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Examining the Affordances of Dual Cognitive Processing to Explain the Development of High School Students' Nature of Science Views

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EXAMINING THE AFFORDANCES OF DUAL COGNITIVE PROCESSING TO EXPLAIN THE DEVELOPMENT OF HIGH SCHOOL STUDENTS' NATURE OF SCIENCE VIEWS

by

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ABSTRACT

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This mixed method study was aimed at examining the influence of dual processing (Type 1 and Type 2 thinking) on the development of high school students' nature of science (NOS) views. Type 1 thinking is intuitive, experiential, and heuristic. Type 2 thinking is rational, analytical, and explicit. Three research questions were asked: (1) Do the experiential process (Type 1) and the logical process (Type 2) influence the development of students' NOS views? (2) If there is an influence on students' NOS views, then what is the nature of relationship between the experiential process (Type 1) and the development of NOS views? (3) What is the nature of relationship between the logical process (Type 2) and the development of NOS views?

The Views of Nature of Science Questionnaire C (VNOS-C; Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002) was administered to 29 high school students at the beginning and at the end of an explicit-reflective NOS intervention offered in an Advanced Placement environmental science course. Changes in students' NOS views were calculated through a chi-square test and examining the percentage of students holding NOS views at various levels of sophistication. With the chi-square goodness of fit test performed, the relationship between pre and post NOS scores was

not significant, $X^2(3, 29) = 4.78$, $p < .05$. The informed and preinformed NOS views increased (14%, 17%) in frequency while the mixed and uninformed NOS views decreased (i.e. improved 26%, 24%) in frequency from pre to posttest. The reading discussions were coded based on the EBR framework (Furtak et al., 2010) to analyze the use of dual processing. Type1 and Type 2 thinking were both used during the intervention and reading reflections. Type 2 thinking was more prominent when analyzing a problem, formulating a hypothesis, or stating logical claims. The association of NOS education and Type 1 and Type 2 thinking in scientific literacy was examined, and implications and future research are discussed.

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CHAPTER 1

INTRODUCTION

In conceptual frameworks for teacher education, specifically in science, appropriate views of nature of science (NOS) are required in order to educate learners. An appropriate understanding of NOS includes the recognition of the purpose of science as seeking for explanations in the natural world (Dogan, Cakiroglu, Bilican, & Cavus, 2013). Science education seeks to nurture an individual's potential in problem solving, analytical processing, and informed decision-making (Koksal & Cakiroglu, 2010).

Current science education reform efforts emphasize scientific literacy as the main goal of science education. The *Benchmarks for Science Literacy* stated by the American Association for the Advancement of Science (AAAS; 1993, 2009) and the *National Science Education Standards* by the National Research Council (NRC; 1996) aim to provide a vision for curriculum, instruction, and assessment in K-12 science education. A scientifically literate person is someone who is familiar with the natural world, understands some key concepts of science, is able to think in a scientific way, and is able to use scientific knowledge for personal and social issues (AAAS, 1993). The most current science reform goals, the Next Generation Science Standards (NGSS Lead States, 2013), focuses on scientifically literate students who will be able to understand the key components of science, and be able to link it to mathematics and technology in the 21st century.

The Next Generation Science Standards (NGSS Lead States, 2013) describe educating students in proper NOS concepts to improve their scientific literacy, and in turn, enhance their perceptions about the natural world around them. In Appendix H of the NGSS framework (NGSS Lead States, 2013), some of the basic understandings about the nature of science stated are: (a)

science is a way of knowing (b) scientific knowledge is based on empirical evidence (c) scientific models, laws, mechanisms, and theories explain natural phenomena, and (d) science is a human endeavor. The approach to teaching is to apply these NOS concepts to practices in the classroom, as reinforced by researchers in the NOS education field (e.g., Southerland, Johnson, & Sowell, 2006).

Nature of Science in the Classroom

To help students construct appropriate views of NOS, teachers need to have informed pedagogical methods and an overall understanding of NOS. However, research has indicated that teachers do not have adequate understandings of NOS (Akerson & Abd-El-Khalick, 2003; Abd-El-Khalick 2005; Irez, 2009; Lederman, 2007). For example, a significant proportion of teachers believed that scientific knowledge is not tentative (Abd-El-Khalick & Lederman, 2000). Some of the variables shown to constrain teachers' NOS views and classroom applications are discomfort with understanding NOS and the lack of resources and experiences for assessing understanding of NOS (Abd-El-Khalick & Lederman, 2000). Since teachers cannot possibly teach what they do not understand, is therefore imperative that science educators improve their understandings of NOS.

Central elements of NOS include: (a) tentative nature of science knowledge, (b) the role of observation, (c) evidence derived through experimentation (empirical evidence), and (d) rational arguments in creating scientific knowledge (Duit, Niedderer, & Schecker, 2007). The tentativeness of NOS includes the realization that scientific knowledge may change in the future, but there is confidence in scientific knowledge that has been previously tested and repeatedly challenged. Empirical evidence explains the reliance upon observational or experimental data, and that all scientific concepts and reasoning are derived from empirical qualitative and quantitative

data. The role of observation relies on using the five senses to create logical inferences involving entities that are not directly observable. Objectivity and subjectivity (being able to create rational arguments) ties in intuition, personal beliefs, and societal values to assess, criticize, and elaborate on key elements involved in science. This also includes peer review in order to improve objectivity.

Other key concepts developing scientific literacy include (a) the myth of the universal scientific method, (b) scientific laws versus theories, and (c) creativity (Bell, 2009). Scientific methods state that scientists employ a wide variety of approaches to generate scientific knowledge; there is no one magical method that must be utilized to come to a conclusion. A scientific theory is a well-supported explanation for a natural phenomenon. A scientific law is a concise description of relationships or patterns in nature (Bell, 2009). There are common false misconceptions that laws turn into theories with repeated testing and hypotheses being proven (McComas, 1998). The final main component of NOS aspects deemed important to educating a scientifically literate person is creativity. Some of the common myths involved with creativity is that science is more procedural than creative, science and its methods can answer all questions, and scientists are particularly objective (McComas, 1998).

Scientists use creativity and imagination during scientific inquiry. It is not all procedural, objective, and rote methodology. "Only the creativity of the individual scientist permits the discovery of laws and invention of theories" (McComas, 1998, p.18). Using creativity that seems plausible to test is one of the main elements that scientists utilize when problem-solving.

