods of science, (b) generalization to other science courses and analyzing data, and (c) application of science concepts and skills.

**Motivational factors.** Abd-El-Khalick and Akerson (2004) also found that internalizing the importance of NOS helped the learners to improve their NOS views. Pintrich et al. (1993) also underscored the importance of motivational factors during the learning process. Motivation was measured by an instrument developed by Midgley, Kaplan, Middleton, and Maehr (1998). This instrument does not measure students’ possession or lack of motivation, but it measures how students think about themselves and their performance during the learning process. The instrument captures three factors: (a) task goal orientation-the extent to which learners tend to find satisfaction in learning,
ability-approach goal orientation—the desire to outperform others or the desire to demonstrate ability, (c) ability-avoid goal orientation—the desire to avoid looking incompetent or the desire that others not think him ignorant or less knowledgeable.

Summary. Based on a critical review of the literature I discussed how factors described above might be related to development of NOS views. I hypothesized that students’ prior conceptions of NOS and epistemological beliefs about science, their metacognitive awareness, thinking dispositions, science self-efficacy beliefs, and motivation might play important roles in the development of informed NOS views and epistemological beliefs about science.

Relationships between Factors Possibly Related to the Development of NOS Views and Student Achievement

This section includes 9 studies. The first 3 studies examined the relationship between metacognitive strategy use and student performance in science. The rest of the studies explored the relationships among motivational beliefs (mastery goal orientation, performance-approach orientation and performance-avoidance goal orientation), science self-efficacy, cognitive/metacognitive strategy use, and student performance in science and mathematics.

Georghiades (2006) conducted a study with 68 5th grade students studying electricity in southern Cyprus. The study followed a quasi-experimental design with two control (n = 30 + 4) and two experimental groups (n = 30 + 4). In other words, there were two 30-student and two 4-student groups. One 30-student group and one 4-student group constituted the experimental group, and the other 30-student and 4-student groups constituted the control group. Both control and experimental groups were taught the unit
over a five-week period (having an 80-minute lesson once a week). The only difference in their treatment was the employment of metacognition in the teaching of the experimental group. The teacher in the experimental group made use of metacognitive activities such as classroom discussion, annotated drawing, concept mapping and keeping diary-like notes at selected points of the instruction. Student’s learning of electricity concepts taught was measured through the same test on three occasions spread over one school year. The first test was administered 1 week after completion of the unit. The second test was administered 2 months after completion of the unit. Finally, the third test was administered 8 months after the completion of the unit.

Students who received metacognitive instruction in the 30-student group performed better than students in 30-student group of the control group on all three test occasions. Similarly, students who received metacognitive instruction in 4-student group performed better than students in 4-student group of the control group on all three test occasions. However, the researcher also reported that metacognitive instruction is more effective in small group settings than whole class settings. Students in 4-student group of the control group consistently performed better than students in 30-student group of the experimental group on all three occasions.

Blank (2000) sought to study the impact of Science Curriculum Improvement Study (SCIS) Learning Cycle and a revised learning cycle model, termed the Metacognitive Learning Cycle (MLC). Participants were 46 junior high school students in a suburban school district of a large Midwestern metropolitan area. Students were enrolled in two intact sections. The first section, the SCIS learning cycle section, consisted of 22 students (10 male and 12 female) and the second section, the metacognitive learning cycle section,
consisted of 24 students (12 male and 12 female). Students came from middle to upper class families. Students were randomly assigned to two sections by computer. Academic abilities of students in each section were comparable as measured by the average Cognitive Skills Index.

Each section studied the same ecology unit for 3 months. Unlike students in the SCIS learning cycle section, students in the metacognitive learning cycle section were asked to make their prior conceptions explicit and to discuss the status of their conceptions and ideas during the phases of metacognitive learning cycle. In this case, status refers to the four conditions that students must satisfy to achieve conceptual understanding—dissatisfaction, intelligibility, plausibility, and fruitfulness.

The researcher stated that metacognitive learning cycle included four phases: concept assessment, exploration, concept introduction, and concept application. The original SCIS learning cycle included only three phases: exploration, concept introduction, and concept application.

The author did not give a detailed description of the ecology unit. Students’ learning about ecology was assessed through an instrument containing 23 multiple choice items and 5 free response items. The content validity of the instrument was approved by one environmental science professor and two science educators. Students’ learning about ecology was measured at the beginning (August) and at the end (November) of 3-month ecology unit. In addition to these pre- and post assessments two delayed ecology assessments were administered in January and May. The same ecology assessment was used in all four occasions.
The author reported that there was no statistically significant difference in ecological understanding across two groups either before or after the intervention. However, both of the delayed post-test mean scores of the metacognitive learning cycle section were higher than the SCIS learning cycle section (January: $F = 3.98$, $p = .05$; May: $F = 4.42$, $p = .04$). Based on these results the author claimed that more meaningful learning may have occurred in the metacognitive learning cycle section than in the SCIS learning cycle section. The author provided qualitative evidence reflecting that students in the metacognitive learning cycle section questioned the ideas presented during the instruction more so than students in the SCIS learning cycle section.

Conner (2007) conducted a study with 16 students in their final year of high school in New Zealand. Students were required to write a 500-word essay on biological, social, and ethical aspects of cancer in preparation for the national university bursary examination. The essay constituted 20% of the final examination which was high stakes assessment. Before writing the essay students were asked to produce relevant questions and refine these questions to structure their essays. Students were also asked to identify and process relevant information from a variety of sources to answer the questions that they identified. Students were asked to write their research questions into their journals and to reflect about their thinking when they are in the process of identifying their questions, searching for information, and writing their essays. The researcher interviewed 16 students before and after they wrote the essay. Before writing the essay students were asked about how they planned writing their essays and after completion of the essay students were asked to comment on how they discriminated between relevant and irrelevant information when they were preparing for writing, how they organized their
essays, and how they could improve their essays. Based on the qualitative analysis of interview transcripts and journal entries the researcher identified three degrees of metacognitive awareness and strategy use among 16 students. Students were also grouped into five categories according to the quality of their essays: Invisible Product, Satisfactory Product, Satisfactory Multiple Product, Quality Product, and Quality Multiple Product. Students in the Satisfactory Multiple Product and Quality Multiple Product categories produced more than one essay, and students in the Invisible Product category did not hand in a final essay.

The researcher reported that students’ differences in their degree of metacognitive awareness and strategy use paralleled the quality of their essays. The author provided evidence from interviews of three selected students to support this claim. However, the author acknowledged that it was difficult to establish the direct link between metacognition and the quality of essays because there was no direct evidence of metacognition. Metacognition is inferred from student interviews, journals, and class work.

Shih (2005) sought to study the relationships between students’ achievement goals (mastery goals, performance-approach goals, and performance avoidance goals), cognitive and metacognitive study strategies, and grades. The participants included 242 sixth-grade students (120 girls and 122 boys) from nine classes in three elementary schools in the northern Taiwan.

Achievement goals were measured by a survey adapted from Elliot and Church’s (1997) achievement goals questionnaire at the beginning of the fall semester. Achievement goals questionnaire included three subscales measuring mastery goals,
performance-approach goals and performance-avoidance goals. Each subscale included 6 items. Mastery goals subscale measured orientation to develop competence or to attain task mastery (e.g., I want to learn as much as possible from this class). Performance-approach subscale measured orientation to demonstrate ability (e.g., It is important to me to do better than the other students). Performance avoidance-goals measured orientation to avoid the demonstration of incompetence (e.g., I worry about the possibility of getting a bad grade in this class).

Cognitive and metacognitive study strategies were measured by a survey adapted from Pintrinch and De Groot’s (1990) Motivated Strategies for Learning Questionnaire at the beginning of the fall semester. Cognitive strategies were measured by 12 items. These items assessed the use of elaboration and rehearsal strategies (e.g., When studying, I copy my notes over to help me remember material; I outline the chapters in my book to help me study). Metacognitive strategy use measured by 9 items. These items assessed the use of planning, monitoring comprehension, and regulating cognition (e.g., When I’m reading I stop once in a while and go over what I have read; I ask myself questions to make sure I know the material I have been studying).

Participants’ grades were obtained from schools. The researcher averaged participants’ scores in different subjects (e.g., math, science, and language arts) to obtain the overall final semester grade.

The researcher reported that mastery goals were positively correlated with performance approach goals (r = .52, p < .01) and performance-approach goals were positively correlated with performance-avoidance goals (r = .54, p < .01). Contrary to the author’s expectations, mastery goals were positively correlated with performance
avoidance goals ($r = .24, p < .01$). This was also unexpected from the revised goal theory standpoint. After controlling for the effect of performance-approach goals, the author found out that mastery goals were not related to performance-avoidance goals ($r = -.06, p > .01$) through the partial correlation procedure. The researcher also reported that mastery and performance-approach goal orientations were positively related to cognitive and metacognitive strategy use, and grades. There were no significant correlations between performance-avoidance goals and aforementioned variables. Mastery goals significantly correlated with cognitive strategy use ($r = .68, p < .01$), metacognitive strategy use ($r = .62, p < .01$), and grades ($r = .28, p < .01$). Performance-approach goals were positively correlated with cognitive strategy use ($r = .41, p < .01$), metacognitive strategy use ($r = .30, p < .01$), and grades ($r = .21, p < .01$). Cognitive and metacognitive strategy use were highly correlated ($r = .78, p < .01$). Both cognitive and metacognitive strategy use correlated with grades ($r = .31, p < .01$ and $r = .27, p < .01$ respectively).

To further investigate the relationship between achievement goals and variables such as cognitive and metacognitive strategy use, and grades, the researcher formed a 2 x 2 matrix of mastery and performance-approach goals (high mastery/low performance-approach, low mastery/high performance-approach, high/high, and low/low). The researcher used the median-splits method to form low/high categorical variables. These four categories served as independent variables, cognitive and metacognitive strategy use, and grades as dependent variables, and performance-avoidance goals as a covariate in the MANCOVA. The researcher reported that the MANCOVA revealed significant main effects for mastery goals Wilk’s $\lambda = .71$, $F (5, 233) = 18.79, p < .001$. The univariate analyses of the main effects of mastery goals were significant for cognitive strategies,
F(1, 237) = 61.67, p < .001; metacognitive strategies, F(1, 237) = 50.58, p < .001; and grades F(1, 237) = 7.17, p < .01. A post hoc Scheffé analysis showed that students with high mastery/high performance-approach and high mastery/low performance-approach reported significantly greater use of cognitive and metacognitive strategy use than students with the low mastery/high performance-approach and low mastery/low performance-approach. The main effects for performance-approach goals were not significant at the multivariate level. However, the univariate tests were significant for cognitive strategies F(1, 237) = 5.18, p < .05 and grades F(1, 237) = 4.34, p < .05. This means that students who scored higher on the performance-approach goals are more likely to employ cognitive strategy use and to obtain better grades than those who scored lower on the performance-approach goals.

Yumusak, Sungur, and Cakiroglu (2007) sought to study the contribution of motivational beliefs, cognitive and metacognitive strategy use to Turkish high school student’s achievement in biology and the relationship between motivational beliefs, cognitive and metacognitive strategy use among Turkish high school students in biology. Participants included 519 tenth-grade students (214 girls and 305 boys) from 15 different high schools in rural and urban areas in Turkey. Participants’ age ranged from 15 to 18 years with an overall mean age of 16.4 years.

The researchers administered the Motivated Strategies for Learning Questionnaire (MSLQ) developed by Pintrich, Smith, Garcia, and McKeachie (1991). The MSLQ was translated and adapted into Turkish by the second author. The MSLQ contains two sections: a motivation section (31 items) and a learning strategies section (50 items). Motivation section included subscales such as intrinsic goal orientation (e.g., In a class
like this, I prefer course material that arouses my curiosity even of it is difficult to learn), extrinsic goal orientation (e.g., Getting a good grade in this class is the most satisfying thing for me right now), task value (e.g., It is important for me to learn the course material in this class), control of learning beliefs (e.g., It is my own fault if I don’t learn the material in this course), self-efficacy for learning and performance (e.g., I’m confident I can learn the basic concepts taught in this course), and text anxiety (e.g., I have an uneasy, upset feeling when I take an exam). Learning strategies section included subscales such as rehearsal (e.g., When I study for this class, I practice saying the material to myself over and over), elaboration (e.g., I try to relate ideas in this subject to those in other courses whenever possible), organization (e.g., I make simple charts, diagrams, or tables to help me organize course material), critical thinking (e.g., When a theory, interpretation, or conclusion is presented in class or in the readings, I try to decide if there is good supporting evidence), metacognitive self-regulation (e.g., When reading for this course, I make up questions to help focus my reading), time and study environment (e.g., I usually study in a place where I can concentrate on my course work), effort regulation (e.g., I work hard to do well in this class even if I don’t like what we are doing), peer learning (e.g., When studying for this course, I often set aside time to discuss course material with a group of students from the class), help seeking (e.g., I ask the instructor to clarify concepts I don’t understand well).

The biology achievement was measured by a 20-item multiple choice test. The questions were selected from standardized tests which were used in Turkish university qualification examinations in previous years. The biology achievement test covered
topics such as biology as a science, basic compounds of living things, cell structure and function, diversity, classification, and ecology.

The researchers performed two multiple linear regression analyses. The first analysis was performed to investigate to what extent motivational beliefs significantly accounted for the variation in students’ biology achievement. The second analysis was performed to investigate to what extent cognitive and metacognitive strategy use significantly accounted for the variation in students’ biology achievement. The researchers checked the assumptions such as multicollinearity, outliers, normality, linearity, homoscedasticity, and independence of residuals were checked before each analysis.

The researchers reported that motivational beliefs significantly accounted for 10% of the variance in students’ biology achievement (R = .32, F = 9.623, p < .005). The researchers stated that extrinsic goal orientation and task value significantly contributed to the prediction of students’ biology achievement. On the other hand, intrinsic goal orientation, control of learning beliefs, self-efficacy for learning and performance, and text anxiety did not significantly contribute to the prediction of students’ biology achievement. The largest contributor was extrinsic goal orientation (β = -.22) indicating that extrinsic goal orientation made the strongest contribution to explaining the variance in students’ biology achievement. However, sign of the beta coefficient indicated that higher level of extrinsic motivation correlated with lower levels of biology achievement. On the other hand, higher levels of task orientation were positively correlated with higher levels of biology achievement.

The researchers also reported that cognitive and metacognitive strategy use significantly accounted for 9% of the variance in students’ biology achievement (R = .29,
The researchers stated that rehearsal strategy use, organization strategy use, management of time and study environment, and peer learning each made a statistically significant contribution to the prediction of students’ biology achievement. The largest predictor of students’ biology achievement was the rehearsal strategy use ($\beta = -0.22$) indicating that higher levels of rehearsal strategy use correlated with lower levels of biology achievement. On the other hand, higher levels of organization strategy use, management of time and study environment, and peer learning were positively correlated with higher levels of biology achievement. Multiple choice questions measuring students’ biology achievement were not memorization questions. They required higher level thinking about basic biology concepts. Therefore, it is not surprising to see a negative correlation between rehearsal strategy use and biology achievement.

The researchers also investigated the relationships between motivational beliefs subscales and cognitive and metacognitive strategy use subscales through canonical correlation. Canonical correlation analysis revealed that higher levels of intrinsic goal orientation, task value, and self-efficacy for learning and performance were positively correlated with higher levels of cognitive and metacognitive strategy use except rehearsal strategy use and help seeking.

Zusho and Pintrich (2003) sought to study how motivation and cognitive strategy use changes over time in chemistry, and how motivational beliefs and cognitive strategy use predict achievement in chemistry. Participants were 458 college students (243 female, 215 male) enrolled in two introductory chemistry courses at a large Midwestern university. The authors did not give a specific percentage but the majority of the students were freshmen or sophomores. Approximately 75% of the students identified themselves...
as white, 9% as Asian-American, 3% as African-American, 1% as Hispanic, and the rest of the students did report their ethnicity.

The researchers measured students’ motivational beliefs and cognitive learning strategies at approximately 5 weeks, 10 weeks, and 15 weeks into the end of semester. Motivational measures included self-efficacy (seven items regarding perceptions of one’s ability to learn the course material), task value (five items regarding the importance and/or utility of the course), mastery goal orientation (six items concerning goals of learning and understanding of the course content), performance goal orientation (ten items regarding a performance approach of trying to do better than or outperform other students in the course), interest (five items concerning personal enjoyment and liking of the course), anxiety (five items regarding emotional and worry components of anxiety). Cognitive strategies measures included rehearsal (five items regarding surface level processing/memorization of course material), organization (seven items concerning deeper processing of course material through the use of charts, diagrams, organizational tables), elaboration (six items concerning deeper processing of content by relating new ideas in course to prior conceptions), and metacognitive self-regulation (ten items regarding the planning, monitoring, and control of one’s own cognition and understanding of course material).

Students’ grades were obtained as a measure of their course performance at the end of the semester. Grades were assigned based on both open-ended and multiple-choice exam questions.

The researcher reported that students’ self-efficacy (F(2, 443) = 15.10, p < .001), task value (F(2, 443) = 91.40, p < .001), and performance goals (F(1, 440) = 11.66, p < .001)
declined over time. However, there were no significant differences in students’ reports of their mastery goals, interest, and anxiety over time.

The researchers also reported that there was a significant decline in students’ reported use of rehearsal strategies (F(1, 452) = 77.51, p < .001) and elaboration strategies (F(1, 451) = 180.77, p < .001), but students’ use of organizational (F(1, 449) = 251.92, p < .001) and metacognitive strategies (F(1, 405) = 18.01, p < .001) increased from time 2 to time 3.