Driver, Leach, Millar, & Scott (1996) help define the five arguments of why understanding NOS is important:

- Utilitarian- To make sense of science and processes in everyday life.
- Democratic-For informed decision-making on socio-scientific issues.
- Cultural- To appreciate the value of science as part of contemporary culture.
- Moral- To develop an understanding of the norms of the scientific community that embody moral commitments that are of value to society.
- Science learning- To facilitate the learning of science subject matter.

These five arguments illustrate the value of NOS aspects to develop a more inherent scientifically literate citizen, and the benefits to a society as a whole. There are three linked domains of science that are critical to scientific literacy: (a) a body of knowledge, (b) a way of knowing, and (c) a set of methods/processes (Bell, 2009). A body of knowledge includes facts, theories, concepts, definitions, etc. A set of methods/processes involves observing, inferring, predicting, experimenting, concluding, etc. The second domain (a way of knowing) incorporates the epistemology of science. Examples of this are how creativity plays an important role in science, scientific knowledge is based upon evidence, and background knowledge influences how scientists view data.

The term NOS typically refers to science as a way of knowing or as epistemology of science (Lederman, 1992). Several researchers have supported NOS content in the learning of science content (Driver et al., 1996; McComas, 1998). Students' understanding of NOS might contribute to more appropriate views of science content (Songer & Linn, 1991). In order to construct better pedagogical implementation of NOS in classrooms and teacher education, the methods that are most effective to teach NOS need to be reviewed.

Lederman (2007) asks the question, "If we become generally more successful at teaching NOS to our students, will they become better decision-makers?" (p. 832). Too often, science is taught as a subject with little connection to the real world (Bell, 2009). If science is taught explicitly through facts, definitions, and vocabulary, the other connections to scientific literacy may be neglected. In order to effectively produce a well-rounded learner in science, proper steps need to be made to ensure that educators at all levels understand how to effectively teach NOS concepts. This can be achieved through implicit and explicit-reflective approaches to change naïve conceptions of NOS (Dogan et al., 2013). Implicit approaches incorporate the essence of inquiry-based activities in order to allow the learner to form conclusions based on what they participated in or witnessed. The explicit-reflective design intentionally influences student engagement to NOS by placing it as the major component of the lesson. This also incorporates a post-activity discussion to help summarize the ideas presented in the lesson. "Simply put, an explicit-reflective approach emphasizes student awareness of certain NOS aspects in relation to their learning activities, and student reflection on these activities from within a framework comprising these NOS aspects" (Abd-El-Khalick & Akerson, 2004, p.792).

Applying Science to Real Life

The context of realistic application of NOS education dates back to Dewey's writings in both philosophy and education (Rudolph, 2000). Students may develop an accurate understanding of what science essentially is, and develop an awareness of the impacts in society with NOS instruction (Bell, 2009). Dewey (1938) thought that education should be viable if it can be applied to real world situations. Recalling information or events from instruction on tests is important, but using that acquired information in other settings holds importance as well. Shtulman and Calabi (2013) investigated the effect of naïve theories of evolution in undergraduate students. The

assumption of knowing about an organism, its predictable properties, and associations enables ability to make fairly accurate predictions about how the organism should look, where it lives, and how it behaves. Yet, this may lead uninformed observers astray. “Despite its utility for reasoning about the properties of individual organisms, essentialism can act as a major impediment for reasoning about population-level phenomena, such as evolution and natural selection” (Shtulman & Calabi, p.144). The appropriate levels of knowledge required to determine these connections may appear simple, but further questioning may show that the student can describe the adaptations of an animal, but are not able to explain the process in which it adapted that way. Simply knowing that a polar bear has white, thick fur does not help the comprehension on how these characteristics came to be based on natural selection principles. Investigating the role of how natural selection selects the traits best suited to their environment using empirical information directs the learner to make more valid inferences and defend their reasoning with scientifically literate choices.

Students could enrich the way students view their world with science, but have a tough time relating the content in school with their day-to-day experiences out of school (Heddy & Sinatra, 2013). “We know how science is being done, that we finally discovered ‘the language of science’ and thus know the ‘method of science’ (Elkana, 2000, p.470). This included more open-ended inquiry approaches to teaching science, and promoting more empirical reasoning to problems with applications to real life scenarios. Scientific theories may be challenging to students; this is only exacerbated without any direct connection from the content material to their individual lives (Adams & Philips, 1991).

It has been argued that for one to make informed personal and societal judgments as a citizen, one must understand how science 0works and how those processes shape the nature of scientific knowledge (Southerland et al., 2006). While there may be no direct use for vocabulary

terms taught within a certain discipline unless you work in that field, using the key terms may be needed at a time when the student is contemplating a problem faced in their own lives. For example, knowing what friction is and how it affects the force and speed of an object, may assist the problem-solving contemplation of moving a heavy object. Without having the tools involved with practical application of this knowledge, the student may not be able to see or how to use the acquired information accordingly. Integration of new knowledge into learners' preexisting mental models is actively constructed through personal and social processes, a major component of constructivism and learning (Luera & Otto, 2005).

Type 1 and Type 2 Thinking

In order to develop a practical reasoning for investigating modes of processing information and how NOS education applies to these theories, the differences of rational thinking versus experiential processes must be examined. How does rational thinking compare to the cognitive processes involved with intuitive types of processing? Psychologists have proposed that rational and intuitive thinking are two fundamentally different modes of processing, This dissertation refers to these two modes as Type 1 (experiential) and Type 2 (rational) thinking (Stanovich & West, 2000). Compared to the Type 1 and Type 2, the alternate terms System 1 and System 2 are unsatisfactory because neuroscience research has not suppored the existence of whole system processing.(Evans, 2010). Therefore, the nomenclature of Type 1 and Type 2 thinking or processing will be used in this dissertation.

The various names for Type 1 (also called System 1) thinking include intuitive, natural, automatic, heuristic, schematic, prototypical, narrative, implicit, imagistic-nonverbal, experiential, mythos, and first-signal system (Epstein, Pacini, Harriet, & Denes-Raj, 1996). These generic modes of cognitive functions apply to "an intuitive mode in which judgments and

decisions are made automatically" (Kahneman, 2003, p. 697). Kahneman's (2003) research starting in the 1970s was guided by the principle that intuitive judgments occupy a position, possibly relating back to evolutionary history, between the automatic operations of observations and operations of reasoning.

The Type 1 cognitive system is fast, effortless, perception-based, and heuristic. A heuristic is an experience-based intuitive judgment, also referred to as a "rule of thumb" or "common sense." Heuristic processing represents the natural mode of the experiential system (Type 1; Epstein et al., 1996). In essence, heuristics are a "tool box theory" based on convenient cognitive shortcuts (Tversky & Kahneman, 1983). "System 1 generates impressions of the attributes of objects of perception and thought. These impressions are neither voluntary nor verbally explicit" (Kahneman, 2003, p.699). Type 1 involving intuitive judgments can be evoked by language. These Type 1 judgments are always intentional and explicit; they are not changed by Type 2 processing.The various names for Type 2 (also called System 2) thinking include thinking-conceptual-logical, analytical-rational, deliberative-effortful-intentional-systematic, explicit, extensional, verbal, logos, and second-signal system (Epstein et al., 1996). Unlike the processing found in Type 1, Type 2 is not restricted to the current stimulus. The processing is slow, effortful, flexible, and often rule-governed. One of the functions of Type 2 thinking is to monitor the quality of mental operations and overt behavior (Kahneman, 2003):

> In the model that is presented here, the perceptual system and the intuitive operations of System 1 generate *impressions* of the attributes of objects of perception and thought. These impressions are neither voluntary nor verbally explicit. In contrasts, judgments are always intentional and explicit even when they are not overtly expressed. Thus, System 2 is involved in all judgments, whether they originate in impressions or in deliberate reasoning. The label *intuitive* is applied to judgments that directly reflect impressions—they are not modified by System 2. (p. 699)

To clarify Kahneman's statement, intuitive judgments (Type 1) are monitored by Type 2 processing at some point; something labeled purely intuitive has not been processed by Type 2 thinking. Type 2 processing describes deliberative calculation, rule-based processing and the use of attentional resources (Lapsley & Hill, 2008). It attempts to decontextualize problems with abstract rules, algorithms, and principles of causal structure. Type 2 is highly related to working memory. Working memory capacity is measured by the number of items that can be kept in short-term storage while performing a competing cognitive task (Evan, 2010). Since Type 1 thinking is quick and judgment based, working memory is only required in short duration to find an acceptable solution. Working memory under Type 2 processing is slower, and requires more cognitive resources to assess the most plausible solution to a problem. The most logical explanations or solutions to problems, even if they are incorrect, are performed using Type 2 thinking as the mediator between the dual-processing modals.

Connecting Nature of Science and Type 1-Type 2 Thinking

According to the dual processing theory, the rational and experiential modes represent two fundamental ways in which people use information and adapt to their environment (Epstein et al., 1996). One of the NOS tenets that students should be able to distinguish between is observation and inference. Observations are descriptive statements about natural phenomena about which observers can reach consensus with relative ease (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). Using Type 1 thinking, observations to a problem can be concluded rather quickly. Inferences are statements about phenomena that are not directly accessible to the senses, and therefore, require some prior knowledge to make a valid argument. If the observer possesses naïve knowledge of a particular phenomenon, then their intuitive inference may seem acceptable and not checked with Type 2 thinking. The observer that has more informed information about a topic may

not be content with their intuitive inference. Type 2 thinking may help problem solve the cognitive conflict aroused, and help lead to a more logical inference.

Another NOS tenet includes the ability to differentiate between scientific laws and theories. If asked the question, “Does a scientific law have a higher status than a scientific theory?” prior knowledge about the characteristics of both areas is required in order to explain the differences between them. A person with limited knowledge about scientific laws may say that theories eventually become laws with enough proof to declare it a law. This is an inappropriate view of what laws and theories are in science; they are different kinds of knowledge and one does not become the other. Type 1 and Type 2 thinking may address this lack of knowledge by assuming that laws are definite and thus theories develop into laws. Type 2 thinking addresses the issue of thinking about laws and theories learned in science classes. If the teacher or student is unable to adequately define what is a law or theory, Type 2 thinking may still be present in the processing of how to explain it without being satisfied with the fast-processing conclusion involved with Type 1 thinking.

If a person is more adept to relying on Type 1 thinking (i.e. forming conclusions quickly without thorough examination), this might influence the level in which NOS knowledge is processed. A person learning about a particular aspect of NOS may rely on what is comfortable and convenient to them. There may be no change in how they view nature of science because it doesn’t fit into their schema. Contrary to this, Type 2 thinking will contemplate the problem before settling on a formal answer or disposition. This may influence their levels of NOS knowledge and ability to learn these aspects effectively. Individuals possess both forms of thinking, but the proportion of how they use each mode may influence their thought processes and

decision-making. The connection between the two types of thinking may also be correlated to how existing NOS levels are modified or improved through a nature of science intervention course.

Type 1 reasoning is cognitively more efficient, quicker, and uses personal experience to address an issue. Type 2 is slower, but uses more of the analytical skills needed to fully ascertain the best possible outcome to a problem. People that use Type 2 processing more often should be able to form opinions and conclusions based on the evidence provided to them. Type 1 thinking may come to a reasonable conclusion, but the logical thinking behind their construct may not be as explicit as Type 2 thinking. Thus, people that exhibit Type 2 processing more often than Type 1 in critical thinking scenarios should be able to improve their NOS views more effectively.

Theoretical Framework

Students that are introduced to new information holds that a cognitive conflict leads them to construct a new way of thinking (Piaget, 1950). If the information provides a more appropriate delineation for change, then that information is accommodated into their cognitive construct. This change replaces any information not deemed valid within the mind of the learner. If the information provides little effectiveness, then it is simply assimilated into their cognitive schema; this assimilation may apply no real practical application, and thus, the creative process of science education has been ceased. Students introduced to a new concept, such as the impact of deforestation on climate change, may not connect the information appropriately unless educators can exchange examples from their own communities. The awareness ineffectually links the infor0mation, preventing the connection from one issue to another.

"The only way to replace a misconception is by constructing a new concept that more appropriately explains our experiences" (Bodner, 1986, p.10). The constructivist model of teaching and learning helps explain why students bring misconceptions to science and math

classes, and why these misconceptions are so resistant to instruction (Bodner, 1986). Additionally, Bodner asks why misconceptions are so resistant to instruction. He explains that once we have constructed knowledge, it “fits” our experiences. Simply being told that people are wrong is not enough to change the misconception, support an opinion, or devise a more developed belief in a topic.