The researcher conducted a hierarchical regression analysis by using five motivational measures and four cognitive measures at time 3 as independent variables to predict students’ final course grade. The researchers found that self-efficacy beliefs (β = .40), task value beliefs (β = .22), and rehearsal (β = .13) were significant predictors of chemistry final grade. Considering the standardized beta coefficients, self-efficacy was the best predictor of the chemistry final grade followed by task value beliefs. Contrary to researchers’ expectations, students’ rehearsal use correlated with chemistry achievement. The researchers attributed this unexpected finding to the nature of the course. They stated that more positive correlations between rehearsal strategy use and achievement in the natural and social science than in the humanities (Wolters and Pintrich, 1998).

Hayden and Roeser (2002) examined the relationship between motivational orientation and performance in science. Participants were 491 10th grade (53%) and 11th grade (47%) high school students enrolled in science classes in a northern California high school. Approximately half of the students were female (51%) and the participants came from ethnically diverse backgrounds: 49% of the students were white, 27% Latino, 8% African American, 8% Asian American, and 8% of other ethnic origins.
Students’ motivational orientation was determined through implicit intelligence theories scale, self-confidence in science ability scale, and achievement goal orientation scale (Midgley et al., 2000). Implicit intelligence theories scales consisted of three items measuring to what extent students believe that their intelligence in science is fixed or malleable (e.g., I can’t change how smart I am in science). Self-confidence scale included four items measuring students’ self-confidence in their science ability (e.g., I feel pretty confident about my intellectual ability in science). Achievement goal orientation scale included mastery, ego approach, and ego avoidance subscales. Mastery goal subscale included six items that emphasized efforts to improve skills and master new material (e.g., An important reason I do science work because I like to learn new things). Ego approach subscale included five items focusing on students’ desires to outperform others (e.g., I would feel successful in science class if I got better grades than most of the other students). Ego avoidance subscale included five items concerned with students’ attempts to hide their perceived inability (e.g., It’s very important to me that I don’t look stupid in my science class).

The researchers classified students into three motivational groups. Students having malleable intelligence beliefs and a mastery goal orientation regardless of their confidence level were classified as mastery oriented (111 students, 28%); students having fixed intelligence beliefs, an ego goal orientation, and high confidence were classified as ego oriented (58 students, 14%); students having fixed intelligence beliefs, an ego goal orientation, and low confidence were classified as helpless (68 students, 17%). The rest of the students (166 students, 41%) were placed into an unclassified group.
The researchers measured students’ science achievement through a 30-item multiple-choice test. The multiple-choice questions were taken from the National Education Longitudinal Study, the National Assessment of Educational Progress (NAEP), and the Third International Mathematics and Science Study (TIMSS).

The researchers reported that there was a significant difference among three motivational groups (F (3, 261) = 4.45, p < .01) in terms of their multiple-choice test results. They stated that helpless students performed worse than all of the other groups on multiple-choice items and there was no statistically significant difference among mastery oriented, ego oriented, and unclassified groups in terms of their multiple-choice test results.

Elliot, McGregor, and Gable (1999) examined the extent to which achievement goals and cognitive/metacognitive study strategy use predict exam performance, and tested whether cognitive/metacognitive study strategies mediate the relationship between achievement goals and exam performance in the normatively graded college classroom. Participants were 164 (56 male and 108 female) undergraduates who were enrolled in an introductory level psychology course at a Northeastern university. The mean age of participants was 19.96 years old with a range of 17 to 40.

Students’ achievement goals were measured by a questionnaire developed by Elliot and Church (1997). This questionnaire included three subscales measuring students’ mastery goals, performance-approach goals, and performance-avoidance goals. Students’ cognitive/metacognitive study strategies were measured in terms of deep processing, surface processing, and disorganization. The researchers used items taken from various surveys to measure cognitive/metacognitive strategy use and justified the creation of deep
processing, surface processing, and disorganization factors through principal components factor analysis. Students’ exam performance was measured by an exam including multiple-choice, short answer, and essay questions worth a total of 100 points.

The researchers reported that there was a significant positive correlation between mastery goals and exam performance \( (r = .17, p < .05) \), performance-approach goals and exam performance \( (r = .23, p < .01) \), and there was a significant negative correlation between performance-avoidance goals and exam performance \( (r = -.27, p < .01) \). The researchers also reported that there was a significant positive correlation between deep processing and exam performance \( (r = .17, p < .01) \) and there was a significant negative correlation between disorganization and exam performance \( (r = -.39, p < .01) \). The correlation between surface processing and exam performance was not significant.

The researchers predicted exam performance from mastery goals, performance-avoidance goals, performance-avoidance goals, and students’ overall GPA. The multiple regression analysis revealed that performance-approach goals \( (F(1, 158) = 6.91, p < .01, \beta = .15) \), performance-avoidance goals \( (F(1, 158) = 6.20, p < .05, \beta = -.15) \), and GPA \( (F(1, 158) = 122.78, p < .0001, \beta = .64) \) were significant predictors of exam performance.

Although there was a positive correlation between mastery goals and exam performance mastery goals was not a significant predictor of exam performance in the regression model. Together performance-approach, performance-avoidance and GPA explained 51% of the variance in exam performance \( (R^2 = .51, p < .0001) \).

The researchers reported that there were significant correlations between certain achievement goals and cognitive/metacognitive strategy use. Mastery goals were positively related to deep processing \( (r = .38, p < .01) \) and negatively related to
disorganization ($r = -0.19$, $p < 0.01$). Performance-approach goals were positively related to surface processing ($r = 0.17$, $p < 0.05$). Performance-avoidance goals were negatively related to deep processing ($r = -0.34$, $p < 0.01$), positively related to surface processing ($r = 0.24$, $p < 0.01$) and disorganization ($r = 0.30$, $p < 0.01$). The multiple regression analysis revealed that mastery goals ($F(1, 157) = 23.96$, $p < 0.0001$, $\beta = 0.36$) and performance-avoidance goals ($F(1, 157) = 11.49$, $p < 0.001$, $\beta = -0.25$) were significant predictors of deep processing. Together mastery goals and performance-avoidance goal accounted for 23% of the variance in deep processing ($R^2 = 0.23$, $p < 0.0001$). Performance-approach and GPA were not significant predictors. When the researchers regressed surface processing on mastery goals, performance-approach, performance-avoidance, and GPA they found that only performance-avoidance ($F(1, 157) = 11.31$, $p < 0.005$, $\beta = 0.27$) was a significant predictor of surface processing. Performance-avoidance alone explained 8% of the variance in surface processing ($R^2 = 0.08$, $p < 0.005$). Performance-avoidance goals ($F(1, 157) = 6.91$, $p < 0.01$, $\beta = 0.20$) and GPA ($F(1, 157) = 21.87$, $p < 0.0001$, $\beta = -0.34$) were significant predictors of disorganization.

The researcher also predicted exam performance from cognitive/metacognitive strategy use. Deep processing ($F(1, 159) = 4.61$, $p < 0.05$, $\beta = 0.17$) and disorganization ($F(1, 159) = 28.29$, $p < 0.0001$, $\beta = -0.39$) were significant predictors of exam performance. Surface processing was not related to exam performance.

The researchers also investigated how cognitive/metacognitive strategy use mediates the relationship between achievement goals and exam performance through structural equation modeling (SEM). The SEM revealed that neither deep processing nor surface processing mediated the relationship between achievement goals and exam performance.
According to the SEM, performance-approach goals were directly related to exam performance ($\beta = .16, p < .05$), mastery goals were not related to exam performance, and performance-avoidance goals were related to exam performance through disorganization. In other words, disorganization mediated the relationship between performance-avoidance and exam performance. Performance avoidance goals were related to disorganization ($\beta = .20, p < .01$) and disorganization was related to exam performance ($\beta = -.14, p < .05$). Therefore, performance avoidance was indirectly related to exam performance. These results meant that higher performance-approach goals are related to higher exam performance, higher performance-avoidance goals are related to higher disorganization, and higher disorganization is related to lower exam performance.

Wolters (2004) investigated how different components of achievement goal theory were related to each other and to students’ cognitive/metacognitive strategy use, and achievement in mathematics. Participants were 525 seventh and eight grade students who came from 38 separate mathematics classes in two junior high schools in a suburban school district in the USA. Students reported their ethnicity as 69% white (362 students), 14% Hispanic (73 students), 4% African American (20 students), 4% Asian (22 students), or less than one percent Native American (2 students). Fifty seven percent of students (299 students) were in the seventh grade and 43% of students (226 students) were in the eight grade. Students’ mean age was 13.2 years. More girls (272 students, 52%,) than boys (253 students, 48%) participated in the study.

Students’ achievement goals were measured through a questionnaire developed by Midgley et al. (1998). This questionnaire measured students’ reported mastery goals, performance-approach goals, and performance-avoidance goals. In addition to
achievement goals, the researcher also measured students’ reported self-efficacy beliefs reflecting to what extent they were capable of successfully completing the tasks and assignments for their mathematics class.

Students’ cognitive/metacognitive strategy use was assessed by items derived from a questionnaire developed by Pintrich, Smith, Garcia, and McKeachie (1993). Cognitive strategy use was measured through eight items reflecting students’ use of rehearsal and elaboration strategies when completing work for their math classes. Metacognitive strategy use included nine items reflecting students’ use of planning, monitoring, and regulatory strategies when completing work for their math class.

The researcher reported that mastery orientation was positively related to performance-approach (r = .15, p < .01) but negatively correlated to performance-avoidance (r = -.24, p < .01) goal orientations. On the other hand, performance-approach goal orientation was positively related to performance-avoidance goal orientation (r = .32, p < .01). Self-efficacy was positively related to mastery orientation (r = .53, p < .01) and performance-approach (r = .20, p < .01) orientation, and it was negatively related to performance-avoidance (r = -.24, p < .01) orientation. Mastery orientation goals were strongly related to both cognitive (r = .52, p < .01) and metacognitive (r = .52, p < .01) strategy use.

The researcher predicted course grade from mastery orientation, performance-approach orientation, performance-avoidance orientation, and self-efficacy. He reported that only performance-approach orientation (β = .12, p < .01) and self-efficacy beliefs (β = .40, p < .01) were significant predictors of the course grade. Mastery goal orientation and performance-avoidance were not significant predictors of the course grade. The
researcher did not attempt to use cognitive/metacognitive strategy use to predict the course grade but the correlations between the course grade and cognitive strategy use (r = .11, p < .05), and the course grade and metacognitive strategy use (r = .21, p < .01) were positive.

Summary—Nine studies reviewed above suggest that there are positive relationships among mastery goal orientation, performance-approach goal orientation, science self-efficacy beliefs and cognitive/metacognitive strategy use in general, and that these aforementioned constructs are generally positively correlated with students’ performance in science and mathematics.
Chapter IV
Design and Method

A review of the literature revealed that the explicit-reflective approach in improving NOS views is effective. However, the literature on what factors mediate the development of NOS views and epistemological beliefs about science is very thin. There needs to be more empirical research to be able to determine the components of NOS conceptual ecology which facilitates or hinders the improvement of NOS views and epistemological beliefs about science.

This study addressed the following research questions:

1. To what extent will an explicit-reflective NOS instruction that satisfies the conditions for learning as conceptual change as described by Abd-El-Khalick and Akerson (2004) and Hewson, Beeth, and Thorley (1998) improve students’ NOS views and epistemological beliefs about science?

2. Are there any correlations within and between students’ pre- and post-instruction NOS views, and pre- and post-instruction epistemological beliefs about science?

3. Are students’ post-instruction NOS views related to their metacognitive awareness, thinking dispositions, science self-efficacy beliefs, and motivation measured at the beginning of the intervention?

4. Are students’ post-instruction epistemological beliefs about science related to their metacognitive awareness, thinking dispositions, science self-efficacy beliefs, and motivation measured at the beginning of the intervention?

The following hypotheses were formed for four research questions respectively. I hypothesized that (1) students’ NOS views and epistemological beliefs about science
would significantly improve after the explicit-reflective NOS instruction: (2) students’
post-instruction NOS views and epistemological beliefs about science would be related to
their pre-instruction NOS views and epistemological beliefs about science; (3) students
with higher metacognitive awareness, motivation, science self-efficacy, and thinking
dispositions would be more likely to develop more sophisticated NOS views at the end of
the explicit-reflective NOS instruction; and (4) students with higher metacognitive
awareness, motivation, science self-efficacy, and thinking dispositions would be more
likely to develop more sophisticated epistemological beliefs about science at the end of
the explicit-reflective NOS instruction.

Participants

A total of 161 undergraduate students (148 Female, 13 male) with a mean age of 19.3
years (ranging from 18 to 44) from a large Midwestern university participated in the
study. The educational levels represented were: 118 freshmen (73.3 %), 36 sophomores
(22.4 %), 6 juniors (3.7%), and 1 senior (0.6 %). Participants were enrolled in an
introductory science course offered in the school of education during the spring 2007.

Context of the Study

The explicit-reflective NOS instruction was given in the context of an introductory
science course. The introductory science course was designed for college students who
plan to be elementary teachers. This course historically is organized around three major
themes: science process skills, hypotheses testing-experimental design in science, and the
nature of matter. In general, the first 4 weeks are spent on science process skills, the
second 4 weeks are spent on hypothesis testing-experimental design, and the rest of the
semester is spent on the nature of matter. This course is coordinated by a faculty member
and taught by doctoral teaching assistants. Students who fail to receive a course grade of C – or above are not admitted to the teacher education program in the School of Education. As a course requirement students participate in 2-hour lab sessions either on Monday and Wednesday or on Tuesday and Thursday. Labs are followed by an hour lecture on Friday mornings; half of the sections attend 9 a.m. lecture and the other half of the sections attend 10:00 a.m. lecture. This means that students receive a total 5 hours of science instruction each week in this course. During the spring 2007 this course was taught in 9 different sections. Each section contained no more than 24 students.

The Explicit-Reflective NOS Instruction

The first theme of the course, the science process skills, was addressed using the context of explicit-reflective NOS instruction. The author taught all the labs and lectures during the first 4 weeks of the course. For 4 weeks participants received explicit-reflective NOS instruction which satisfied the conditions for learning as conceptual change as described by Abd-El-Khalick and Akerson (2004) and Hewson, Beeth, and Thorley (1998). The explicit-reflective NOS emphasized the following target NOS aspects as recommended by NSTA (2000): tentative, empirical, inferential, subjective and creative NOS, and the functions and relationships of theories and laws. At the beginning of the intervention the author’s NOS views which reflect the science education community’s views (e.g., Schwartz et al., 2004) as well as students’ pre-instruction NOS views were explicitly discussed. Students were given opportunities to make their NOS views explicit through the “The Card Exchange Activity” (Cobern & Loving, 1998) during the intervention. Students’ pre-instruction NOS views were also revisited several times during the NOS instruction. Students were engaged in selected content free NOS
activities such as “Tricky Tracks”-“Rabbit? Duck?”-“Young Woman? Old Woman?”-“Aging President”- “The Tube” and “The Cubes.” These activities are explained in great detail in Lederman and Abd-El-Khalick (1998). NOS instruction was also embedded within science content through the “Rutherford’s Enlarged” activity (Abd-El-Khalick, 2002) and a presentation about the history of the atomic theory. Students were also engaged in inquiry-oriented lessons such as a grave mistake (Watercourse & Council for Environmental Education, 2004) which easily lend themselves to address NOS aspects explicitly after the lesson. Each activity was followed by small group and whole-class discussions. At the beginning of the discussions NOS aspects were explicitly addressed by the instructor as they relate to the activities and lessons. Students were then asked to discuss whether they agreed with instructor’s interpretations of NOS aspects and justify their agreements or disagreements. Students’ pre-instruction NOS views were revisited several times during the discussions to give them an opportunity to compare their current views against pre-instruction NOS views. NOS activities used as part of the explicit-reflective NOS instruction and target NOS aspects addressed within the context of these activities are presented in Table 1.
Students were assigned to various readings which presented the science education community’s perspective on NOS aspects (See Figure 1). Using NOS reading assignments as focal points students were asked to reflect in writing on NOS aspects throughout the intervention. Students were asked to write a 1-2 page reflection paper per reading. For each reading students answered the following questions: “Are the ideas in this reading consistent with our discussions of NOS? If yes, how? If no, why?” While writing the reflection papers students were asked to try to focus on the following NOS aspects: tentative, empirical, inferential, subjective and creative NOS, and theories and laws. Students were encouraged to make their NOS views explicit and provide justification for their NOS views while writing their reflection papers and during the class discussions. I expected that this would lead students to determine the status of their NOS views for themselves. In other words, students would be able to determine to what extent their NOS views are intelligible, plausible, and fruitful to them. NOS instruction aimed at

<table>
<thead>
<tr>
<th>Week</th>
<th>Activity</th>
<th>Target NOS aspects</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The card exchange activity</td>
<td>Empirical, inferential, creative, and subjective NOS</td>
</tr>
<tr>
<td></td>
<td>The bottle</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The tube</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rabbit? Duck?</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Tricky tracks</td>
<td>Empirical, inferential creative, tentative, and subjective NOS</td>
</tr>
<tr>
<td></td>
<td>The cubes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Aging president</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>A grave mistake</td>
<td>Empirical, inferential creative, and tentative NOS</td>
</tr>
<tr>
<td>4</td>
<td>Rutherford’s enlarged presentation-History of atomic theory</td>
<td>Empirical, inferential creative, tentative NOS, and functions and relationships of theories and laws</td>
</tr>
<tr>
<td></td>
<td>Presentation-Kinetic theory of gases, Boyle’s and Charles’s laws</td>
<td></td>
</tr>
</tbody>
</table>
raising the status of informed NOS views while simultaneously lowering the status of naïve NOS views. Class discussions and reflection papers were included in the explicit-reflective NOS instruction to increase the metacognitive aspect of the instruction. The instructor paid a special attention to the use of language during the explicit-reflective NOS instruction. Significant science terms such as “law”, “hypothesis”, and “theory” were carefully used. The instructor deliberately avoided using statements such as “What did the data show?” or “What did the findings tell us?” In appropriate occasions the instructor conveyed the idea that the data does not dictate to scientists what to conclude, but scientists formulate their explanations or conclusions to account for the data. The instructor kept a detailed log of his teaching moves and interplay of ideas between himself and students.