The conceptual change model (CCM) is based on a learner’s rational assessment of competing knowledge claims (Posner, Strike, Hewson, & Gertzog, 1982). “The CCM models the process of conceptual change for individual learners after patterns of paradigmatic changes in science” (Southerland, Johnson, & Sowell, 2006, p. 875). Through the process of rational comparison, learners may change their prior conception if the new conception is more intelligent and plausible. Conceptual change is a gradual, time-consuming process that involves the addition or deletion of beliefs during the process of reorganizing the theories in which the beliefs are embedded (Broughton, 2008). Those concepts that are deeply embedded are most likely to be resistant to change (Chinn & Brewer, 1993).

The conceptual ecology construct (Southerland et al., 2006) was used to describe a collection of beliefs that a learner might possess. It was adopted in the CCM model, for prior conceptions need to be challenged in order for any change to occur. In a conceptual change model, a conceptual ecology is considered to be the modified environment in which change occurs. This environment is thought to include cognitive aspects, dispositional, and some social and cultural influences. Some researchers prefer the term *learning ecology* compared to *conceptual ecology* because the latter is largely restricted to the cognitive domain (e.g. Abd-El-Khalick & Akerson, 2004). Learning ecology includes elements from other areas, such as motivational, contextual, social, and cultural domains (Abd-El-Khalick & Akerson, 2004). Regardless of which term is

used, the CCM model is applied to the importance of shaping the NOS learning in teacher education.

A set of concepts are replaced with another if the learner has a higher status in how plausible and fruitful the new concept relates to their existing construct (Abd-El-Khalick & Akerson, 2004). Since students change their conceptions based on conflicting evidence, it is imperative that teachers know how to introduce pedagogical techniques to replace naïve assumptions in the students. Simply telling students that the sky is blue because of the visible wavelength seen during the day is on the longer end of the spectrum may not make any sense to some learners. The students may still continue to believe that the sky is blue because it's a reflection from the ocean, since that is what they have always thought. Promoting a challenge to this naïve information about the visible light spectrum and colors may help influence positive cognitive restructuring.

If teachers have a weak knowledge of NOS concepts, then they may not be able to affect the conceptual change of the students. Nature of science pedagogy should be explicit, reflective, and activity-based (Abd-El-Khalick & Lederman, 2000). Therefore, actively incorporating explicit-reflective activities will allow for conceptual change to be observed with teachers and students.

Hewson, Beeth, and Thorley (1998) put fourth four general guidelines for conceptual change. First, students and teachers' ideas about the target topic should be made an explicit part of the classroom discourse. Specifically, students should have structured opportunities to explain the nature of their ideas, express the strong points and weaknesses, and evaluate the consistency of the ideas being presented to the class. Second, learners should think about their cognitive processes and how they developed their rationale for a discourse topic. Third, the relevance, fruitfulness, and

plausibility need to be discussed and negotiated. Fourth, the justification for ideas should be made explicit. All of these components are an important part of conceptual change in classroom discussions (Hewson et al., 1998).

Combining these four points for conceptual change with an intervention strategy that used activity-based, explicit-reflective approaches about NOS, Abd-El-Khalick and Akerson (2004) examined preservice elementary teachers' conceptual change, noting that the NOS instructional outcomes were cognitive rather than affective. The significance of this application of the NOS conceptual change would not be observed in how teachers applied it to their own pedagogical practices. Students who sought to clarify the meanings of key NOS terms and concepts developed more informed views. The participants who did little to compare and contrast NOS terms showed little change of their NOS views. This implies that it takes instructional motivation and scaffolding by the instructor to appropriately develop conceptual change in NOS views with an explicit-reflective approach.

Study Purpose

The literature presented on NOS education is well supported in promoting a scientifically literate student. With the dual processing theory provided as a framework during NOS instruction, the following research questions will be examined:

(a) Do the experiential processing (Type 1) and the logical processing (Type 2) influence the development of students' NOS views?

(b) If there is an influence on students' NOS views, then what is the nature of relationship between experiential (Type 1) and the development of NOS views?

(c) What is the nature of relationship between logical (Type 2) and the development of NOS views?

Significance of the Study

The influence of Type 1 and Type 2 thinking on NOS education has potential to shed light on the cognitive processing involved with learning about NOS. With the combination of content material and how to apply logic involved in science, problem-solving abilities may improve. In addition, the ability to make the most informed decision could translate to all situations in life.

Teachers and students who do not possess adequate views of NOS will struggle to become scientifically literate citizens. If teachers do not have an effective understanding of NOS aspects, they will not know how to develop effective lesson planning. This will cause problems in nurturing NOS content matter in science courses. Furthermore, teachers who do know their own limitations of NOS knowledge will not seek professional development in this area. With the appropriate information and pedagogical techniques associated with NOS instruction, teacher education in science may improve.

CHAPTER 2

LITERATURE REVIEW

The present study is orientated towards showing the relationship between the development of high school students' NOS views and the dual processing theory. The dual processing research displays the role of Type 1 and Type 2 thinking in learning and cognition. In order to show how NOS teaching practices and education may be influenced by the dual processing theory, the studies have been organized into the following categories: (a) research on students' conceptions, (b) research on teachers' conceptions, (c) factors that influence the development of teachers' and students' NOS views, (d) implicit and explicit-reflective practices, (e) dual processing modes of thinking, (f) dual processing and decision-making, (g) cognitive-experiential self-theory, (h) dual processing and NOS, and (i) assessing Type 1 thinking and Type 2 thinking.

Nature of Science (NOS) Conceptions and Development

Research on Students' Conceptions of NOS

There has been extensive research on students' conceptions of NOS over the last 60 years. Students do not typically acquire a well-developed understanding of NOS and that development can be difficult to achieve (Lederman, 1992; Lederman & O'Malley, 1996; Tamir & Zohar, 1991). Lederman (2007) discussed several studies that demonstrated an inept view of the aspects of NOS in students of all levels, grades, and nations over the last five decades. Among the most common misconceptions of students included the idea that scientific theories will eventually become scientific laws with further evidence. Zeidler, Walker, Ackett, and Simmons (2002) investigated students' conceptions of NOS in secondary and undergraduate levels. It was evident that a significant number of students in the study did not understand scientific knowledge to be tentative and partially subjective, and involve creativity. Koenig, Schen, and Bao (2012) found that with an

explicit NOS intervention, students' Likert NOS survey scores improved with an overall gain of 5.9% in total score from the pre/posttest. This suggests that with proper intervention strategies, students can improve their NOS views.

Not only did students possess inadequate views of NOS in many different areas, but also language and culture affected their views (Sutherland & Dennick, 2002). There appears to be a lack of research in how language and culture impact the development of NOS knowledge, but their findings suggested there is some correlation between NOS views and where (i.e., classrooms, field experience, labs) students are learning about science. "The overwhelming conclusion that students did not possess adequate conceptions of the nature of science or scientific reasoning is considered particularly significant when one realizes that a wide variety of assessment instruments were used in the research" (Lederman, 2007, p.838).

If students are developing inadequate views of NOS, then the evidence should point directly to the teachers who are not effectively demonstrating these elements in schools. If a teacher has well-substantiated views of NOS, but their students are not properly learning these principles, then it is likely a pedagogical problem that needs to be addressed, perhaps using the explicit-reflective pedagogy. If it's not an issue of proper implementation and practice, then it may be the teachers themselves that cannot teach NOS to their students due to inadequate views. If a teacher does not have the content knowledge associated with NOS instruction, then it should not be a surprise that students are not learning the key aspects involved with nature of science.

Research on Teachers' Conceptions of NOS

Starting back in the 1950s, Anderson (1950) surveyed over one hundred high school science teachers. The teachers were asked eight questions about the scientific method, and the results showed that the teachers possessed serious misconceptions. The findings suggested

teachers lacked the insight and training in the use of the scientific method of solving problems, in addition to, possessing the lack of procedures for proper instruction to scientific attitudes. Miller (1963) sampled students and teachers conceptions to see if there was any disparity. Surprisingly, a significant percentage (i.e., ranging from 11% to 68%) of high school students scored higher on the understanding of science assessment than 25% of the science teachers. Miller concluded that many teachers did not understand science as well as their students, much less understand science well enough to teach it properly (Lederman, 2007). Carey and Strauss (1970) used a scientific inventory system, the Wisconsin Inventory of Science Process (WISP), to assess experienced teachers' conceptions of NOS. The results showed three findings: (a) in general, science teachers did not possess adequate conceptions of NOS; (b) teachers who have a broad background in science indicate little different in NOS understanding compared with non-science majors or high school students, and (c) academic variables such as years of teaching experience are not significantly related to a teachers' conceptions of science.

Recent approaches on teachers' conceptions have been oriented towards explaining the impact of NOS interventions on improving teachers' NOS knowledge. The two approaches include the implicit and explicit methods (Abd-El-Khalick & Lederman, 2000). The implicit approach suggests that an understanding of NOS is a learning outcome that is facilitated through process skill instruction, science course work, and practicing science methods (i.e. doing science) (Bell, Blair, Crawford, & Lederman, 2003). Scientific inquiry activities and skill instruction lead the movement behind improving teachers' NOS views. Through manipulation of certain aspects in a learning environment, the teacher could learn the fundamentals involved with scientific processing and improve their NOS knowledge. The explicit approach utilizes elements of philosophy of science (i.e., empirical, tentative, or bounded aspects) in order to improve teachers'

understanding of NOS. Through the development of science methods courses or education courses that taught about the history of science education, the explicit approach aims on to provide the necessary component for teachers to nurture NOS aspects during instruction.

Abd-El-Khalick, & Lederman (2000) noted that not every science-based inquiry activity is implicit, nor is every instructional sequence in history of science explicit. A lesson on the history of science could be implicit if there was no discussion of the various NOS aspects involved. An inquiry-based activity could be labeled explicit if a reflection on the process followed after the lesson. Both approaches can be employed to develop the NOS abilities in teachers during an intervention.

The implications of this research show that explicit-reflective opportunities should be provided for teachers who are in need of improving their NOS views. Teacher candidates have been found to be severely lacking in NOS areas as well (Palmquist & Finley, 1997; Akerson & Abd-El-Khalick, 2003; Abd-El-Khalick 2005; Irez, 2009; Lederman, 2007). “NOS should be made a pervasive theme throughout science teacher education” (Abd-El-Khalick & Lederman, 2000, p.695). Prospective teachers should be asked to design lessons that aim to promote understanding of NOS aspects. The goal is to have pre-service teachers think about the various areas associated with teaching about NOS, and plan activities that foster the development of science abilities in their students.

Teachers with an inadequate level of NOS comprehension may overestimate their ability to teach these concepts to students. This may prove problematic if experienced science teachers believe they possess appropriate NOS views, and teacher candidates that expect to enter the classroom prepared to teach these concepts accordingly (Kruger & Dunning, 1999). Teacher self-efficacy has shown to be correlated to teaching behavior (Morrell & Carroll, 2003), so the

question of confidence in teachers' NOS ability may be higher than is actually demonstrated. Kruger and Dunning (1999) explained that difficulties in recognizing one's own incompetence lead to inflated self-assessments. Incompetent individuals lack what cognitive psychologists term metacognition or self-monitoring, so the unaccomplished individuals do not possess the degree of metacognitive skills necessary to portray an accurate self-assessment. Kruger and Dunning (1999) present the idea that those with a high level of ability, or experts, tend to underestimate their abilities, while those with poor or low abilities in an area tend to overestimate their level of comprehension.

Factors that Influence the Development of Teachers and Students' NOS Views

In Abd-El-Khalick and Akerson (2004), the authors aimed to explore the factors mediating the development of NOS views. The participants in the study were 28 pre-service elementary teachers enrolled in an elementary science methods course. The researchers reported less than 30% of the participants had informed views across the main aspects of NOS examined. During the study, the researchers examined the differences between the focus group participants' NOS views. They noticed that the deep learners who sought to clarify the meanings of NOS terms, and who monitored their changes in their NOS ideas, developed more informed views. The participants that focused on the key aspects improved, while in contrast, the focus group participants who showed limited attempts to compare and contrast the target NOS aspect showed little change. Ultimately, this showed that the explicit-reflective approach succeeded in improving NOS views, but only in the participants that utilized the reflective aspect of this methodology.

Dispositions are viewed as having open-minded thinking aid in the development of NOS views (Southerland et al., 2006). Other factors that influence the development of NOS views include: (a) science self-efficacy beliefs, (b) motivational factors, (c) metacognitive awareness,

and (d) prior conceptions. Having confidence in one's own ability to understand science is related to students' abilities to accurately pursue improvement in their overall knowledge of how science works. Motivation is correlated to developing NOS views because if there is a lack of motivation, the engagement process of explicit-reflective activities is highly reduced. It is the requirement of the teacher and the student to satisfy motivational factors to stimulate engagement during NOS activities.