*Figure 2.* Alphabetical listing of nature of science readings which were assigned to students.

*Data Collection*

Data were collected through the following surveys: (1) The VNOS-B open-ended NOS questionnaire, (2) epistemological beliefs questionnaire, (3) metacognitive awareness inventory, (3) thinking dispositions scale, (4) science self-efficacy instrument, and (5) achievement goal orientation scale.
Student NOS questionnaire. The Views of Nature of Science Questionnaire Version B (VNOS-B) (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002), open-ended NOS questionnaire, was used to assess students’ pre-intervention NOS views, and was administered again at the end of the intervention to determine changes in students’ NOS views. After answering each question in the VNOS-B, students was asked to rate their level of confidence in their answer using a bi-polar 0-10 continuous scale. The left end of the scale indicated 0% confidence and the right end of the scale indicated 100% confidence (See Appendix A). A total of 23 students were chosen for follow-up interviews. Ten students were interviewed immediately after the pre-administration of the VNOS-B at the beginning of the intervention and the remaining 13 students were interviewed immediately after the post-administration of the VNOS-B at the end of the intervention. Interviews were important to establish the validity of the VNOS-B and not to misinterpret the students’ responses during data analysis. Interviews were conducted by the author. Students were provided with their pre- or post-instruction questionnaires and asked to explain their written responses. Follow-up questions were asked to clarify students’ verbal explanations or justifications of their written responses. All interviews lasted about 35 minutes, were audio-taped and transcribed for analysis. Validity and reliability information about the VNOS-B are provided with great detail in Abd-El-Khalick et al. (2001) and Lederman et al. (2002). The VNOS-B successfully differentiates between experts’ and novices’ NOS views.

Other constructs were only measured at the beginning of the instruction. Collecting data on the other constructs only at the beginning of the study was sufficient for the purpose of this study. I hypothesized that students’ post-instruction NOS views and
epistemological beliefs about science would be mostly a product of their pre-instruction NOS views and epistemological beliefs, and their metacognitive awareness, thinking dispositions, science self-efficacy beliefs, and motivation measured at the beginning of the intervention. I expected that students scoring high on metacognitive awareness, thinking dispositions, science self-efficacy beliefs, and motivation at the beginning of the intervention would be in a better position to be able to develop more informed NOS views and epistemological beliefs about science. In other words, I hypothesized that the aforementioned factors measured at the beginning of the study would determine to what extent one can develop informed NOS views and epistemological beliefs about science through a four week intensive intervention.

*Epistemological beliefs questionnaire.* Students’ epistemological beliefs were measured by Hofer’s (1997) 4 dimensional epistemological beliefs questionnaire. This measure consists of 18 items, each to be rated by students on a 1 (*strongly disagree*) to 5 (*strongly agree*) Likert scale (See Appendix A). This epistemological belief instrument contains four different subscales: (a) certainty/simplicity of knowledge (8 items), (b) justification for knowing (4 items), (c) source of knowledge (4 items), and (d) attainability of truth (2 items). For each of the four subscales, the items indicate the following views: certainty/simplicity of knowledge (e.g., truth is unchanging in science); justification for knowing (e.g., I am more likely to accept ideas of someone with first-hand experience than the ideas of researchers in science); source of knowledge (e.g., sometimes you just have to accept answers from the experts in science even if you don’t understand them); attainability of truth (e.g., scientists can ultimately get to truth). Hofer (1997) started with 27-item instrument. As a result of exploratory factor analysis she
ended up having 18-item instrument after deleting items that had lower than .40 factor loadings. All the items except two items in certainty/simplicity of knowledge subscale were negatively worded. Therefore, negatively worded items were reverse coded during the data analysis. Hofer (1997) reported that four-factor solution was justified through exploratory factor analysis. Hofer (1997) also reported the following Cronbach’s alpha coefficients of .80, .60, .64, and .74 for certainty/simplicity of knowledge, justification for knowing, source of knowledge, and attainability of truth, respectively.

Metacognitive awareness inventory. Students’ metacognitive awareness were measured by the metacognitive awareness inventory (MAI) developed by (Schraw & Dennison, 1994). This instrument includes 52 items (See Appendix A). Ratings for each item were made on a bi-polar 0-10 continuous scale. The left end of the scale indicated total disagreement and the right end of the scale indicated total agreement with each item. Students recorded their responses by drawing a slash across the rating scale at a point that best corresponded with their level of agreement. According to Schraw and Dennison (1994) metacognitive awareness has two dimensions: (a) knowledge of cognition and (b) regulation of cognition. Each dimension indicates the following views: knowledge of cognition (e.g., I know what kind of information is most important to learn; I am aware of what strategies I use when I study; and I use different learning strategies depending on the situation); regulation of cognition (e.g., I think about what I really need to learn before I begin a task; I focus on meaning and significance of new information; I ask myself if I have considered all options after I solve a problem). Schraw and Dennison (1994) validated their two-factor solution through factor analyses. They reported that unrestricted factor analyses (exploratory factor analyses) did not lead to a parsimonious
factor solution and internal consistency of factors obtained as a result of unrestricted
factor solution was below their desired value of .80. Then, they forced a two-factor
solution on the data in light of the theoretical considerations of Brown (1987) and Jacobs
and Paris (1987). They reported that their two-factor solution explained 65% of the
variance in their sample, and all the items loaded either on knowledge of cognition or on
regulation of cognition with the exception of a few items. They also reported that
Cronbach’s alpha coefficients of both factors were higher than .90.

Thinking dispositions scale. Students also completed the actively-openminded
thinking (AOT) scale (Stanovich & West, 1997; Sá, Stanovich, & West, 1999). This
measure consists of 41 items, each to be rated by students on a 1 (strongly disagree) to 5
(strongly agree) Likert scale (See Appendix A). Stanovich and West (in press) gave a
detailed explanation of how the AOT was created. The AOT scale’s 41 items are
selected from various sources: 10 items from a flexible thinking scale developed by
Stanovich and West (1997); 8 items from the Openness-Values dimension of the Revised
NEO Personality Inventory (Costa & McCrae, 1992); 9 items tapping dogmatism
(Paulhus & Reid, 1991; Robinson, Shaver, & Wrightsman, 1991; Troldahl & Powell,
1965); 3 items from the categorical thinking subscale of Epstein and Meiser’s (1989)
constructive thinking inventory; 9 items from the belief identification scale developed by
Sá, Stanovich and West (1999); 2 items from a counterfactual thinking scale developed
by Stanovich and West (1997).

The flexible thinking items encompass reflectiveness rather than cognitive rigidity
(e.g., if I think longer about a problem I will be more likely to solve it) and the seeking
and processing of information that goes against one’s beliefs (e.g., people should always
take into consideration evidence that goes against their beliefs). The absolutism items in this subscale were developed to tap early stages of Perry’s (1970) epistemological beliefs model characterized by cognitive rigidity (e.g., it is better to simply believe in a religion than to be confused by doubts about it). The dogmatism items are the opposite of items in the flexible thinking subscale (e.g., no one can talk to me out of something I know is right). The categorical thinking items in this subscale are also appropriate to tap the early stages of Perry’s (1970) epistemological beliefs model (e.g., there are basically two kinds of people in this world: those who are for the truth and those who are against the truth; I think that there are many wrong ways, but only one right way to almost anything). The belief identification subscale has items such as “It makes me happy and proud when someone famous holds the same beliefs as I do.” Counterfactual thinking subscale indicates the ability to decenter and adopt alternative perspectives (e.g., my beliefs would not have been very different if I had been raised by a different set of parents).

Sá, West and Stanovich (1999) reported that the subscales of AOT have moderate inter-correlations and that the creation of the composite score and validity of the instrument were justified by factor analysis.

_Science self-efficacy instrument._ Science self-efficacy beliefs were measured by a modified version of an instrument which was specifically designed to measure biology self-efficacy of nonmajor college students (Baldwin, Ebert-May, & Burns, 1999). This measure consists of 23 items, each to be rated by students on a 1 (strongly disagree) to 5 (strongly agree) Likert scale (See Appendix A). The instrument has three dimensions: (a) methods of science (8 items), (b) generalization to other science courses and analyzing data (9 items), and (c) application of science concepts and skills (6 items). For each of the
three subscales, the items indicate the following views: methods of science (e.g., How confident are you that you could read the procedures for an experiment and feel sure about conducting the experiment on your own?); generalization to other science courses and analyzing data (e.g., How confident are you that you will be successful in another science course?; How confident are you that you could analyze a set of data?); application of science concepts and skills (e.g., How confident are you that you could explain something that you learned in this science course to another person?). Baldwin, Ebert-May, and Burns (1999) reported that the subscales of their instrument are moderately correlated and their three-factor solution is justified by factor analysis. They reported the following Cronbach’s alpha coefficients of .88, .88, and .89 for methods of science, generalization to other science courses and analyzing, and application of science concepts and skills, respectively.

Motivation instrument. Students’ level of motivation was measured by the achievement goal orientation survey. This measure consists of 17 items, each to be rated by students on a 1 (strongly disagree) to 5 (strongly agree) Likert scale (See Appendix A). This instrument was developed by Midgley et al. (1998). The instrument captures three factors: (a) task goal orientation (6 items), (b) ability-approach goal orientation (5 items), and (c) ability-avoid goal orientation (6 items). For each of the subscales, the items indicate the following views: task goal orientation (e.g., an important reason why I do my school work is because I like to learn new things); ability-approach goal orientation (e.g., I would feel really good if I were the only one who could answer the teachers’ questions in class); ability-avoid goal orientation (e.g., one of my main goals is to avoid looking like I can’t do my work). Midgley et al. (1998) reported that three
subscales measuring each of these factors were developed over 8 years. They also
reported that results of the studies conducted in 7 different contexts provided evidence
about the internal consistency, stability, and the construct validity of the scales. Finally,
they reported that their three factor solution is supported with confirmatory factor
analysis. They reported the following Cronbach’s alpha coefficients of .83, .86, and .73
for task goal orientation, ability-approach goal orientation, and ability-avoid goal
orientation, respectively.

Data Analysis

Means, standard deviations, maximum and minimum scores derived from each
instrument were calculated. The Cronbach’s alpha for each instrument or subscales of
each instrument was also calculated.

The first round of data analysis focused on validating the author’s interpretation of
students’ written responses in the VNOS-B. First of all, written pre- and post-responses
of 23 students who were interviewed were used to generate a profile of their NOS views
on the target NOS aspects: tentative, empirical, inferential, subjective and creative NOS,
and the distinction between theories and laws. Then, each NOS aspect was analyzed and
assigned a score according to a 5-point scoring scheme created by Abd-El-Khalick
(2004):

1. No answer, incomprehensible or irrelevant answer-0 points;

2. An answer that clearly reflects a more uninformed view of the science aspect addressed
   in the student response= 1 point;

3. An answer that partially reflects a more uninformed view of the science aspect addressed
   in the student response= 2 points;
4. An answer that partially reflects a more informed view of the science aspect addressed in the student response. The view, however, is poorly articulated or supported with adequate arguments/examples = 3 points;

5. An answer that clearly reflects a more informed view of the science aspect addressed in the student response. The view, however, is not well articulated or supported with an incomplete argument/example = 4 points;

6. An answer that clearly reflects a more informed view of the science aspect addressed in the student response. The view is well articulated and/or supported with an adequate argument/example = 5 points (p.8).

Then, the same 23 students’ responses in the follow-up interviews were transcribed and scored separately using the same 5-point scoring scheme. After obtaining two sets of scores for these students’ NOS views on each target NOS aspect, scores from the written NOS questionnaire were compared to the scores generated from the separate analysis of follow-up interviews. These scores were then checked against the data by looking for negative cases and then the necessary modifications were made on the scores by arriving at a single score. Although the follow-up interviews provided extra information with regard to students’ NOS views, these interviews did not justify a major score change across the target NOS aspects. Scores obtained from the written student responses in the VNOS-B and scores obtained from the follow-up interview transcripts were consistent with each other.

After establishing the validity of author’s interpretation of students’ written responses in the VNOS-B, pre- and post-profiles were produced for each participant. Then, each NOS aspect was analyzed and assigned a score according to the same 5-point scoring scheme. The pre- and post-profiles for each participant were compared to assess changes
in participants’ NOS views. As Abd-El-Khalick (2002) suggested the 5-point scoring scheme does not capture the richness of students NOS views in full capacity, but the scoring scheme is used for the purpose enabling the statistical data analysis given the numbers of participants in the study.

A graduate student in science education independently scored 32 students’ written responses in the pre- and post administration of the VNOS-B using the same 5-point scoring scheme. The author and the rater already shared a common understanding about NOS aspects mentioned in the science education reform documents (AAAS, 1993; NRC, 1996) and the important conceptual distinctions embodied at different levels of the scoring scheme. The author’s and graduate students’ scores for each NOS aspect in the pre- and post-profiles of 32 students were highly correlated. Inter-rater agreement between the author and graduate student was above 75% for each NOS aspect.

After answering each question in the VNOS-B, students were asked to rate their level of confidence using a bi-polar 0-10 continuous scale. Students’ average level of confidence in their responses in the VNOS-B was calculated by adding students’ confidence level in each question and dividing the total confidence by the number of questions.

Examination of histograms of scores and skewness and kurtosis values for each NOS aspect and subscales of other instruments revealed that the assumption of normality was violated in almost all pre- and post NOS aspects, and assumption of normality was not violated in subscales of other instruments (see Appendix C).

Although the assumption of normality was violated in almost all pre- and post NOS aspects, a series of dependent samples t-tests were performed to determine whether
students’ pre and post NOS views across target NOS aspects significantly differed. Harris (1998) stated that the only time one should seriously be concerned about the assumptions of the t-test is when one is comparing two samples with very unequal sample sizes and their distribution are very far from normal, and they have variance 10 times bigger or smaller than the other. Harris (1998) suggested not using the t-test when all the violations are happening simultaneously. Therefore, the use of t-test in this case was justified because the distribution of NOS scores was not very far from normal, and pre- and post NOS scores had variances that did not differ by a factor of more than 2.

In addition to a series of independent samples t-tests, to determine whether the explicit-reflective NOS instruction is effective in improving students’ NOS views percentages of students holding various levels of NOS views sophistication in their pre- and post-profiles were also compared to assess changes in students’ NOS views. To facilitate this comparison NOS scores were used to form categories such as “uninformed” (indicating a misconception was held by the student), “partially informed” (indicating a developing view), or “informed” (indicating a fully developed understanding). Students’ NOS views which were assigned a score of 1 or 2 were identified as “uninformed,” NOS views which were assigned a score of 3 were identified as “partially informed,” and NOS views which were assigned a score of 4 or 5 were identified as “informed.”

To determine whether the explicit-reflective NOS instruction is effective in improving students’ epistemological beliefs about science, a multivariate analysis of variance (MANOVA) was performed by using pre- and post-administration of epistemological beliefs questionnaire as grouping variable and four dimensions of the epistemological beliefs questionnaire as independent variables. Then, the targeted
dependent-samples t-tests were performed to determine which epistemological beliefs dimensions improved significantly as a result of explicit-reflective NOS instruction. The MANOVA approach was not used in assessing the difference in students’ pre and post NOS views because this test is based on the assumption of multivariate normality. Tabachnick and Fidell (2001) stated that even if each dependent variable is normally distributed this does not guarantee the normal distribution of the linear combination of the dependent variables. For this reason, only targeted dependent samples t-tests were performed to assess the difference in students’ pre and post NOS views because t-tests are robust to violations of assumptions such as normality, homogeneity of variance, and unequal sample sizes (Harris, 1998).

The MANOVA approach enables one to test whether two or more groups differ significantly on a linear combination of more than one independent variable. The MANOVA approach considers the correlation between independent variables which is ignored in the case of t-tests or univariate ANOVAs (Bray & Maxwell, 1985). For this very reason, it is theoretically possible not to find any significant difference between two or more groups on a single independent variable, but it is entirely possible to find a significant difference between two or more groups on a linear combination of independent variables through MANOVA even if all the independent variables individually do not differentiate between the groups through t-tests or ANOVAs. When the independent variables are correlated among themselves the MANOVA approach is more appropriate than repetition of t-tests or ANOVAs. MANOVA approach also decreases the rate of making a family-wise Type I error. For all these methodological reasons, a series of dependent-samples t-tests or ANOVAs on each epistemological
beliefs dimension were not performed initially. However, MANOVA is an omnibus test, and thus obtaining a significant result does not indicate which independent variable(s) contributes to the difference between pre and post NOS scores. After obtaining a significant difference between pre- and post-instruction epistemological beliefs scores through MANOVA, then it was entirely appropriate to perform the targeted dependent-samples t-tests to determine which epistemological beliefs dimension improved significantly as a result of explicit-reflective NOS instruction.

Although the assumption of normality was violated in all pre- and post NOS scores, correlations among students’ pre- and post-instruction NOS views were calculated because Harris (1998) stated that violation of normality rarely lead to serious misinterpretations when calculating Pearson product-moment correlation coefficient. Correlations among students’ pre- and post-instruction epistemological beliefs about science were also calculated. To determine if there is a relationship between students’ post instruction NOS views and the factors such as metacognitive awareness, thinking dispositions, science self-efficacy beliefs, and motivation measured at the beginning of the intervention correlations among students’ post-intervention NOS views and these constructs were calculated. Similarly, to determine if there is a relationship between students’ post instruction epistemological beliefs about science and aforementioned constructs correlations among students’ post instruction epistemological beliefs about science and students’ metacognitive awareness, thinking dispositions, motivation, and science self-efficacy beliefs measured at the beginning of the intervention were also calculated.
Chapter V

Results

Descriptive statistics with regard to VNOS-B, epistemological beliefs, metacognitive awareness, thinking dispositions, science self-efficacy, and motivation surveys are presented in Table 2, 3, and 4. Cronbach’s alpha coefficients of scales are presented in Table 5.