Metacognitive awareness relies on the ability to understand one's own learning. The ability to monitor or self-regulate the conception acquisition is vital to NOS development. Without the metacognitive checkpoints, students with less metacognitive awareness are less likely to reflect on their NOS learning compared to students with more metacognitive awareness. Prior conceptions highly influence the development of NOS views because if an alternative idea persists in the minds of teachers or students after direct NOS instruction, then the concept is highly unlikely to be improved. Cognitive conflict strategies can be used to challenge students' naïve NOS conceptions during the explicit-reflective NOS instruction.

Implicit and Explicit Reflective Practices

The authentic research experience does not directly target specific aspects of NOS, so the implicit method of NOS teaching is limited in improving NOS overall knowledge. Bell, Blair, Crawford, and Lederman (2003) examined students who participated in different laboratory internships in an effort to observe whether the implicit approach and hands-on training in real life scientific environments influenced NOS conceptions. The researchers found the students' level of experience in doing science did improve, but there was little change in their understanding of NOS. In other studies, researchers asserted that students had improved their conceptions of NOS through visceral research experience, but no formal assessment of NOS conceptions had been

conducted (Barab & Hay, 2001; Richmond & Kurth, 1999). The essence of the explicit-reflective approach is that it targets specific aspects of NOS education and allows learners to evaluate what they have experienced through exposure to the elements of NOS. Some researchers have observed substantial changes in elementary teachers' NOS views when an explicit-reflective approach to NOS instruction had been used (Abd-El-Khalick, Akerson, & Lederman, 2000). Abd-El-Khalick and Akerson (2004) suggested that structured reflections and modeling through classroom dialogue helped preservice teachers reconcile their meaning of NOS. Tsai (2006) studied pre-service teachers' NOS levels during a science instruction course and found that the NOS aspect level greatly improved during the NOS intervention for most of the participants. Khishfe and Abd-El-Khalick (2002) reported that explicit and reflective inquiry-orientated NOS instruction is more effective than an implicit inquiry-orientated method.

Southerland et al. (2006) defended the complex ties between NOS conceptions and goals, dispositions, and beliefs. The researchers stated that the central aspects of the NOS framework provided teachers with a more mindful awareness of their own knowledge of the critical components of NOS instruction. With metacognitive elucidation of how to incorporate NOS into the standard curriculum and activities, teachers were able to understand how to facilitate and embed these aspects accordingly into their curriculum. However, studies have shown that students and teachers lack adequate NOS conceptions (Akerson & Abd-El-Khalick, 2003; Lederman, 1999).

Because a teacher's ability to teach NOS is vital to student understanding of the fundamentals, special support or training should be provided to teachers so that they can improve their understanding about NOS and their pedagogical knowledge about teaching NOS. When teachers received explicit-reflective NOS instruction through inquiry-based workshops, they were

able to improve their NOS views (Akerson & Abd-El-Khalick, 2003; Akerson & Hanuscin, 2007). Koenig, Schen, and Bao (2012) emphasized the development of a sophisticated view of NOS amongst teacher candidates along with an understanding of the instructional practices. This can be accomplished with teacher development courses that highlight NOS fundamental and pedagogical implications. However, most pre-service classes do not touch on this topic outside of a methods course (Backus & Thompson, 2006). Since teaching about the nature of science can get lost in the content of a science course, it is im0portant to emphasize the value of it to both practicing educators and pre-service teachers.

Dual Processing

Dual Processing Modes of Thinking

Studies to explore cognitive monitoring have shown that many intuitive judgments are quick and can be flawed. In a personal communication with a colleague (Kahneman, 2003, p.699), Shane Frederick told Kahneman (of which they conducted previous work together) that he would use simple puzzles to study cognitive self-monitoring. The example was: “A bat and a ball cost $1.10 in total. The bat costs $1 more than the ball. How much does the ball cost?” Frederick found that many intelligent students impulsively answered the question that the ball costs “10 cents” because that amount is about the right magnitude. About 50% of Princeton students and 56% of the students at the University of Michigan that participated gave the wrong answer. The relevance of this data shows that there is a high rate of offering a response without checking it with Type 2 thinking. People are often content to trust a plausible judgment that quickly comes to mind (Kahneman, 2003). Type 2 thinking offers a metacognitive reflection on the answer. The quick answer that comes to mind in the bat and ball problem is that if the bat costs $1 more than ball, and the total cost is $1.10, then the ball must cost $.10. If the problem is checked with Type 2 thinking,

then the wording of costs *more than* the $1 would check the intuitive the answer, supporting the plausible and correct answer of the ball must cost $.05 cents in order for the bat to cost $1 more than the ball.

Tversky and Kahneman (1973) found that 66% of participants considered it more likely that words of three or more letters in a typical example of English text start with the letter K than have the letter K as their third letter. In reality, about twice as many words have the letter K as their third letter. Harvey (2007) replicated the study and pointed out that words starting with the letter K are easier to come to mind, thus this available heuristic was applied in more cases.

Dual Processing and Decision-Making

In Harvey's paper on forecasting research (2007), he states that different heuristics are useful in different types of forecasting tasks (predicting outcomes). The heuristic being applied relies heavily on the information stored in memory (anchored to an idea), and the experience in using the heuristic (representativeness). Harvey did note that improvements in judgment and decision-making via learning were highly task-dependent and that forecasting dids not appear to be influenced by task-dependent learning options. Therefore, forecasting is limited to only available heuristics.

Human decision-making has been viewed as using systematic, mathematical, and probabilistic reasoning in order to secure the best possible situation (Miller, Rowe, Cronin, & Bampouras, 2012). Observing decision making in the real world as an academic exercise or logic game residing a social vacuum is an unrealistic view. Rationalistic models of decision making do not critically incorporate components of complex practice tasks within complex cultural, social, and institutional contexts (Miller et al., 2012). Everyday decision making is often motivated by making decisions that would provide good enough rather than optimal outcomes. The advantages

of Type 1 thinking are its speed, presumably reliable option based on perceptions, some prior knowledge, and intuition.

Shah and Oppenheimer (2008) argued that the term heuristic has been used so often in research, the clear definition cannot be defined. They express that a heuristic, commonly associated with Type 1 processing, is an effort-reducing process in decision-making. Choosing a selection in Type 2 thinking expends a lot of effort. It requires five main components to be utilized in cognitive functions: (a) identifying all cues, (b) recalling and storing cue values, (c) assessing the weights of each cue, (d) integrating information for all alternatives, and (e) all alternatives must be compared (Shah & Oppenheimer, 2008).