Table 2
Means, standard deviations, maximum and minimum pre and post NOS views scores across six NOS aspects obtained from VNOS-B

<table>
<thead>
<tr>
<th>NOS aspects</th>
<th>Mean</th>
<th>SD</th>
<th>Max.</th>
<th>Min.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tentative NOS</td>
<td>Pre</td>
<td>3.25</td>
<td>1.09</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>3.98</td>
<td>0.64</td>
<td>5</td>
</tr>
<tr>
<td>Inferential NOS</td>
<td>Pre</td>
<td>0.62</td>
<td>0.84</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>1.25</td>
<td>1.36</td>
<td>5</td>
</tr>
<tr>
<td>Theories and laws</td>
<td>Pre</td>
<td>1.56</td>
<td>0.80</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>2.58</td>
<td>1.19</td>
<td>5</td>
</tr>
<tr>
<td>Empirical NOS</td>
<td>Pre</td>
<td>2.10</td>
<td>1.56</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>3.15</td>
<td>1.30</td>
<td>5</td>
</tr>
<tr>
<td>Creative NOS</td>
<td>Pre</td>
<td>3.02</td>
<td>0.91</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>4.04</td>
<td>0.65</td>
<td>5</td>
</tr>
<tr>
<td>Subjective NOS</td>
<td>Pre</td>
<td>2.62</td>
<td>1.27</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>3.90</td>
<td>0.64</td>
<td>5</td>
</tr>
</tbody>
</table>

Note. High scores indicate endorsing more sophisticated NOS views.

Table 3
Means, standard deviations, maximum and minimum scores of pre and post epistemological beliefs survey

<table>
<thead>
<tr>
<th>Epistemological beliefs dimensions</th>
<th>Mean</th>
<th>SD</th>
<th>Max.</th>
<th>Min.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Certainty of knowledge</td>
<td>Pre</td>
<td>32.47</td>
<td>3.19</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>34.67</td>
<td>3.49</td>
<td>40</td>
</tr>
<tr>
<td>Justification for knowing</td>
<td>Pre</td>
<td>11.16</td>
<td>2.35</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>11.75</td>
<td>1.93</td>
<td>16</td>
</tr>
<tr>
<td>Source of knowledge</td>
<td>Pre</td>
<td>13.67</td>
<td>2.05</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>15.02</td>
<td>2.23</td>
<td>20</td>
</tr>
<tr>
<td>Attainability of truth</td>
<td>Pre</td>
<td>6.72</td>
<td>1.58</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>7.29</td>
<td>1.64</td>
<td>10</td>
</tr>
</tbody>
</table>

Note. High scores indicate agreement with more sophisticated epistemological beliefs.
### Table 4
Means, standard deviations, maximum and minimum scores of metacognitive awareness, thinking dispositions, science self-efficacy, and motivation surveys

<table>
<thead>
<tr>
<th>Measure</th>
<th>Mean</th>
<th>SD</th>
<th>Max.</th>
<th>Min.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Metacognitive awareness</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knowledge of cognition</td>
<td>157.90</td>
<td>23.02</td>
<td>215</td>
<td>90</td>
</tr>
<tr>
<td>Regulation of cognition</td>
<td>101.30</td>
<td>21.92</td>
<td>160</td>
<td>36</td>
</tr>
<tr>
<td><strong>Thinking dispositions</strong></td>
<td>141.20</td>
<td>11.51</td>
<td>181</td>
<td>114</td>
</tr>
<tr>
<td><strong>Science self-efficacy</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Methods of science</td>
<td>21.22</td>
<td>5.04</td>
<td>36</td>
<td>9</td>
</tr>
<tr>
<td>Generalization to other science courses</td>
<td>19.29</td>
<td>3.99</td>
<td>29</td>
<td>10</td>
</tr>
<tr>
<td>Application of science concepts</td>
<td>18.27</td>
<td>3.76</td>
<td>30</td>
<td>9</td>
</tr>
<tr>
<td><strong>Motivation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task goal orientation</td>
<td>20.75</td>
<td>3.05</td>
<td>28</td>
<td>10</td>
</tr>
<tr>
<td>Ability-approach goal orientation</td>
<td>19.85</td>
<td>4.09</td>
<td>30</td>
<td>6</td>
</tr>
<tr>
<td>Ability-avoid goal orientation</td>
<td>13.25</td>
<td>3.71</td>
<td>25</td>
<td>5</td>
</tr>
</tbody>
</table>

### Table 5
Cronbach’s alpha coefficients for each scale

<table>
<thead>
<tr>
<th>Measure</th>
<th>α</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Epistemological beliefs</strong></td>
<td></td>
</tr>
<tr>
<td>Certainty of knowledge</td>
<td>0.64</td>
</tr>
<tr>
<td>Justification for knowing</td>
<td>0.40</td>
</tr>
<tr>
<td>Source of knowledge</td>
<td>0.49</td>
</tr>
<tr>
<td>Attainability of truth</td>
<td>0.67</td>
</tr>
<tr>
<td><strong>Metacognitive awareness</strong></td>
<td></td>
</tr>
<tr>
<td>Knowledge of cognition</td>
<td>0.92</td>
</tr>
<tr>
<td>Regulation of cognition</td>
<td>0.91</td>
</tr>
<tr>
<td><strong>Thinking dispositions</strong></td>
<td>0.80</td>
</tr>
<tr>
<td><strong>Science self-efficacy</strong></td>
<td></td>
</tr>
<tr>
<td>Methods of science</td>
<td>0.87</td>
</tr>
<tr>
<td>Generalization to other science courses</td>
<td>0.82</td>
</tr>
<tr>
<td>Application of science concepts</td>
<td>0.87</td>
</tr>
<tr>
<td><strong>Motivation</strong></td>
<td></td>
</tr>
<tr>
<td>Task goal orientation</td>
<td>0.78</td>
</tr>
<tr>
<td>Ability-approach goal orientation</td>
<td>0.80</td>
</tr>
<tr>
<td>Ability-avoid goal orientation</td>
<td>0.78</td>
</tr>
</tbody>
</table>
Research Question 1

Data exemplars for description of students’ NOS views were presented in Appendix B. To investigate if there is a significant difference between pre and post NOS scores on each NOS aspect, a dependent samples t-test was performed on each NOS aspect by using pre and post categorization of NOS scores as grouping variable.

Table 6 indicates that participants’ post NOS scores across six target NOS aspects were significantly higher than their pre NOS scores. According to Harris (1998) an effect-size of 0.2 is considered small, one of 0.5 medium, and one of 0.8 large. Effect-size values of tentative, inferential, and empirical NOS were above medium or close to large, and effect-size values of creative, subjective NOS, and theories and laws were large.

Table 6
Dependent-samples t-test results

<table>
<thead>
<tr>
<th>Target NOS aspects</th>
<th>Mean pre</th>
<th>Mean post</th>
<th>t</th>
<th>df</th>
<th>Effect-size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tentative NOS</td>
<td>3.25</td>
<td>3.98</td>
<td>8.59*</td>
<td>160</td>
<td>0.67</td>
</tr>
<tr>
<td>Inferential NOS</td>
<td>0.62</td>
<td>1.25</td>
<td>5.59*</td>
<td>160</td>
<td>0.75</td>
</tr>
<tr>
<td>Theories and laws</td>
<td>1.56</td>
<td>2.58</td>
<td>9.89*</td>
<td>160</td>
<td>0.85</td>
</tr>
<tr>
<td>Empirical NOS</td>
<td>2.10</td>
<td>3.15</td>
<td>8.81*</td>
<td>160</td>
<td>0.67</td>
</tr>
<tr>
<td>Creative NOS</td>
<td>3.02</td>
<td>4.04</td>
<td>12.22*</td>
<td>160</td>
<td>&lt;0.90</td>
</tr>
<tr>
<td>Subjective NOS</td>
<td>2.62</td>
<td>3.90</td>
<td>13.14*</td>
<td>160</td>
<td>&lt;0.90</td>
</tr>
</tbody>
</table>

*p<.01

At the beginning of the study, most of the students did not hold informed conceptions of the six target NOS aspects except the tentative NOS aspect (see Table 7). It was evident that students’ NOS views across six target NOS aspects were more favorable at the end of the intervention. This indicated that the explicit-reflective NOS instruction was successful in improving students’ NOS views. However, these findings should be interpreted with caution. Eighty eight students (54.6 %) at the beginning of the study and
145 students (90%) at the end of the study indicated that scientific theories do change over time because of new discoveries, facts, and advances in technology. These findings can be interpreted to reflect an informed understanding of tentative NOS aspect. However, a holistic examination of students’ NOS views, nonetheless, indicated that this seemingly higher percentage of students holding informed tentative NOS views can be misleading because even after the explicit-reflective NOS instruction, the great majority of students did not hold informed understanding about the functions and relationships of theories and laws. At the end of the study, only 31 students (19.2%) held informed views about the functions and relationships of theories and laws compared to 145 students (90%) holding seemingly informed tentative NOS views. These findings corroborate with the findings of Abd-El-Khalick (2001). Abd-El-Khalick (2001) also drew attention to the discrepancy between these seemingly informed tentative NOS views and uninformed views of the functions and relationships of theories and laws. A considerable number of students held seemingly informed tentative NOS views while holding the view that theories are intermediary steps before laws. These students perceived “theory change” as simply changing an “idea” or “guess” about a certain scientific phenomenon.

Student gains in their NOS views on other NOS aspects such as inferential and subjective NOS should also be considered with caution. A substantial percentage of students expressed irrelevant views with regard to inferential NOS in both pre- and post-administration of the VNOS-B (54% and 41% respectively). This means that the question designed to assess inferential NOS in the VNOS-B (question 2) needs to be adjusted in a way that it can better tap the inferential NOS views of students. This question often produced answers like “I don't know what an atom looks like, and I'm going to say that
scientists took an educated guess on what it might look like.” Students’ content knowledge about the structure of the atom was an obstacle in assessing whether students have informed conceptions of the inferential NOS. Even after the instruction percentage of students holding partially informed (19.3%) or informed (6.8%) views about inferential NOS was low compared to other target NOS aspects.

Compared to 37 students (23%) at the beginning of the study, 132 students (82%) expressed more informed views of subjective NOS. However, students attributed this subjectivity to scientists’ personal bias, not to scientists’ theoretical orientations. Students often attempted to explain the possibility of two competing explanations in science on the same phenomenon by referring to scientists’ personal subjectivity stemming from their creativity and, social and cultural backgrounds or upbringings. Almost all students did not mention scientists’ theoretical orientation to explain the possibility of different or competing explanations. Subjective NOS scores reflect students’ views about personal subjectivity of scientists rather than the subjectivity stemming from scientists’ theoretical orientation.

Desired changes were apparent in students’ views of the creative NOS aspect. Compared to 44 students (27.3%) at the beginning of study, 140 students (87%) thought that scientists use their creativity and imagination during the entire scientific endeavor, and the use of creativity and imagination is not limited to planning and design of the scientific investigations.

Lastly, students were able to articulate the view that scientific knowledge is based on evidence and observations of nature in a more sophisticated fashion at the end of the instruction. Compared to 32 students (19.9 %) at the beginning of the intervention, 83
students (51.5%) students held informed views of empirical NOS at the end of the intervention. These students endorsed the view that scientific knowledge is not only based on evidence and observations of nature but also it is partly product of subjective and creative human elements.

Students’ average level of confidence in their responses in the VNOS-B was calculated by adding their confidence levels across the all the questions and dividing the total confidence by the number of questions. Students’ average level of confidence in their responses in pre-administration of the VNOS-B was 5.21 out of 10 and their average level of confidence in their responses was 6.73 out of 10. This indicates that students not only improved their NOS views but also they increased their level of confidence in their more informed NOS views.
Table 7

Percentage of participants falling into six different levels of sophistication in NOS views across six NOS aspects before and after the intervention

<table>
<thead>
<tr>
<th>Category</th>
<th>Tentativeness</th>
<th>Inferential NOS</th>
<th>Theories and Laws</th>
<th>Empirical NOS</th>
<th>Creativity</th>
<th>Subjectivity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>Irrelevant</td>
<td>3.7</td>
<td>0.6</td>
<td>54.0</td>
<td>41.0</td>
<td>5.6</td>
<td>4.3</td>
</tr>
<tr>
<td>Uninformed</td>
<td>11.3</td>
<td>1.3</td>
<td>41.0</td>
<td>32.9</td>
<td>80.0</td>
<td>34.8</td>
</tr>
<tr>
<td>Partially informed</td>
<td>30.4</td>
<td>8.1</td>
<td>3.7</td>
<td>19.3</td>
<td>14.4</td>
<td>41.7</td>
</tr>
<tr>
<td>Informed</td>
<td>54.6</td>
<td>90.0</td>
<td>1.2</td>
<td>6.8</td>
<td>0</td>
<td>9.2</td>
</tr>
</tbody>
</table>
A multivariate analysis of variance was performed by using pre- and post categorization of epistemological beliefs scores as grouping variable on four dependent variables: certainty of knowledge, justification for knowing, source of knowledge, and attainability of truth. SPSS 14.0 MANOVA was used for the analyses. Results of evaluation of assumptions of normality, homogeneity of variance, linearity, and multicollinearity were satisfactory. With the use of Wilks’ criterion, it can be stated that the linear combination of dependent variables measured at the beginning of the study were significantly different than the linear combination of the same dependent variables measured at the end of the study, F (4, 317) = 14.71, p < .001.

To further investigate if there is a significant difference between pre and post epistemological beliefs scores on each dimension, a dependent samples t-test was performed. Table 8 indicates that participants’ post-epistemological beliefs scores across four dimensions were significantly higher than their pre-epistemological beliefs scores. Effect size values of certainty of knowledge and source of knowledge dimensions were above medium, and effect size values of justification for knowing and attainability of truth dimensions were above small or close to medium. This suggests that the explicit-reflective NOS instruction led not only to statistically significant favorable changes in students epistemological beliefs about science but also these changes were meaningful beyond being statistically significant. After the explicit-reflective NOS instruction students were more likely to endorse the following views: (a) certainty and simplicity of knowledge-knowledge is tentative and relative as opposed to being fixed and concrete, (b) justification for knowing-knowledge claims in science can be critically evaluated in light of evidence and views of experts without not being totally dependent upon the
authority or expert opinion, (c) source of knowledge—knowledge does not reside in external authority, and (d) attainability of truth—attainability of absolute truth is not possible in science.

Table 8

<table>
<thead>
<tr>
<th>Epistemological beliefs dimensions</th>
<th>Mean pre</th>
<th>Mean post</th>
<th>t</th>
<th>df</th>
<th>Effect size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Certainty of knowledge</td>
<td>32.47</td>
<td>34.67</td>
<td>8.51*</td>
<td>160</td>
<td>0.69</td>
</tr>
<tr>
<td>Justification for knowing</td>
<td>11.16</td>
<td>11.75</td>
<td>3.30*</td>
<td>160</td>
<td>0.31</td>
</tr>
<tr>
<td>Source of knowledge</td>
<td>13.67</td>
<td>15.02</td>
<td>7.73*</td>
<td>160</td>
<td>0.66</td>
</tr>
<tr>
<td>Attainability of truth</td>
<td>6.72</td>
<td>7.29</td>
<td>4.66*</td>
<td>160</td>
<td>0.36</td>
</tr>
</tbody>
</table>

*p<.01

Findings of this study suggest that the explicit-reflective NOS instruction was effective in improving students’ NOS views and epistemological beliefs about science. After the explicit-reflective NOS instruction the number of participants holding more adequate NOS views increased across all six NOS aspects. Similarly, students held more sophisticated epistemological beliefs about science after the explicit-reflective NOS instruction.

Research Question 2

Students’ pre-intervention NOS views were correlated within themselves. Similarly, students’ post-intervention NOS views were also correlated within themselves (see Table 9). A careful examination of correlations among students’ pre-intervention NOS views and correlations among students’ post-intervention NOS views indicated that students’ held a consistent NOS conceptual framework both before and after the intervention. For instance, at the beginning of the intervention tentative NOS aspect correlated with empirical NOS (r = .31, p < .01), creative NOS (r = .29, p < .01) and subjective NOS (r =
theories and laws correlated with creative NOS (r = .16, p < .05) and subjective NOS (r = .22, p < .01); empirical NOS correlated with creative NOS (r = .17, p < .01) and subjective NOS (r = .21, p < .01); creative NOS correlated with subjective NOS (r = .24, p < .01); and finally inferential NOS correlated with subjective NOS (r = .17, p < .05), and theories and laws (r = .17, p < .05).

Similarly, at the end of the intervention tentative NOS correlated with theories and laws (r = .16, p < .05), empirical NOS (r = .31, p < .01), creative NOS (r = .31, p < .01), and subjective NOS (r = .25, p < .01); theories and laws correlated with empirical NOS (r = .18, p < .05), creative NOS (r = .21, p < .01), and subjective NOS (r = .29, p < .01); empirical NOS correlated with creative NOS (r = .24, p < .01) and subjective NOS (r = .20, p < .01); creative NOS correlated with subjective NOS (r = .47, p < .01); and finally inferential NOS correlated with empirical NOS (r = .17, p < .05).

Table 9 indicates that there were also significant correlations between pre- and post-intervention NOS views. It is interesting to note that each of the six post-intervention NOS aspects except the creative NOS aspect was correlated with its corresponding pre-instruction NOS aspect. For example, there were significant correlations between pre and post tentative NOS (r = .32, p < .01), pre and post inferential NOS (r = .24, p < .01), pre and post theories and laws (r = .19, p < .05), pre and post empirical NOS (r = .47, p < .01), and pre and post subjective NOS (r = .32, p < .01). The correlation between pre and post creative NOS was not significant at p < .05 level, (r = .12, p = .12). These correlations indicate that to some extent students’ prior conceptions of most NOS aspects were predictive of their corresponding NOS conceptions at the end of the intervention.
Table 9

Intercorrelations among participants’ pre and post NOS views across six NOS aspects

<table>
<thead>
<tr>
<th>Measure</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOS aspects</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Tentativeness post</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Inferential NOS post</td>
<td>0.83</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Theories and laws post</td>
<td>0.16*</td>
<td>0.15</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Empirical NOS post</td>
<td>0.31**</td>
<td>0.17*</td>
<td>0.18*</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Creativity post</td>
<td>0.31**</td>
<td>0.09</td>
<td>0.21**</td>
<td>0.24**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Subjectivity post</td>
<td>0.25**</td>
<td>0.12</td>
<td>0.29**</td>
<td>0.20**</td>
<td>0.47**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Tentativeness pre</td>
<td>0.32**</td>
<td>0.03</td>
<td>0.31**</td>
<td>0.30**</td>
<td>0.07</td>
<td>0.12</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Inferential NOS pre</td>
<td>0.11</td>
<td>0.24**</td>
<td>0.12</td>
<td>0.10</td>
<td>0.04</td>
<td>-0.01</td>
<td>0.07</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Theories and laws pre</td>
<td>-0.07</td>
<td>0.21**</td>
<td>0.19*</td>
<td>0.14</td>
<td>0.07</td>
<td>0.19*</td>
<td>0.10</td>
<td>0.17*</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Empirical NOS pre</td>
<td>0.21**</td>
<td>0.06</td>
<td>0.13</td>
<td>0.47**</td>
<td>0.00</td>
<td>0.09</td>
<td>0.31**</td>
<td>0.03</td>
<td>0.11</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Creativity pre</td>
<td>0.13</td>
<td>0.17*</td>
<td>0.16*</td>
<td>0.18*</td>
<td>0.12</td>
<td>0.07</td>
<td>0.29**</td>
<td>0.15</td>
<td>0.16*</td>
<td>0.17*</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>12. Subjectivity pre</td>
<td>-0.01</td>
<td>0.02</td>
<td>0.18*</td>
<td>0.28**</td>
<td>0.12</td>
<td>0.32**</td>
<td>0.21**</td>
<td>0.17*</td>
<td>0.22**</td>
<td>0.21**</td>
<td>0.24**</td>
<td>1</td>
</tr>
</tbody>
</table>

*p<.05, **p<.01
Students’ pre-intervention epistemological beliefs about science were correlated within themselves. Similarly, students’ post-intervention epistemological beliefs about science were also correlated within themselves (see Table 10). For instance, at the beginning of the intervention certainty of knowledge dimension correlated with source of knowledge dimension (r = .31, p < .01) and attainability of truth dimension (r = .24, p < .01); source of knowledge dimension correlated with attainability of truth dimension (r = .20, p < .05); and justification for knowing dimension was not found to be correlated with any of the other dimensions.

Similarly, at the end of the intervention certainty of knowledge dimension correlated with source of knowledge dimension (r = .39, p < .01) and attainability of truth dimension (r = .32, p < .01); source of knowledge dimension correlated with attainability of truth dimension (r = .27, p < .01); and justification for knowing dimension was not found to be correlated with any of the other dimensions.

Table 10 indicates that there were also significant correlations between pre- and post-intervention epistemological beliefs about science. Each of the four dimensions of pre-intervention epistemological beliefs was correlated with its corresponding post-intervention epistemological beliefs dimension. For example, there were significant correlations between pre- and post-intervention certainty of knowledge (r = .52, p < .01), pre- and post-intervention justification for knowing (r = .45, p < .01), pre- and post-intervention source of knowledge (r = .46, p < .01), and pre- and post-intervention attainability of truth (r = .54, p < .01). These correlations indicate that to a great extent students’ prior epistemological beliefs about science were predictive of their
corresponding epistemological beliefs about science measured at the end of the intervention.
Table 10
Intercorrelations among participants’ pre- and post-epistemological beliefs dimensions

<table>
<thead>
<tr>
<th>Measure</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epistemological beliefs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>dimensions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Certainty of knowledge pre</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Justification for knowing pre</td>
<td>-0.15</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Source of knowledge pre</td>
<td>0.31**</td>
<td>-0.10</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Attainability of truth pre</td>
<td>0.24**</td>
<td>-0.14</td>
<td>0.20*</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Certainty of knowledge post</td>
<td>0.52**</td>
<td>-0.05</td>
<td>0.26**</td>
<td>0.21**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Justification for knowing post</td>
<td>-0.02</td>
<td>0.45**</td>
<td>0.01</td>
<td>-0.02</td>
<td>-0.13</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Source of knowledge post</td>
<td>0.29**</td>
<td>-0.04</td>
<td>0.46**</td>
<td>0.21**</td>
<td>0.39**</td>
<td>-0.05</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>8. Attainability of truth post</td>
<td>0.17*</td>
<td>-0.13</td>
<td>0.10</td>
<td>0.54**</td>
<td>0.32**</td>
<td>-0.07</td>
<td>0.27**</td>
<td>1</td>
</tr>
</tbody>
</table>

*p<.05, **p<.01
There were also significant correlations between pre-intervention epistemological beliefs about science and post-intervention NOS views; pre-intervention epistemological beliefs about science and pre-intervention NOS views; post-intervention epistemological beliefs about science and pre-intervention NOS views; and post-intervention epistemological beliefs about science and post-intervention NOS views.

It was found that post-intervention tentative NOS aspect was correlated with pre-intervention attainability of truth dimension of epistemological beliefs (r = .28, p < .01). Similarly, post-intervention theories and laws were correlated with epistemological beliefs’ pre-intervention attainability of truth dimension (r = .18, p < .05) and certainty of knowledge dimension (r = .16, p < .05). These findings suggest that students who think that attainability of absolute truth is not possible in science at the beginning of the intervention are more likely to develop more informed tentative NOS views. These findings also suggest that students endorsing the views that attainability of absolute truth is not possible in science, and scientific knowledge is tentative and contextual at the beginning of the intervention are more likely to develop more informed NOS views about theories and laws at the end of the intervention. It was found that other post-intervention NOS aspects were not correlated with any of the epistemological beliefs dimensions measured at the beginning of the study.

It was also found that epistemological beliefs’ pre-intervention certainty-simplicity of knowledge dimension correlated with pre-intervention tentative NOS aspect (r = .23, p < .01); epistemological beliefs’ post-intervention certainty of knowledge dimension correlated with post-intervention subjective NOS aspect (r = .24, p < .01), post-intervention theories and laws (r = .22, p < .01), and pre-intervention theories and laws (r
and epistemological beliefs’ post-intervention attainability of truth dimension also correlated with post-intervention theories and laws \( (r = .24, p < .01) \).

**Research Question 3**

It was found that post-intervention NOS views were not significantly correlated with any of the dimensions of metacognitive awareness, science self-efficacy, motivation, and thinking dispositions (see Table 11).
Table 11
Inter correlations among participants’ post-instruction NOS views, metacognitive awareness, thinking dispositions, science self-efficacy beliefs, and motivation

<table>
<thead>
<tr>
<th>Measure</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.Tentative NOS</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.Inferential NOS</td>
<td>0.08</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.Theories and laws</td>
<td>0.16*</td>
<td>0.15</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.Empirical NOS</td>
<td>0.31**</td>
<td>0.16*</td>
<td>0.18*</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.Creative NOS</td>
<td>0.31**</td>
<td>0.09</td>
<td>0.21**</td>
<td>0.24**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.Subjective NOS</td>
<td>0.25**</td>
<td>0.12</td>
<td>0.29**</td>
<td>0.20**</td>
<td>0.47**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.Knowledge of cog.</td>
<td>-0.04</td>
<td>-0.04</td>
<td>-0.03</td>
<td>-0.01</td>
<td>-0.02</td>
<td>0.03</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.Regulation of cog.</td>
<td>0.00</td>
<td>-0.07</td>
<td>-0.05</td>
<td>-0.05</td>
<td>-0.03</td>
<td>-0.03</td>
<td>0.79**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9.Thinking disp.</td>
<td>0.04</td>
<td>0.10</td>
<td>0.13</td>
<td>0.07</td>
<td>0.09</td>
<td>0.06</td>
<td>-0.01</td>
<td>0.00</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.Methods of sci.</td>
<td>0.01</td>
<td>0.00</td>
<td>0.02</td>
<td>0.04</td>
<td>0.00</td>
<td>-0.06</td>
<td>0.37**</td>
<td>0.24**</td>
<td>0.03</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11.Generalization</td>
<td>-0.07</td>
<td>-0.02</td>
<td>0.01</td>
<td>0.00</td>
<td>0.07</td>
<td>-0.08</td>
<td>0.44**</td>
<td>0.35**</td>
<td>0.08</td>
<td>0.66**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12.Application</td>
<td>0.01</td>
<td>0.05</td>
<td>0.02</td>
<td>0.09</td>
<td>0.06</td>
<td>0.01</td>
<td>0.35**</td>
<td>0.26**</td>
<td>0.10</td>
<td>0.61**</td>
<td>0.68**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13.Task goal</td>
<td>-0.09</td>
<td>0.05</td>
<td>0.00</td>
<td>0.09</td>
<td>0.02</td>
<td>-0.06</td>
<td>0.35**</td>
<td>0.35**</td>
<td>0.10</td>
<td>0.28**</td>
<td>0.30**</td>
<td>0.30**</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14.Ability-approach</td>
<td>-0.07</td>
<td>-0.10</td>
<td>-0.08</td>
<td>0.04</td>
<td>0.11</td>
<td>-0.06</td>
<td>0.02</td>
<td>0.00</td>
<td>-0.27**</td>
<td>0.06</td>
<td>0.20*</td>
<td>0.12</td>
<td>0.03</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>15.Ability-avoid</td>
<td>-0.02</td>
<td>-0.04</td>
<td>-0.05</td>
<td>0.15</td>
<td>-0.04</td>
<td>0.04</td>
<td>0.06</td>
<td>0.12</td>
<td>-0.11</td>
<td>-0.01</td>
<td>0.09</td>
<td>0.06</td>
<td>-0.02</td>
<td>0.44**</td>
<td>1</td>
</tr>
</tbody>
</table>

*p<.05, **p<.01
Research Question 4

It was found that post-intervention epistemological beliefs about science were only correlated with thinking dispositions (see Table 12). Three of the four dimensions, except the justification for knowing dimension, were correlated significantly with the thinking dispositions. The correlation between certainty of knowledge and thinking dispositions was \( r = .46, p < .01 \), the correlation between source of knowledge and thinking dispositions was \( r = .27, p < .01 \), and the correlation between attainability of truth and thinking dispositions was \( r = .17, p < .05 \). These correlations indicate that students who have more tendency to considering alternative opinions and evidence, and searching and processing of information that goes against their own beliefs at the beginning of the intervention are more likely to think that science is tentative, less likely to depend on authority, and less likely to think that attainability of absolute truth is possible in science than their peers with less sophisticated thinking dispositions.

Although it was found that metacognitive awareness, science self-efficacy, and motivation were not correlated with post-intervention NOS views and epistemological beliefs about science they were positively correlated among themselves (see Table 11 and Table 12).
<table>
<thead>
<tr>
<th>Measure</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Certainty of knowledge</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Justification for knowing</td>
<td>-0.12</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Source of knowledge</td>
<td>0.39**</td>
<td>-0.05</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Attainability of truth</td>
<td>0.32**</td>
<td>-0.07</td>
<td>0.27**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Knowledge of cognition</td>
<td>0.08</td>
<td>-0.03</td>
<td>0.10</td>
<td>0.08</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Regulation of cognition</td>
<td>0.05</td>
<td>0.01</td>
<td>0.04</td>
<td>0.10</td>
<td>0.79**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Thinking dispositions</td>
<td>0.46**</td>
<td>-0.07</td>
<td>0.27**</td>
<td>0.17*</td>
<td>-0.01</td>
<td>0.00</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Methods of science</td>
<td>-0.01</td>
<td>-0.08</td>
<td>0.00</td>
<td>0.00</td>
<td>0.37**</td>
<td>0.24**</td>
<td>0.03</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Generalization</td>
<td>-0.02</td>
<td>-0.07</td>
<td>-0.03</td>
<td>-0.02</td>
<td>0.44**</td>
<td>0.35**</td>
<td>0.08</td>
<td>0.66**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Application</td>
<td>0.03</td>
<td>-0.09</td>
<td>-0.03</td>
<td>0.05</td>
<td>0.35**</td>
<td>0.26**</td>
<td>0.10</td>
<td>0.61**</td>
<td>0.68**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Task goal orientation</td>
<td>0.04</td>
<td>-0.05</td>
<td>-0.02</td>
<td>0.02</td>
<td>0.35**</td>
<td>0.35**</td>
<td>0.10</td>
<td>0.28**</td>
<td>0.30**</td>
<td>0.30**</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. Ability-approach</td>
<td>-0.14</td>
<td>0.03</td>
<td>-0.10</td>
<td>-0.08</td>
<td>0.02</td>
<td>0.00</td>
<td>-0.27**</td>
<td>0.06</td>
<td>0.20*</td>
<td>0.12</td>
<td>0.03</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>13. Ability-avoid</td>
<td>0.04</td>
<td>-0.06</td>
<td>-0.03</td>
<td>-0.08</td>
<td>0.06</td>
<td>0.12</td>
<td>-0.11</td>
<td>-0.01</td>
<td>0.09</td>
<td>0.06</td>
<td>-0.02</td>
<td>0.44**</td>
<td>1</td>
</tr>
</tbody>
</table>

*p<.05, **p<.01
Chapter VI

DISCUSSION

The overarching aim of this study was to examine the impact of the explicit-reflective NOS instruction that satisfied the conditions for learning as conceptual change as described by Abd-El-Khalick and Akerson (2004) and Hewson et al. (1998) on NOS views and epistemological beliefs about science, and the factors mediating the development of NOS views and epistemological beliefs about science.

Students were provided with ample opportunities to assess the status of their NOS views and their epistemological beliefs about science in relation to NOS views promoted by science education community and science education reform documents (AAAS, 1993; NRC, 1996). The explicit-reflective NOS instruction aimed at raising the status of informed NOS views and epistemological beliefs about science while simultaneously lowering the status of uninformed NOS views. As a result of the explicit-reflective NOS instruction students’ NOS views improved across all target NOS aspects. Similarly, students’ epistemological beliefs also improved across all dimensions of epistemological beliefs. Findings of this study are parallel to the findings of previous studies suggesting that the explicit-reflective NOS instruction is effective in improving students’ NOS views (e.g., Abd-El-Khalick, 2001; Abd-El-Khalick & Akerson, 2004; Akerson et al., 2006).

The current study provided extra evidence with regard to the effectiveness of the explicit-reflective NOS instruction by measuring students’ epistemological beliefs about science as well as their NOS views. Positive changes in students’ NOS views both as assessed by the VNOS-B (Lederman et al., 2002) and epistemological beliefs about science as
measured by Hofer’s (1997) epistemological beliefs instrument support the proponents of
the explicit-reflective instruction in improving students’ NOS views.

The explicit-reflective NOS instruction lasted for four weeks. This relatively short
period of instruction focused on improving students’ NOS views and epistemological
beliefs led to discernable positive changes in students’ NOS views and epistemological
beliefs about science. Most of the activities engaged during the NOS instruction were
content-free activities. The success of the explicit-reflective instruction can be further
increased if the NOS instruction is more embedded within the science content and the
NOS becomes an integral part of the instruction throughout the semester.

As it was stated earlier the findings with regard to student gains in their NOS views
should be considered with caution. Students improved their NOS views in the desired
direction, but a holistic and careful examination of students’ overall post instruction NOS
views reflects a “naïve relativistic” position. Although students endorsed the view that
scientific knowledge was tentative or subject to change, their conception of tentativeness
was not identical to the conception of tentativeness which was promoted by the explicit-
reflective NOS instruction. Their conception of tentativeness or theory change in science
was similar to simply changing an “idea” or “guess” about a certain scientific
phenomenon. Students’ were not able to comprehend the inherent difficulties involved in
the replacement of an old theory by the formulation of a new theory as it was explained
by Kuhn (1970). Students’ uninformed conceptions about the functions and relationships
of theories and laws, and their conceptions of subjectivity in science contributed to this
“naïve relativistic” position. Most students’ viewed theories as intermediary steps before
laws and not as legitimate products of science as laws. Subjectivity in science was
perceived as personal bias of scientists. Students’ conceptions of tentativeness and
subjectivity in science were consistent with an attitude of “do your own thing” or
“anything goes” which was prevalent in college students’ epistemological views (e.g.,
Perry, 1970). According to Perry (1970), college students who are at the multiplicity
stage express “do your own thing” or “anything goes” attitude in their epistemological
views.