This algorithm for solving problems uses great mental resources, but people do not have unlimited processing capacity. In order to reduce the effort of the computation in thinking, Type 1 (applying heuristics) processing can simplify the cognitive load with five effort-reducing steps: (a) examine fewer cues, (b) reduce the difficulty associated with retrieving and storing cues, (c) simply the weighting principles for cues, (d) integrate less information, and (e) examine fewer alternatives (Shah & Oppenheimer, 2008).

Sloman (1996) demonstrated that people struggle with this dichotomy between familiar and weak-associated knowledge. The associative system of reasoning, more commonly linked to Type 1 thinking, draws inferences on the basis of similarity and stereotypes, feature sets drawn from personal experience. The computational system of the brain relies on both types of thinking, but Type 2 tends to be more empirica and based on logic over intuition. An example is Sloman's association problem from his previous work in 1993 (Sloman, 1996). Participants in his study were asked to rate the convincingness of an argument based on a 10-point scale with 10 indicating the most convincing. The mean rating for the following argument was a 9.6:

All birds have an ulnar artery. Therefore, all robins have an ulnar artery.

The second argument received only a mean of 6.4, showing significantly lower scores:

All birds have an ulnar artery. Therefore, all penguins have an ulnar artery.

The significance of this association argument is that both scores should have received a 10-point answer. The participants were asked in a debriefing meeting if they all agreed there was an obvious category inclusion rule, and they overwhelmingly said yes. However, some were adamant that their responses were also sensible, though they failed to express why.

Expanding upon this idea, other researchers presented in Sloman's paper (1996) a similar argument to participants:

Robins have an ulnar artery. Therefore, birds have an ulnar artery.

Robins have an ulnar artery. Therefore, ostriches have an ulnar artery.

The majority of participants chose the first argument because robins and birds are more similar than robins and ostriches. However, most people also conceded that the second argument is at least as strong because ostriches are birds, so the evidence should show that all birds would have that anatomical property. This logical argument failed to erase an even more compelling intuition. The author asks how much evidence can a fact about robins provide for an animal as dissimilar as an ostrich?

Evans (2010) described the dual-process theory as *default-interventionist*. The rapid Type 1 process provides a quick default solution to a problem, but may be intervened upon with explicit Type 2 reasoning. "When this intervention occurs, the default intuition may (or may not) be overridden" (Evans, 2010, p. 314). One of the current interests in dual-processing research is what determines the likelihood of intervention with Type 2. As stated in Thompson (2009), possibilities

include the amount of time available, presence of competing demands, motivation to think "rationally," and feeling of confidence in the initial intuition.

Those who are labeled "intuitive" may be unkindly described as being deficient in rational thinking (Evans, 2010). Type 2 thinking is not defined as the superior method of processing to Type 1; in fact, both may be useful in certain scenarios. Understanding the modes of thinking is imperative in moving forward to understanding how NOS education may influence one type or the other, and if teachers' NOS views are impacted from this dual-processing theory.

Cognitive-Experiential Self-Theory

According to the cognitive-experiential self-theory (CEST) (Epstein, Pacini, Harriet, & Denes-Raj, 1996), a dual information-processing mode exists in thinkers: a rational and experiential system. The rational is affiliated with Type 2 processing, while the experiential is more associated with Type 1 thinking. According to the CEST, the rational system operates on the analytic, conscious level, and is intentional. The experiential system is assumed to be automatic, associationistic, and more resistant to change (Epstein et al., 1996). "Heuristic processing represents the natural mode of the experiential system" (Epstein et al., 1996, p.391). Behavior and cognition integrate between the two systems, but sometimes there is conflict between the intuitive Type 1 "feeling" and the "logical" Type 2 thinking. There are degrees of relative dominance of either system, but there are parameters in selecting which type is dominant, including personal preferences, and the customary way of responding to a situations (Epstein et al., 1996). For example, Type 1 thinking is often used in solving interpersonal problems, while Type 2 thinking is used in complex problem solving, commonly found in math and science.

The CEST theory states that the two interacting systems are independent, yet there is a certain degree to which they rely on each other. "Assuming that two information processing modes

exist, it would be of interest to demonstrate reliable individual differences in their relative usage and to have an instrument for effectively measuring those differences" (Epstein et al., 1996, p.390).

Dual Processing and Nature of Science

The theory of rational decision-making "requires that a rational person should anticipate the consequences of their decisions, estimating the probability and utility of various outcomes, combining the two to calculate the *expected utility* of each action, and then choosing the action that maximizes this quantity" (Evans, 2010, p.320). Evans found that when people were presented with an unorthodox situation, they tended to focus on a single hypothesis and hold on to it until there was a good reason to give it up. (Evans, 2010). This relates to conceptual change in science. An individual retains their current construct until cognitive conflict is introduced, and a more appropriate selection is made and replaces the old conception.

Abd-El-Khalick and Akerson (2004) stated that a set of concepts is replaced if the new concept is more meaningful and plausible to the existing construct. The components of NOS education were determined to be necessary in formal education, despite not having a universal consensus on what all of the aspects of NOS entail (McComas, 1998). A teacher who has a better comprehension of what these aspects are may be able to help facilitate NOS learning by providing insight into a student's current understanding of nature of science. Since a teacher cannot effectively teach that which they do not understand, implementation of NOS pedagogical techniques will be challenging if inadequate views of NOS exist. The reflective component of NOS instruction is essential to allowing concepts to change. If the learner is allowed to interpret the new information with a focus on metacognition, then the goal of NOS education could be

accomplished. With proper pedagogy and reflection, the students may conceptually modify their existing schema with more appropriate ideas (Lederman, 2007).

There are reliable measurements to assess NOS aptitude (Koksal & Cakiroglu, 2010). For example, Lederman, Abd-El-Khalick, Bell, and Schwartz (2002) used an open-ended instrument called the Views of Nature of Science Questionnaire (VNOS). In their study, the authors aimed to discuss the usefulness of descriptive NOS profiles and how it was related to teaching and learning about NOS. Each question on the form addressed one or more of the major components of NOS knowledge discussed in chapter one. The authors evaluated the form based on if the answers were more naïve or informed views based on the response and examples provided by the participants in each section. The overall goal was to address some of the naïve views of NOS in follow-up interviews with the participants to elucidate why they held their views, and how to emphasize reflection to better prepare the participant for thinking about their own NOS knowledge. This could, in turn, reflect improvements in both NOS teaching and learning in students and educators.