Perry (1970) described the epistemological development of college students.
Although Perry’s original scheme contains nine stages, it was convenient for most
researchers to clump these nine stages into four: dualism, multiplicity, relativism and
commitment to relativism. According to Perry (1970), many students come to college at
the dualism stage. In dualism stage, students see the things as right or wrong. They think
that knowledge is objective and the instructor is the representative of authority. As the
students are exposed to conflicting views of different authorities on the same issues, they
question the right or wrong view of the world. They think that there are some issues that
cannot be definitively known. Students who are thinking at this level are in multiplicity
position. Within this stage, students believe that there is truth, but that there is room for
uncertainty. In relativity stage, students come to think that there are few issues that can be
known for sure. This stage is much different from other positions because there is a major
departure from dualistic way of thinking. Metacognition is developed within this stage.
Authority becomes open to debate and criticism. In the commitment to relativism
position, students find relativism disorienting. Students seek to develop commitments to
do away with disorienting.
In an unpublished manuscript Deniz and Akerson (2006) documented personal epistemology of 173 students enrolled in the same introductory science course exactly one year before the current study took place. According to Perry’s (1970) scheme, it was found that 112 students are in dualism, 62 students are in multiplicity, and 9 students are relativism stage. None of the students was found to be in commitment to relativism stage. Combined with the findings of Deniz and Akerson (2006), findings of the current study suggest that students’ overall epistemic views might interfere with improving their specific NOS views or epistemological beliefs about science. Although there is no general agreement about how to conceptualize and assess personal epistemology (e.g., Hofer, 1997; Perry, 1970; Schommer, 1990), it can be thought that students hold overall epistemic views about the nature of general knowledge and these overall epistemic views provide a basis for someone to form their context-dependent epistemological beliefs such as epistemological beliefs about science. The relationship between overall epistemic views such as Perry’s (1970 positions and context-dependent epistemological beliefs such as Hofer’s (1997) context dependent multidimensional epistemological beliefs should be considered as a dynamic relationship. It can be thought that overall epistemic views can influence to what extent one can improve their context-dependent epistemological beliefs, and in turn, improved context-dependent epistemological beliefs can facilitate one’s transition from a lower epistemological position to a higher epistemological position.

Students held more or less consistent NOS views and epistemological beliefs about science both at the beginning and at the end of the intervention. Post-instruction NOS views of students across all target NOS aspects except the creative NOS aspect were
correlated with their corresponding pre-instruction NOS views. These findings suggest that students’ initial NOS views to some extent determine how much one can improve one’s NOS views. Similarly, post-instruction epistemological beliefs of students across four dimensions were correlated with their corresponding pre-instruction epistemological beliefs about science. These findings also suggest that initial epistemological beliefs about science determine how much one can improve their epistemological beliefs about science to some degree. Pintrich et al. (1993) suggested that prior knowledge can play two contradictory roles in conceptual change. They contemplated that prior knowledge can either impede conceptual change through students’ alternative frameworks, or it can facilitate conceptual change by providing students a conceptual basis for evaluating the validity of newly encountered ideas. The findings of the current study suggest that students’ pre-instruction NOS views and epistemological beliefs about science were related to their post-instruction NOS views and epistemological beliefs about science, and they were at least not strong enough to impede raising the status of informed NOS views and epistemological beliefs about science.

As I found, Clough (2006) also underscored the importance of students’ prior conceptions and experiences when learning about NOS. Clough (2006) claimed that students often ignore contrary information and modify newly presented information so that it fits to their existing conceptual framework. In other words, he claimed students interpret newly presented information from within their existing conceptual framework. The correlations between students’ pre and post NOS views and pre and post epistemological beliefs dimensions in this study support Clough’s (2006) claim that
students interpret newly presented information from within their existing conceptual framework.

It is interesting to note that certain aspects of students’ NOS views assessed by the VNOS-B (Lederman et al., 2002) and certain dimensions of epistemological beliefs about science measured by Hofer’s (1997) epistemological beliefs instrument were found to be related to each other both at the beginning and at the end of the intervention. Considering the underlying assumptions of the VNOS-B and epistemological beliefs instrument the relationships between certain NOS views and epistemological beliefs dimensions should not be surprising. However, the relationships between pre-intervention attainability of truth dimension and certain post-intervention NOS aspects such as tentative NOS, and the functions and relationships of theories and laws warrant a special attention. As it was argued by Abd-El-Khalick et al. (1998) and Akerson et al. (2000) the explicit-reflective NOS instruction did not specifically focus on a controversial NOS aspect such as the attainability of truth or the existence of one objective reality. However, it was found that students were less likely to think that attainability of absolute truth is possible in science after the explicit-reflective NOS instruction, and it was also found that students’ pre-intervention conceptions with regard to attainability of truth were related to their post-intervention tentative NOS views, and their post-intervention views about the functions and relationships of theories and laws. In other words, students who thought that attainability of absolute truth is not possible in science at the beginning of the intervention were more likely to develop more informed views about tentative NOS aspect and, the functions and relationships of theories and laws.
The studies presented in the literature review section indicated that there are positive relationships among mastery goal orientation, performance-approach goal orientation, science self-efficacy beliefs and cognitive/metacognitive awareness in general, and that these aforementioned constructs are generally positively correlated with students’ performance in science and mathematics. Contrary to the author’s expectations students’ post-instruction NOS views were not found to be correlated with metacognitive awareness, science self-efficacy beliefs, motivation, and thinking dispositions. It was assumed that metacognitive awareness, science self-efficacy beliefs and motivation would be positively correlated with conceptual change in NOS views. In other words, it was hypothesized that students with higher metacognitive awareness, science self-efficacy beliefs, motivation, and thinking dispositions would be in a better position to improve their NOS views through the explicit-reflective NOS instruction. However, it can be thought that metacognitive awareness plays a more central role in learning as conceptual change about NOS compared to science-self efficacy beliefs, motivation, and thinking dispositions. In addition to the studies presented in the literature review section there are other studies suggesting that metacognitive awareness improves students’ performance by enabling them to plan and monitor their own learning (e.g., Garner & Alexander, 1989; Pressley & Ghatala, 1990; Swanson, 1990). Science self-efficacy belief, motivation, and thinking dispositions may not be directly related to the learning as conceptual change about NOS, but they may moderate the conceptual change through their relation to metacognitive strategy use.

Students’ metacognitive awareness, science self-efficacy beliefs, and task goal orientation (one of the dimensions of the motivation instrument) were positively
correlated among themselves. Findings of the current study suggest that students with higher task goal orientation and science self-efficacy beliefs were more likely to engage in metacognitive strategy use. These findings are consistent with the studies reported in the literature review. In addition to the studies mentioned in the literature review other studies also reported a strong correlation between task goals and the use of cognitive and metacognitive strategies, and a negative correlation between task goals and superficial metacognitive engagement (Nolen, 1988; Meece et al., 1988). Anderman and Young (1994) reported that task goals were positively correlated with deep metacognitive strategy use in science and negatively correlated with surface metacognitive strategy use. In addition to task goals, Anderman and Young (1994) reported that ability goals were negatively correlated with deeper metacognitive strategy use and positively correlated with surface metacognitive strategy use. In the current study, it was found that ability goals were not correlated with deep or surface metacognitive strategy use. Midgley et al. (1998) reported that an orientation to task goals was positively related with academic self-efficacy. The results of the current study also indicated that task goal orientation was positively related to students’ science self-efficacy. McMillan and Forsyth (1991) suggested that students with higher self-efficacy in their ability to understand and apply scientific concepts would be more likely to engage in learning than students with low self-efficacy. Baldwin et al. (1999) suggested that students’ low science self-efficacy may lead to a dislike for science, and this may potentially lead to avoidance of learning science. As it was hypothesized above, both Baldwin et al. (1999) and McMillan and Forsyth (1991) implied that science self-efficacy beliefs were not directly related to
learning outcomes in science, but their relations to engagement or metacognitive strategy use in science learning made them indirectly related to learning outcomes.

It can be assumed that students with higher task goal orientation and science self-efficacy beliefs would be more likely to engage in metacognitive strategy use in a way that increases the probability of developing more informed NOS views and epistemological beliefs about science. Although the link between students’ task goal orientation, science self-efficacy beliefs, and metacognitive strategy use was established, this link was not found to be related to students’ gains in their NOS views and epistemological beliefs about science. Although there are some studies (Garner & Alexander, 1989; Pressley & Ghatala, 1990; Swanson, 1990) indicating that metacognitively aware learners perform better than unaware learners, there are other studies (Glenberg & Epstein, 1987; Leonsario & Nelson, 1990) that are at odds with intuitive assumptions about metacognition. However, the number of latter studies is small compared to the number of studies suggesting a positive relationship between metacognition and performance. In line with intuitive assumptions about metacognition Abd-El-Khalick and Akerson (2004) reported that metacognitively-aware learners who sought to clarify meanings of key NOS ideas and monitor the changes in their NOS views developed more informed NOS views. The current study measured students’ self-reported metacognitive strategy use in their learning. It may be the case that students’ self-reported metacognitive strategy use may be different than their actual metacognitive strategy use during the NOS instruction. Similarly, the current study measured students’ overall self-reported motivation in the learning process not their specific motivation to learn about NOS. Furthermore, limitations in the measures of these constructs might have
also reduced the likelihood of finding a relationship. Abd-El-Khalick and Akerson (2004) reported that preservice teachers’ realization of the importance of learning and teaching about NOS facilitated the development of more informed NOS views. If students did not internalize the importance of learning about NOS they might not engage in deep metacognitive strategy use. It should also be considered that realization of the importance of learning about NOS is a necessary but not sufficient condition. This realization should be coupled with higher metacognitive strategy use in learning about NOS. Even if students realized the importance of learning about NOS their overall metacognitive strategy use ability might be a regulating factor.

Contrary to my expectations, thinking dispositions were not found to be related to students’ post-instruction NOS views. However, thinking dispositions were found to be related to students’ post-instruction epistemological beliefs about science. It was hypothesized that students who were more open to consider alternative opinions and evidence, and to process information going against their own beliefs would be more likely to improve their NOS views and epistemological beliefs about science than their peers with less sophisticated thinking dispositions. Students’ NOS views and thinking dispositions were assessed through different methods. Students’ NOS views were assessed through an open-ended NOS questionnaire. Students’ NOS views were qualitatively analyzed and each NOS aspect was assigned a score from 0 to 5. Thinking dispositions scores were measured through a self-report quantitative instrument. This discrepancy in assessment methods might have contributed to finding no relationship between post-instruction NOS views and thinking dispositions. Students’ epistemological beliefs about science were also measured through a self-report quantitative instrument,
and this might have contributed to finding a relationship between thinking dispositions and epistemological beliefs about science.

Clough (2006) contemplated three different scenarios when learning about NOS as conceptual change. In the first scenario, he hypothesized that students may mistakenly think that newly presented ideas perfectly fit with their existing NOS ideas. Therefore, they do not see any need to revise their current NOS ideas. In the second scenario, he hypothesized that students may think that newly presented ideas are more or less similar to their existing NOS ideas. In this case students may slightly revise their existing NOS ideas or they form a separate schema for newly presented NOS ideas which are not connected to old NOS ideas. In the third scenario, he hypothesized that students may recognize a cognitive conflict between newly presented NOS ideas and their existing NOS ideas. In this case, students are involved in searching for information that will resolve the conflict. The last scenario is the most desirable scenario which can lead to more favorable changes in students’ NOS ideas. Searching for information in resolving the cognitive conflict is an indication of one’s willingness to exercise metacognitive activity in learning about NOS. Even if students recognize this conflict they may not be motivated enough to resolve it. Therefore, making students realize the importance of learning about NOS is a necessary but not sufficient first step in helping students improve their NOS ideas. This can explain the reason why students’ metacognitive awareness in the current study was not found to be correlated with their post-instruction NOS views and epistemological beliefs about science. Students’ potential metacognitive ability would not be helpful if students are not motivated enough to exercise their metacognitive ability. In fact, White (1998) drew attention to students’ willingness to exercise
metacognitive ability to control their own learning. White (1998) stated that two dimensions of metacognitive awareness (knowledge of cognition and regulation of cognition) matter as prerequisites for the development of a more important third dimension, which is willingness to exercise metacognitive ability to control one’s own thought process. In this study, students’ willingness to exercise their metacognitive ability to control their thought process during the explicit-reflective NOS instruction was not measured and it is virtually unknown. Combined with students’ motivation to learn about NOS, willingness to exercise metacognitive ability can account for the variance in students’ post-intervention NOS view and epistemological beliefs about science. As it was described in Clough’s (2006) second scenario, if students think that newly presented ideas are more or less similar to their existing NOS ideas, students may also not exercise metacognitive ability to control their NOS learning. For these reasons, a substantial amount of time should be spent to raise students’ awareness about the importance of learning about NOS, and to make the distinction crystal clear between NOS ideas advocated by the science education community and students’ NOS ideas.

Thinking dispositions were found to be positively correlated with three dimensions of post-intervention epistemological beliefs about science: (a) certainty of knowledge, (b) source of knowledge, and (c) attainability of objective truth. More sophisticated thinking dispositions indicates openness to belief change, cognitive flexibility (reflectiveness), tendency to consider alternative opinions and evidence, and searching and processing of information that goes against one’s beliefs. The findings of this study suggest that students with more sophisticated thinking dispositions would be more likely to improve their epistemological beliefs across three dimensions of epistemological beliefs about
science. In other words, these students would be more likely to think that scientific knowledge is subject to change and attainability of absolute truth in science is not possible, and they would be less likely to depend on authority in science.

Implications for Preservice Elementary Teacher Education

Students who plan to become elementary science teachers entered the introductory science course holding uninformed conceptions of NOS views. The intensive explicit-reflective NOS instruction was, at best, limited in improving students’ NOS views. Although the explicit-reflective NOS instruction was successful in improving students’ NOS views to some extent students’ overall NOS views corresponded with “naïve relativistic” position at the end of the instruction. Helping students move toward a “naïve relativistic” position can be considered as a necessary step before students adopt a more committed form of relativism in their NOS views. Helping students develop more informed NOS views consistent with the science education reform documents (AAAS, 1993; NRC, 1996) is a perennial goal of science education (Abd-El-Khalick, 2001). Therefore, reaching this goal is, at best, unrealistic within the time frame of one month intensive explicit-reflective NOS instruction. However, some structural changes can be made within the introductory science course to help students develop more informed NOS views. As it was suggested by Abd-El-Khalick (2001) the NOS framework developed during the first month of the course can provide a theoretical perspective for students to interpret their experiences in learning science process skills and science content throughout the remainder of the course. From time to time students can be asked to reflect on their learning experiences from within the perspective of NOS framework developed at the beginning of the course.
As it was mentioned earlier helping students improve their NOS views is a perennial goal of science education. Therefore, reaching this goal should not be limited within the time frame of only one introductory science course. NOS aspects can be addressed in other science courses which have to be taken by prospective elementary teachers in a similar fashion. If students have extended exposure to NOS aspects in various science courses and they are encouraged to reflect on their learning experiences in these courses from within the perspective of NOS framework, they would be in a better position to improve their NOS views. Abd-El-Khalick (2001) stated that learning about NOS within the context of elementary science methods courses can impede the translation of acquired NOS views during the instruction. If preservice elementary teachers come to science methods courses with relatively informed NOS views, two objectives could be achieved at the same time: (a) science educators can focus on NOS pedagogy rather than teaching about NOS and (b) the translation of preservice teachers NOS views into their instructional practice can be facilitated because of extended NOS exposure in various science courses. Preservice elementary teachers can be helped to improve their NOS views not only through curricular and instructional restructuring within science and science teaching methods courses but also through a genuine collaboration among all interested parties such as teachers of science and science teaching methods courses, and science education faculty.

Several researchers (e.g., Sinatra & Kardash, 2004; Tsai, 2002) drew attention to the link between teachers’ NOS views or epistemological beliefs about science and their choice of instructional practices. These researchers suggested that teachers’ epistemological beliefs about science and their teaching practices are closely aligned. It
was suggested that teachers holding more sophisticated epistemological beliefs about science were more likely to choose inquiry-oriented constructivist teaching practices than their peers with less sophisticated epistemological beliefs about science. Therefore, helping preservice teachers improve their NOS views and epistemological beliefs about science can help them to choose teaching practices that are advocated by science education reform documents (AAAS, 1993; NRC, 1996). If these researchers are correct, helping preservice teachers develop more sophisticated NOS views and epistemological beliefs about science may be an important initial step enabling them to improve their prospective students’ understanding and achievement in science.

**Plans for Future Research**

Future research in this area should consider exploring the relationships among overall epistemic views (e.g., Perry, 1970; King & Kitchener, 1998), context dependent epistemological beliefs—epistemological beliefs about science (e.g., Hofer, 1997), and NOS views. Overall epistemic views can be a limiting or facilitating factor in development of epistemological beliefs about science and NOS views. However, improvements in epistemological beliefs about science and NOS views can also influence overall epistemic views. In other words, improved epistemological beliefs about science and NOS views can facilitate one’s transition from a lower epistemological position to a higher epistemological position. These assertions warrant further inquiry.

In order to be able to better understand the role of metacognitive awareness in learning about NOS, special attention should be paid to students’ level of motivation and their willingness to exercise metacognitive ability in learning about NOS. Evidence of students’ motivation and willingness to exercise metacognitive ability in learning about
NOS should be carefully documented by analyzing the videotaped NOS lessons and students’ reflection papers about NOS readings. Metacognition is not a simple construct. Therefore, it may not be possible to assess metacognition by a simple, single self-report quantitative instrument. Future research should consider using a variety of diverse but supporting measures in assessing metacognition.

In the current study, students’ self-reported science self-efficacy beliefs, task goal orientation, and metacognitive awareness were found to be related to each other. It was mentioned earlier that science self-efficacy beliefs and task goal orientation may not be directly related to conceptual change in NOS views and epistemological beliefs about science. However, they gain importance because of their relation to metacognitive awareness. Future research is needed in order to better establish the link among science self-efficacy beliefs, task goal orientation, and metacognitive awareness and to establish the link between metacognitive awareness and the conceptual change in NOS views and epistemological beliefs about science.

Thinking dispositions were not found to be related to metacognitive awareness, science self-efficacy beliefs, and motivation except the ability-approach goal orientation. However, thinking dispositions were found to be related to students’ post-instruction epistemological beliefs about science. Therefore, future research aiming to explain the variation in students’ NOS views and epistemological beliefs about science should consider thinking dispositions as one of the possible factors mediating the development of NOS views and epistemological beliefs about science.
Limitations of the Study

In the current study, primarily survey instruments were utilized to identify relations between epistemological beliefs about science and the factors mediating the development of these epistemological beliefs. Finding a relationship between epistemological beliefs and the mediating factors was constrained by the validity and reliability of these measures. Especially, epistemological beliefs and metacognitive awareness are not simple constructs to measure. Instruments aiming to measure these multifaceted constructs need considerable development in order to capture the complexity of these constructs. Thus more qualitative work or a mixed-methods approach is needed to further explore the relationships between epistemological beliefs about science-NOS views and the factors mediating the development of epistemological beliefs about science and NOS views.
Appendices

Appendix A: Instruments

Appendix B: Data Exemplars for Description of Students’ NOS Views

Appendix C: Histograms and Skewness and Kurtosis Values for NOS Aspects and Subscales of Instruments
Appendix A1: Views of Nature of Science Version B (VNOS-B) Questionnaire

1. After scientists have developed a theory (e.g., the 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.

How confident are you in your explanation? (0 = 0% Confidence, 10= 100% Confidence)

0   1    2    3    4    5    6   7   8    9    10

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

How confident are you in your explanation? (0 = 0% Confidence, 10= 100% Confidence)

0   1    2    3    4    5    6   7   8    9    10

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

How confident are you in your explanation? (0 = 0% Confidence, 10= 100% Confidence)

0   1    2    3    4    5    6   7   8    9    10

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

How confident are you in your explanation? (0 = 0% Confidence, 10= 100% Confidence)

0   1    2    3    4    5    6   7   8    9    10
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.

How confident are you in your explanation? (0 = 0% Confidence, 10 = 100% Confidence)

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

How confident are you in your explanation? (0 = 0% Confidence, 10 = 100% Confidence)

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?

How confident are you in your explanation? (0 = 0% Confidence, 10 = 100% Confidence)
Appendix A2: Science Self-Efficacy Survey

Please circle SA (Strongly Agree), A (Agree), N (Neutral), D (Disagree), or SD (Strongly Disagree)

<p>| How confident are you that after reading an article about a science experiment, you could write a summary of its main points? | SA A N D SD |
| How confident are you that you could critique a laboratory report written by another student? | SA A N D SD |
| How confident are you that you could write an introduction to a lab report? | SA A N D SD |
| How confident are you that after reading an article about a science experiment, you could explain its main ideas to another person? | SA A N D SD |
| How confident are you that you could read the procedures for an experiment and feel sure about conducting the experiment on your own? | SA A N D SD |
| How confident are you that you could write the methods section of a lab report (i.e., describe the experimental procedures)? | SA A N D SD |
| How confident are you that after watching a television documentary dealing with some aspect of science, you could write a summary of its main points? | SA A N D SD |
| How confident are you that you will be successful in this science course? | SA A N D SD |
| How confident are you that you could write up the results to a lab report? | SA A N D SD |
| How confident are you that after watching a television documentary dealing with some aspect of science, you could explain its main ideas to another person? | SA A N D SD |
| How confident are you that you will be successful in another science course? | SA A N D SD |
| How confident are you that you could write the conclusion to a lab report? | SA A N D SD |
| How confident are you that after listening to a public lecture regarding some science topic, you could write a summary of its main points? | SA A N D SD |
| How confident are you that you could analyze a set of data (i.e., look at the relationships between variables)? | SA A N D SD |
| How confident are you that after listening to a public lecture regarding some science topic, you could explain its main ideas to another person? | SA A N D SD |
| How confident are you that you could tutor another student on how to write a lab report? | SA A N D SD |
| How confident are you that you could critique an experiment described in a science textbook (i.e., list the strengths and weaknesses)? | SA A N D SD |</p>
<table>
<thead>
<tr>
<th>Question</th>
<th>Option</th>
</tr>
</thead>
<tbody>
<tr>
<td>How confident are you that you could tutor another student for this science course?</td>
<td>SA A N D SD</td>
</tr>
<tr>
<td>How confident are you that you could ask a meaningful question that could be answered experimentally?</td>
<td>SA A N D SD</td>
</tr>
<tr>
<td>How confident are you that you could explain something that you learned in this science course to another person?</td>
<td>SA A N D SD</td>
</tr>
<tr>
<td>How confident are you that you could use a scientific approach to solve a problem at home?</td>
<td>SA A N D SD</td>
</tr>
</tbody>
</table>
Appendix A3: Motivation Survey (Achievement Goal Orientation Survey)

Please circle SA (Strongly Agree), A (Agree), N (Neutral), D (Disagree), or SD (Strongly Disagree)

<table>
<thead>
<tr>
<th>Statement</th>
<th>SA</th>
<th>A</th>
<th>N</th>
<th>D</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>I like school work that I’ll learn from, even if I make a lot of mistakes.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>An important reason why I do my school work is because I like to learn new things.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I like school work best when it really makes me think.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>An important reason why I do my work in school is because I want to get better at it.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I do my school work because I’m interested in it.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>An important reason I do my school work is because I enjoy it.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I would feel really good if I were the only one who could answer the teachers’ questions in class.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I want to do better than other students in my classes.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I would feel successful in school if I did better than most of the other students.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I’d like to show my teachers that I’m smarter than the other students in my classes.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Doing better than other students in school is important to me.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>It’s very important to me that I don’t look stupid in my classes.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>An important reason I do my school work is so that I don’t embarrass myself.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The reason I do my school work is so my teachers don’t think I know less than others.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The reason I do my work is so others won’t think I’m dumb.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>One reason I would not participate in class is to avoid looking stupid.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>One of my main goals is to avoid looking like I can’t do my work.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix A4: Epistemological Beliefs Instrument

*Please circle SA (Strongly Agree), A (Agree), N (Neutral), D (Disagree), or SD (Strongly Disagree)*

<table>
<thead>
<tr>
<th>Statement</th>
<th>SA</th>
<th>A</th>
<th>N</th>
<th>D</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Truth is unchanging in science.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In science, most work has only one right answer.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All professors in this science would probably come up with the same answers to scientific questions.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Most of what is true in science is already known.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In science, it is good to question the ideas presented. *</td>
<td>SA</td>
<td>A</td>
<td>N</td>
<td>D</td>
<td>SD</td>
</tr>
<tr>
<td>Principles in this science are unchanging.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Answers to questions in science change as experts gather more information.*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All experts in science understand the science in the same way.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Correct answers in science are more a matter of opinion than fact.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>There is really no way to determine whether someone has the right answer in science.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I am more likely to accept ideas of someone with first-hand experience than the ideas of researchers in science</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First-hand experience is the best way of knowing something in science.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sometimes you just have to accept answers from the experts in science, even if you don’t understand them.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>If you read something in a textbook for science, you can be sure it’s true.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>If my personal experience conflicts with ideas in the textbook, the book is probably right.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I am most confident that I know something when I know what the experts think.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>If scientists try hard enough, they can find the answers to almost anything.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scientists can ultimately get to truth.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Positively worded items. Negatively worded items were reverse coded during the data analysis.*
Appendix A5: Metacognitive Awareness Inventory

Please read the statement and consider how much you agree with it. Then mark the scale to the right. (0) means total disagreement, 10 means total agreement.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>I ask myself periodically if I am meeting my goals.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 10</td>
</tr>
<tr>
<td>I consider several alternatives to a problem before I answer.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 10</td>
</tr>
<tr>
<td>I try to use strategies that have worked in the past.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 10</td>
</tr>
<tr>
<td>I pace myself while learning to have enough time.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 10</td>
</tr>
<tr>
<td>I understand my intellectual strengths and weakness.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 10</td>
</tr>
<tr>
<td>I think about what I really need to learn before I begin a task.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 10</td>
</tr>
<tr>
<td>I know how well I did once I finish a task.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 10</td>
</tr>
<tr>
<td>I set specific goals before I begin a task.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 10</td>
</tr>
<tr>
<td>I slow down when I encounter important information.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 10</td>
</tr>
<tr>
<td>I know what kind of information is more important to learn.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 10</td>
</tr>
<tr>
<td>I ask myself if I have considered all options when solving a problem.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 10</td>
</tr>
<tr>
<td>I am good at organizing information.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 10</td>
</tr>
<tr>
<td>I consciously focus my attention on important information.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 10</td>
</tr>
<tr>
<td>I have a specific purpose for each strategy I use.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 10</td>
</tr>
<tr>
<td>I learn best when I know something about the topic.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 10</td>
</tr>
<tr>
<td>I know what the teacher expects me to learn.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 10</td>
</tr>
<tr>
<td>I am good at remembering information.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 10</td>
</tr>
<tr>
<td>I use different learning strategies depending on the situation.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 10</td>
</tr>
<tr>
<td>I ask myself if there was an easier way to do things after I finish.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 10</td>
</tr>
<tr>
<td>I have control over how well I learn.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 10</td>
</tr>
<tr>
<td>I periodically review to help me understand important relationship.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 10</td>
</tr>
<tr>
<td>I ask myself questions about the material before I begin.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 10</td>
</tr>
<tr>
<td>I think of several ways to solve a problem and choose the best.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 10</td>
</tr>
<tr>
<td>I summarize what I’ve learned after I finish.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 10</td>
</tr>
<tr>
<td>I ask others for help when I don’t understand something.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 10</td>
</tr>
<tr>
<td>I can motivate myself to learn when I need to.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 10</td>
</tr>
<tr>
<td>I am aware of what strategies I use when I study.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 10</td>
</tr>
<tr>
<td>I find myself analyzing the usefulness of strategies when I study.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 10</td>
</tr>
<tr>
<td>I use my intellectual strengths to compensate for my weakness.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 10</td>
</tr>
<tr>
<td>I focus on the meaning and significance of new information.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 10</td>
</tr>
<tr>
<td>I create my own examples to make information meaningful.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 10</td>
</tr>
<tr>
<td>I am a good judge of how well I understand something.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 10</td>
</tr>
<tr>
<td>I find myself using helpful learning strategies automatically.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 10</td>
</tr>
<tr>
<td>I find myself pausing regularly to check my comprehension.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 10</td>
</tr>
<tr>
<td>I know when each strategy I use will be most effective.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 10</td>
</tr>
<tr>
<td>I ask myself how well I accomplished my goals when finished.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 10</td>
</tr>
<tr>
<td>I draw pictures or diagrams to help me understand when learning.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 10</td>
</tr>
<tr>
<td>I ask myself if I have considered all options after I solve problem.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 10</td>
</tr>
<tr>
<td>Statement</td>
<td>Rating</td>
</tr>
<tr>
<td>---------------------------------------------------------------------------</td>
<td>--------</td>
</tr>
<tr>
<td>I try to translate new information into my own words.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 1 0</td>
</tr>
<tr>
<td>I change strategies when I fail.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 1 1 0</td>
</tr>
<tr>
<td>I use the organizational structure of the text to help me learn.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0</td>
</tr>
<tr>
<td>I read instructions carefully before I begin task.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0</td>
</tr>
<tr>
<td>I ask myself if what I’m reading is related to what I already know.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0</td>
</tr>
<tr>
<td>I reevaluate my assumptions when I get confused.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0</td>
</tr>
<tr>
<td>I organize my time to best accomplish my goals.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0</td>
</tr>
<tr>
<td>I learn more when I am interested in the topic.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0</td>
</tr>
<tr>
<td>I try to break studying down into smaller steps.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0</td>
</tr>
<tr>
<td>I focus on overall meaning rather than specifics.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0</td>
</tr>
<tr>
<td>I ask myself questions about how well I am doing while I am learning something new.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0</td>
</tr>
<tr>
<td>I ask myself if I learn as much as I could have once I finish a task.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0</td>
</tr>
<tr>
<td>I stop and go back over new information that is not clear.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0</td>
</tr>
<tr>
<td>I stop and reread when I get confused.</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0</td>
</tr>
</tbody>
</table>
Appendix A6: Thinking Dispositions Scale

*Please circle SA (Strongly Agree), A (Agree), N (Neutral), D (Disagree), or SD (Strongly Disagree)*

<table>
<thead>
<tr>
<th>Statement</th>
<th>SA</th>
<th>A</th>
<th>N</th>
<th>D</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Even though freedom of speech for all groups is a worthwhile goal, it is unfortunately necessary to restrict the freedom of certain political groups.*</td>
<td>SA</td>
<td>A</td>
<td>N</td>
<td>D</td>
<td>SD</td>
</tr>
<tr>
<td>What beliefs you hold have more to do with your own personal character than the experiences that may have given rise to them.*</td>
<td>SA</td>
<td>A</td>
<td>N</td>
<td>D</td>
<td>SD</td>
</tr>
<tr>
<td>I tend to classify people as either for me or against me.*</td>
<td>SA</td>
<td>A</td>
<td>N</td>
<td>D</td>
<td>SD</td>
</tr>
<tr>
<td>A person should always consider new possibilities.</td>
<td>SA</td>
<td>A</td>
<td>N</td>
<td>D</td>
<td>SD</td>
</tr>
<tr>
<td>There are two kinds of people in this world: those who are for the truth and those who are against the truth.*</td>
<td>SA</td>
<td>A</td>
<td>N</td>
<td>D</td>
<td>SD</td>
</tr>
<tr>
<td>Changing your mind is a sign of weakness.*</td>
<td>SA</td>
<td>A</td>
<td>N</td>
<td>D</td>
<td>SD</td>
</tr>
<tr>
<td>I believe we should look to our religious authorities for decisions on moral issues.*</td>
<td>SA</td>
<td>A</td>
<td>N</td>
<td>D</td>
<td>SD</td>
</tr>
<tr>
<td>I think there are many wrong ways, but only one right way, to almost anything.*</td>
<td>SA</td>
<td>A</td>
<td>N</td>
<td>D</td>
<td>SD</td>
</tr>
<tr>
<td>It makes me happy and proud when someone famous holds the same beliefs that I do.*</td>
<td>SA</td>
<td>A</td>
<td>N</td>
<td>D</td>
<td>SD</td>
</tr>
<tr>
<td>Difficulties can usually be overcome by thinking about the problem, rather than through waiting for good fortune.</td>
<td>SA</td>
<td>A</td>
<td>N</td>
<td>D</td>
<td>SD</td>
</tr>
<tr>
<td>There are a number of people I have come to hate because of the things they stand for.*</td>
<td>SA</td>
<td>A</td>
<td>N</td>
<td>D</td>
<td>SD</td>
</tr>
<tr>
<td>Abandoning a previous belief is a sign of strong character.</td>
<td>SA</td>
<td>A</td>
<td>N</td>
<td>D</td>
<td>SD</td>
</tr>
<tr>
<td>No one can talk me out of something I know is right.*</td>
<td>SA</td>
<td>A</td>
<td>N</td>
<td>D</td>
<td>SD</td>
</tr>
<tr>
<td>Basically, I know everything I need to know about the important things in life.*</td>
<td>SA</td>
<td>A</td>
<td>N</td>
<td>D</td>
<td>SD</td>
</tr>
<tr>
<td>It is important to persevere in your beliefs even when evidence is brought to bear against them.*</td>
<td>SA</td>
<td>A</td>
<td>N</td>
<td>D</td>
<td>SD</td>
</tr>
<tr>
<td>Considering too many different opinions often leads to bad decisions.*</td>
<td>SA</td>
<td>A</td>
<td>N</td>
<td>D</td>
<td>SD</td>
</tr>
<tr>
<td>There are basically two kinds of people in this world, good and bad.*</td>
<td>SA</td>
<td>A</td>
<td>N</td>
<td>D</td>
<td>SD</td>
</tr>
<tr>
<td>I consider myself broad-minded and tolerant of other people's lifestyles.</td>
<td>SA</td>
<td>A</td>
<td>N</td>
<td>D</td>
<td>SD</td>
</tr>
<tr>
<td>Certain beliefs are just too important to abandon no matter how good a case can be made against them.*</td>
<td>SA</td>
<td>A</td>
<td>N</td>
<td>D</td>
<td>SD</td>
</tr>
<tr>
<td>Most people just don't know what's good for them.*</td>
<td>SA</td>
<td>A</td>
<td>N</td>
<td>D</td>
<td>SD</td>
</tr>
<tr>
<td>It is a noble thing when someone holds the same beliefs as their parents.*</td>
<td>SA</td>
<td>A</td>
<td>N</td>
<td>D</td>
<td>SD</td>
</tr>
<tr>
<td>Coming to decisions quickly is a sign of wisdom.*</td>
<td>SA</td>
<td>A</td>
<td>N</td>
<td>D</td>
<td>SD</td>
</tr>
<tr>
<td>I believe that loyalty to one's ideals and principles is more</td>
<td>SA</td>
<td>A</td>
<td>N</td>
<td>D</td>
<td>SD</td>
</tr>
</tbody>
</table>
Of all the different philosophies which exist in the world there is probably only one which is correct.  

My beliefs would not have been very different if I had been raised by a different set of parents.  

If I think longer about a problem I will be more likely to solve it.  

I believe that the different ideas of right and wrong that people in other societies have may be valid for them.  

Even if my environment (family, neighborhood, schools) had been different, I probably would have the same religious views.  

There is nothing wrong with being undecided about many issues.  

I believe that laws and social policies should change to reflect the needs of a changing world.  

My blood boils over whenever a person stubbornly refuses to admit he's wrong.  

I believe that the "new morality" of permissiveness is no morality at all.  

One should disregard evidence that conflicts with your established beliefs.  

Someone who attacks my beliefs is not insulting me personally.  

A group which tolerates too much difference of opinion among its members cannot exist for long.  

Often, when people criticize me, they don't have their facts straight.  

Beliefs should always be revised in response to new information or evidence.  

I think that if people don't know what they believe in by the time they're 25, there's something wrong with them.  

I believe letting students hear controversial speakers can only confuse and mislead them.  

Intuition is the best guide in making decisions.  

People should always take into consideration evidence that goes against their beliefs.

*Negatively worded items. Negatively worded items were reversed coded during the data analysis.
## Appendix B: Data Exemplars for Description of Students’ NOS Views

<table>
<thead>
<tr>
<th>Score</th>
<th>Tentative NOS</th>
<th>Inferential NOS</th>
<th>Theories and Laws</th>
<th>Empirical NOS</th>
<th>Creative NOS</th>
<th>Subjective NOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Theories do not ever change. A theory is a rule that must always hold true.</td>
<td>An atom is a small scientific particle. Scientists know how about the atom due to telescopes. Scientists seem very certain about the structure of the atom although there is no guarantee due to the fact that it is a microscopic image.</td>
<td>Yes, scientific theory is that which a scientist believes is true but hasn't been proved to be a law, and scientific law is that which has been proven to be true in all circumstances.</td>
<td>Scientific knowledge is something that we know is true and has been proven. An opinion is not proven, it is just what someone thinks</td>
<td>I do not think imagination is part of the data collection because at the end of the experiment are facts that they have recorded and those facts are simply what they are and can not be changed to be something creative.</td>
<td>None of these conclusions have yet been determined by a solid evidence, therefore it could not be seen as scientifically true.</td>
</tr>
<tr>
<td>2</td>
<td>There is always a possibility for human error so scientists could alter their theories over time. Information learned from one theory could help in forming a new one. We bother to teach theories because they come from evidence and could be proven to be the absolute truth.</td>
<td>Scientist have done very extensive research on what atoms look like by using high powered microscopes and other useful instruments. Scientist may not be 100% sure if that is exactly what an atom looks like, but with extensive research they have all agreed on what its structure should look like.</td>
<td>A theory is an assumption or a conclusion that scientists come to after much observation and evidence is brought forward. A law is a theory that is polished to a point that we are almost positive the theory is true in science. In all trails this theory has gone as expected. Even though a law is a developed theory, theories do not always become laws.</td>
<td>Scientific knowledge is basically knowledge gained through facts and/or things that have been proven. Scientific opinion is basically anything someone thinks surrounding science.</td>
<td>I'm sure there are creative scientists. I just have yet to meet one. They are always so straight forward and analytical. If someone was truly creative they probably would choose a different line of work because all the laws and rules would drive them crazy.</td>
<td>Even looking at all the same data, we don't have enough data to know for sure. If we had enough data to know for sure then the answer wouldn't be argued. Because of the lack of data the scientists all came up with possible conclusions of what might be happening. Although no one knows for sure.</td>
</tr>
<tr>
<td>Score</td>
<td>Tentative NOS</td>
<td>Inferential NOS</td>
<td>Theories and Laws</td>
<td>Empirical NOS</td>
<td>Creative NOS</td>
<td>Subjective NOS</td>
</tr>
<tr>
<td>-------</td>
<td>------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>3</td>
<td>Scientific theories change but not all scientific theories change. The basic</td>
<td>They have a guess but we do not have the technology or equipment to look at</td>
<td>Theory does not eventually turn into law because law does not explain your observations. Theory comes</td>
<td>Knowledge is something that can be backed up by experiments, while opinion can be</td>
<td>Creativity and imagination do not play a part after data collection. I do believe</td>
<td>Scientists do not have the same interpretations, facts, and ideas for their</td>
</tr>
<tr>
<td></td>
<td>idea of a theory stays the same but as the world and the environment change</td>
<td>an actual atom. There have been many different types of atom structures, so</td>
<td>last because it tells how you've done things and how you've came up with your solutions.</td>
<td>what you think is happening.</td>
<td>that these factors play an important role in the designing of experiments and</td>
<td>explanations. They all have a different way of thinking, and have experienced</td>
</tr>
<tr>
<td></td>
<td>then its surroundings change as well.</td>
<td>it's hard to say what a real one looks. I do believe, however that we will</td>
<td></td>
<td></td>
<td>investigations, but after the experiment and investigations are finished a</td>
<td>experiments and gathered different data to support their ideas.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>get the technology and be able to actually look at a real atom in action.</td>
<td></td>
<td></td>
<td>scientist is forced to work with the data provided by the experiment and/or</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>investigation.</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>After scientists develop a theory, it is very possible for the theory to</td>
<td>I do not know what an atom looks like. Scientists do not know what an atom</td>
<td>There is a difference between scientific theory and law. A scientific theory explains why an occurrence</td>
<td>There is a difference between scientific knowledge and opinion. Scientific</td>
<td>Scientists use their imagination during and after the data collection. It is an</td>
<td>These conclusions can all be different even though they all have or seen the</td>
</tr>
<tr>
<td></td>
<td>change because there is so much new evidence that is found every single day</td>
<td>looks like, they only have made inferences as to how an atom might work. I am</td>
<td>takes place within the world of science. A scientific law however is a relationship in the form of a</td>
<td>knowledge has been tested out, experienced and observed. It has been through</td>
<td>on going process because there is no set way how to carry out scientific</td>
<td>same data because they all infer the world around them differently.<em>subjectivity</em></td>
</tr>
<tr>
<td></td>
<td>because scientists are constantly testing these theories to see if they can</td>
<td>not sure the exact evidence scientists use but I know that they do not have</td>
<td>formula between items or variables in the occurrence.</td>
<td>testing after testing in order to be called scientific knowledge. Opinion, on</td>
<td>experiments. They try many new ways to see if they can achieve similar results.</td>
<td>Also, these peoples backgrounds and other influences in their life could cause</td>
</tr>
<tr>
<td></td>
<td>expand the theory and come up with a brand new one.</td>
<td>direct evidence to what an atom looks like.</td>
<td></td>
<td>the other hand, is different. It is basically what a person thinks about</td>
<td></td>
<td>them to see the world around them differently.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>something.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix B: Data Exemplars for Description of Students’ NOS Views (Continued)

<table>
<thead>
<tr>
<th>Score</th>
<th>Tentative NOS</th>
<th>Inferential NOS</th>
<th>Theories and Laws</th>
<th>Empirical NOS</th>
<th>Creative NOS</th>
<th>Subjective NOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>The theory does change and evolve. Scientific theories are taught as a basis or foundation for further investigation and experimentation. A theory changing and evolving was seen in the example of the theories of atoms. The beginning diagram was able to set a foundation for research, and later other scientists used it to experiment and grow with this diagram.</td>
<td>Scientists do not know what an atom looks like. Because of it's miniscule size, they are not capable of actually viewing the atom itself, much less within an atom. Scientists however do have a diagram of what they believe an atom to look like. Evidence they use to build this diagram would be the properties and abilities an atom has. Through experimentation and research scientists were able to realize what an atom does and does not do and from that discover what an atom must look like and include to function as it does. With all the collection of that kind of data they are able to visualize what must be in it, its structure must be like.</td>
<td>Scientific theories and scientific laws are completely different things. A scientific theory uses laws, facts, and observations to explain why something is that way it is. However, a law simply states what something is/does, not why. The end goal of science is a theory, not a law. An example is that the law of gravity says that two objects will hit the ground at the same time when dropped at the same instance from a tower. It does not explain why this phenomenon is true.</td>
<td>Scientific knowledge is based on evidence and observations and opinion is just what one person thinks. Some one might say that global warming isn't happening because it's cold outside right now, that's an opinion. If someone said that global warming is occurring because of the difference in temperatures is great over the past ten winters, that's scientific knowledge because they are using evidence to back up their claim.</td>
<td>They must imagine how things work to even get to the point of experiment and investigation. They have to wonder why things are the way they are. They need to create when it comes to how they think something might work and then test it. Like when scientists were trying to figure out how DNA works. They finally figured out that it's a double helix.</td>
<td>These conclusions are possible because people look at different things in different perspectives. Two scientists can look at a certain data and come up with different explanations. Also, because different people have different prior knowledge and experience, they will inevitably draw up different conclusions. For example, in one of the articles we read, there was a picture of a stairway. Some people may see it as a stairway going up and some people may see it as a stairway going down.</td>
</tr>
</tbody>
</table>
Appendix C: Histograms and Skewness and Kurtosis Values for NOS Aspects and Subscales of Instruments

Tentative NOS Pre

- Skewness = -1.55
- Kurtosis: 1.67

Inferential NOS Pre

- Skewness = -1.69
- Kurtosis: 3.29

Theories and Laws Pre

- Skewness = 0.29
- Kurtosis = -0.56

Empirical NOS Pre

- Skewness = -0.36
- Kurtosis = -1.49
**Imaginative NOS Pre**

Skewness = -1.28  
Kurtosis = 1.99

**Subjective NOS Pre**

Skewness = -0.98  
Kurtosis = -0.19

**Tentative NOS Post**

Skewness = -2.50  
Kurtosis = 13.35

**Inferential NOS Post**

Skewness = 0.76  
Kurtosis = -0.73
Certainty-Simplicity of Knowledge Pre

Skewness = 0.07
Kurtosis = 0.35

Justification for Knowing Pre

Skewness = 0.16
Kurtosis = -0.10

Source of Knowledge Pre

Skewness = 0.17
Kurtosis = -0.05

Attainability of Truth Pre

Skewness = 0.17
Kurtosis = -0.68
Certainty-Simplicity of Knowledge Post

- Skewness = 0.03
- Kurtosis = -1.11

Justification for Knowing Post

- Skewness = 0.08
- Kurtosis = -0.10

Source of Knowledge Post

- Skewness = 0.29
- Kurtosis = 0.35

Attainability of Truth Post

- Skewness = -0.17
- Kurtosis = -0.68
Science Self-Efficacy Beliefs-Methods of Science

Skewness = 0.26
Kurtosis = -0.17

Science Self-Efficacy Beliefs-Generalization to Other Science Concepts

Skewness = 0.21
Kurtosis = -0.40

Science Self-Efficacy Beliefs-Application of Science Concepts

Skewness = 0.30
Kurtosis = 0.30

Motivation-Task Goal Orientation

Skewness = 0.36
Kurtosis = 0.72
Motivation-Ability Approach Goal Orientation
Skewness = 0.32
Kurtosis = 0.88

Motivation-Ability Avoid Goal Orientation
Skewness = 0.21
Kurtosis = -0.10

Thinking Dispositions
Skewness = 0.42
Kurtosis = 0.17

Metacognitive Awareness-Knowledge of Cognition
Skewness = -0.05
Kurtosis = -0.20
Metacognitive Awareness-Regulation of Cognition

- Mean = 101.3043
- Std. Dev. = 21.92146
- Skewness = 0.00
- Kurtosis = -0.04

Frequency

<table>
<thead>
<tr>
<th>Frequency Distribution</th>
<th>Regulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>10</td>
</tr>
<tr>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>5</td>
<td>20</td>
</tr>
<tr>
<td>0</td>
<td>25</td>
</tr>
</tbody>
</table>

Mean = 101.3043
Std. Dev. = 21.92146
N = 161
References


Hasan Deniz

Office
University of Nevada, Las Vegas
College of Education
Department of C&I Room 381
4505 Maryland Pkwy
Las Vegas, NV 89154
(702) 895-1324

Home
2300 E. Silverado Ranch Blvd. #2018
Las Vegas, NV 89183
(702)-837-5637
email: hasan.deniz@unlv.edu

Education
Ph. D. 2007 Indiana University, Bloomington, IN
Science Education
Minor: Biology
Dissertation: Exploring the Components of Conceptual
Ecology Mediating the Development of Nature of Science Views

M.S. 2002 Indiana University, Bloomington, IN
Science Education

Graduate Studies 1999-2000 Celal Bayar University, Manisa, TURKEY
Biochemistry

B. S. 1998 Dokuz Eylul University, Izmir, Turkey
Biology Education

Certification
Republic of Turkey: Secondary School Science Teaching Certificate
Endorsements: Biology, Chemistry, Grades 6-11

Professional Work Experience
2007 Assistant Professor of Science Education
University of Nevada, Las Vegas NV

2006-2007 Instructor of Q405 Integrated Science for Elementary Teachers with Science Area of Concentration
Indiana University, Bloomington IN
Responsibilities include developing the course syllabus and teaching the
course through inquiry with a special emphasis on nature of science (NOS) and pedagogical content knowledge (PCK). Equal emphasis is given to both science content and elementary science teaching methods.

2006-2007

**Coordinator of School of Education Saturday Science Program**
Indiana University, Bloomington IN
Saturday Science Program was established by Dr. Dorothy L. Gabel with a large NSF grant. It offers hands-on and inquiry-oriented three science courses for elementary students in grades K-8 every semester. Responsibilities include advertising Saturday Science Program through traditional and technological means, developing an overarching theme for three Saturday Science courses, hiring instructors, and supervising field experiences of Q405 Integrated Science for Elementary Teachers with Science Area of Concentration and E328 Elementary Science Teaching Methods students in Saturday Science Program.

2005-2006

**Coordinator of Q200 Introduction to Scientific Inquiry**
Indiana University, Bloomington IN
Q200 Introduction to Scientific Inquiry is one of the largest classes offered in Indiana University. Approximately 264 students take Q200 each semester in 11 different sections. It was designed as a remedial science course for elementary teachers. Students receive 4 hours of inquiry-oriented instruction in the lab followed with an hour lecture. Students who failed to receive C – or above are not accepted to the Teacher Education Program. Responsibilities included developing the course syllabus, teaching the lab portion of one section, teaching the lecture portion of whole course, holding weekly meetings with 6 associate instructors and a material person, preparing two exams, two lab practicals and a final exam, and reporting the final grades to the Office of the Registrar. This job was historically offered to a science education faculty. I was the first doctoral student in the School of Education history coordinated this course.

2005-2006

**Guest Instructor in M446 Secondary Science Teaching Methods Course**
Indiana University, Bloomington IN
Responsibilities included teaching a nature of science unit upon invitation by the instructor of the course (Teddie Phillipson-Mower).

2005

**Guest Instructor in Q611 Seminar in Science Education**
Responsibilities included compiling specific history and philosophy of science readings and leading the class discussion in one week upon invitation by the instructor of the course (Dr. Valarie Akerson).
2005  **Teaching Assistant in Science Education Training Program for Korean Elementary School Teachers**  
Indiana University, Bloomington IN  
Responsibilities included working with Korean elementary teachers in an inquiry-oriented science teaching program over the summer 2005.

2005  **Instructor in Saturday Science Program**  
Indiana University, Bloomington IN  
Responsibilities included teaching K-3 students an ecology unit.

2004-2005  **Associate Instructor**  
Indiana University, Bloomington IN  
Responsibilities included teaching lab portions of three sections of Q200 Introduction to Scientific Inquiry, grading exams, lab practicals and students’ semester science projects, and reporting the final grades to the coordinator of the course.

2002-2004  **Graduate Assistant**  
Indiana University, Bloomington IN  
Responsibilities included managing the laboratory of Q200 Introduction to Scientific Inquiry, setting up materials before the class and ordering new materials.

2001-2002  **Instructional Designer**  
Indiana University, Bloomington IN  
Responsibilities included conducting needs analysis, designing and developing computer-assisted instruction for A560 Microscopic Study of the Anatomy of the Human Body and A215 Basic Human Anatomy courses, conducting usability tests, and producing software.

1999-2000  **Research and Teaching Assistant**  
Celal Bayar University, Manisa, TURKEY  
Responsibilities included collecting blood samples from patients in Celal Bayar University Medical School Hospital, analyzing blood samples, recording the results in the data base, preparing materials for the lab portions of two biochemistry courses taken by first and second year medical students, and coteaching the lab portions of these courses with their designated professors.

1998-1999  **Biology Teacher**  
Korfez Private School, Izmir, TURKEY  
Responsibilities included teaching one section of 10th grade and three sections of 11th grade biology and mentoring students regarding university qualification exam.
1997-1998  **Preservice Biology Teacher**  
Karsiyaka Public High School, Izmir, TURKEY  
Responsibilities included part-time teaching and laboratory preparation in a 9th grade biology class.

1995-1998  **Field Biologist**  
Dokuz Eylul University, Izmir, TURKEY  
Responsibilities included searching, mapping and protecting sea turtle (Caretta caretta and Chelonia mydas) nests, and helping the baby sea turtles reach into the sea on the Mediterranean coast of Turkey during the summer.

**Refereed Publications**


**Presentations**


Grants Funded

2004 Undergraduate Research Experiences: A Situated Way of Learning Science in Authentic Contexts. Indiana University School of Education Gross Research Funds. $3,000

2005 Indiana University School of Education Travel Grant. $350

2005 Acceptance of Biological Evolution among Preservice Turkish Biology Teachers. Indiana University School of Education Gross Research Funds. $1,500

2006 Assessing College Students’ Epistemological Beliefs. Indiana University School of Education Gross Research Funds. $3,500
2006  Indiana University School of Education Travel Grant. $350

Service

2002  Graduate Student Member in School of Education Student Advocacy Committee  
Indiana University, Bloomington IN  
Responsibilities included reviewing written student appeals regarding a conflict between students and their instructors, and making recommendations to the Dean of School of Education with reference to each appeal.

2003-present  Conference Proposal Reviewer  

2006  Coordinator of Indiana University Second Science Education Research Symposium  
Responsibilities include disseminating the information about the symposium, calling for proposals, reviewing the proposals, preparing the symposium schedule, arranging the symposium room and technical equipment, and arranging a keynote speaker.

2006-present  Reviewer for Journal of Research in Science Teaching
2007-present  **Reviewer for Journal of Science Education and Technology**

2007-present  **Electronic Journal of Science Education Editorial Board Member**

**Honors and Awards**

2006  Outstanding Associate Instructor Award awarded by Indiana University School of Education

2000-present  Republic of Turkey National Education Ministry Scholar

2004  Received Scholarship Appreciation Certificate from National Education Ministry, Turkey. This competitive certificate is given to graduate students who have 3.90 or above GPA

2002  Received Scholarship Appreciation Certificate from National Education Ministry, Turkey

2001  Received Scholarship Appreciation Certificate from National Education Ministry, Turkey

1994-1998  Republic of Turkey Prime Ministry Scholarship

**Memberships in Professional Organizations**

2000-present  The Honor Society of Phi Lambda Theta
2000-present  Hoosier Association of Science Teachers Inc. (HASTI)
2004-present  National Science Teachers Association (NSTA)
2004-present  National Association of Research in Science Teaching (NARST)