Assessing Type 1 and Type 2 Thinking

There are self-reporting measures to evaluate Type 1 and Type 2 thinking such as the Need for Cognition (NFC) scale (Cacioppo & Petty, 1982), and non-self-report scales measures from which the responses to vignettes may be objectively scored as heuristic or rational (Epstein et al., 1996; Klaczynski, 2001). Efforts to isolate reasoning versus intuitive experiments have been controversial (Evans, 2010; Stanovich & West, 1998). Type 1 can be shown as being predominately used at times (Frederick 2005; Evans, 2010), but even the performance on tasks designed to observe Type 2 processing are often strongly influenced, or even dominated, by Type 1 thinking (Evans, 2010). This hints to the conclusion that intuition rather than reasoning is the

dominant form of human thinking. Stanovich (2009) suggested that people are by nature beings who minimize the use of effortful reasoning and hence rely on intuition.

The Cognitive Reflection Test (CRT) is comprised of just three questions to observe the process of thinking (Frederick, 2005). Across a range of measures and time preferences, participants with higher CRT scores were more patient. Participants with higher CRT scores were also less risk averse for gains and less risk seeking for losses (Frederick, 2005). Each had an intuitively suggested wrong answer and a correct answer that could be found with some reflective reasoning. Harvard University undergraduates solved 1.43 of the 3 questions, with only 20% managing to solve all three. The intuitive errors were correlated to impulsive personality traits, such as paying for next-day shipping rather than waiting for a couple of days for free shipping. Evans (2010) suggested that intuition is a matter of both cognition and personality. For example, gamblers trust their Type 1 processes, essentially their feelings of confidence without the intervention of Type 2 thinking, is why gambling is successful regardless of knowing the odds that are involved.

Oechssler, Roider, and Schmitz (2009) showed links between cognitive abilities and behavioral biases. Results noted impulsiveness was related to lower CRT scores. The risk levels were obtained with questions such as the following:

> You have two alternatives: You can receive 10 Euros, or you can receive a lottery ticket that yields a 75% chance of winning 20 Euros. There is a 25% probability it is worthless.
>
> In a lake, there is a patch of lily pads. Every day, the patch doubles in size. If it takes 48 days for the patch to cover the entire lake, how long would it take for the patch to cover half of the lake? [____ days]

These assessment questions of intuitive versus rational thinking and judgment may provide answers on how Type 1 and Type 2 thinking are associated with the conceptual change learning

model. If new information about the nature of science is presented to a class, which mode of processing will be predominant in influencing the NOS knowledge accommodation?

Type 1 is often quick and uses heuristics to come to a conclusion. Does this mean fast conclusions are always Type 1? Gladwell stated that "less is more" to support the merits of intuitive reasoning (Evans, 2010). There is an example of how hospitals propose three short questions while examining patients to determine if they need treatment for a suspected heart attack (Evans, 2010). This explicit rule following is short and simple, and it is a Type 2 process. Problems presented in research of dual-processing experiments have shown that Type 2 is required to find the correct solution in analytical situations (Stanovich & West, 2008; Kahneman & Frederick, 2002). These Type 2 interventions are noted to occur more likely in those of higher cognitive ability.

Conclusion

Through evaluation of Type 1 thinking, Type 2, and NOS views, a comparison and analysis of how each variable correlates to one another may be determined. With an appropriate intervention of NOS instruction, the influence of Type 1 thinking and Type 2 thinking on NOS views may be evaluated.

The cognitive-experiential self-theory has sufficient literature to lead into certain questions about how this applies to NOS aspects and teacher education. People cognitively assess a problem using both modes of thinking, but the mode of thinking that is the most predominant during NOS based activities is still unclear. Learning about NOS aspects may improve teachers' conceptions about science, and those conceptions may translate into the classroom.

In regards to science teacher education, understanding the development of how NOS views may be improved involves metacognitive abilities that may be applied to a situation. The result of

understanding which mode of thinking is the dominant version relies on how it can be applied to problem solving in any area. Since science typically incorporates problem-solving techniques, the dual processing awareness in teacher education may help improve NOS views in students.

CHAPTER 3

METHODOLOGY

The purpose of this study was to examine the influence of the dual processing modes of thinking on the development of nature of science (NOS) views. The literature supported the explicit-reflective approach to teaching NOS, which may help promote a comprehensive understanding of how science is utilized in both practice and interpretation. The dual processing modes (Type 1 and Type 2 thinking) represent how people incorporate information into their working schema.

Type 1 thinking is intuitive, automatic, heuristic, schematic, narrative, and implicit (Epstein, Pacini, Harriet, & Denes-Raj, 1996). Type 2 thinking includes thinking-conceptual-logical, analytical-rational, verbal, and explicit details (Epstein et al., 1996). Both modes are present in every student; defining and analyzing the moments in which a person is demonstrating the use may show the direction NOS education guides a student to improved scientific thinking. Because Type 2 thinking is more conceptual, analytical, and explicit than Type 1 thinking, students receiving a NOS treatment were expected to display Type 2 thinking during instruction more often than Type 1 thinking.

Research Questions

One main goal of science education is to produce scientifically literate citizens (NGSS Lead States, 2013). Through examination of how Type 1 and Type 2 thinking influence the development of NOS views, the hypothesis is that students who showed primarily Type 2 thinking during the NOS instruction should be more likely to improve their NOS conceptions. Consequently, the following research questions guided the study:

(1) Do experiential processing (Type 1) and logical processing (Type 2) influence the development of students' NOS views?

(2) If there is an influence on students' NOS views, then what is the nature of relationship between experiential (Type 1) and the development of NOS views?

(3) What is the nature of relationship between logical (Type 2) and the development of NOS views?

In order to witness the phenomena of dual processing and NOS development, a mixed-methods research design was applied. Because the thinking event and maturation of NOS knowledge could be subtle, the effects of the dual processing influence were assessed with a combination of quantitative and qualitative procedures.

Setting and Participants

The location was in a large, urban high school located in the Southwest region of the United States. A total of 29 students (18 female, 11 male) participated in a year-long Advanced Placement (AP) environmental science course. The prerequisites for this course were biology and chemistry. The students were not required to take the AP exam at the end of the year, but still received AP credit for taking the course. The student population was a mixture of juniors and seniors (ages 16-18) from whom volunteers were recruited to participate with an added incentive of a pizza party at the end of the study. Each student was given a number according to the seating chart so they could participate anonymously.

A veteran female science instructor taught the course, but was not involved in the study. She took attendance, and then left the room. The researcher helped design the lessons and proctor the class during the study. One of the researcher's dissertation committee co-chairs helped administer the NOS intervention and set up the reading materials. The other co-chair had an

extensive background in NOS research, and the addition of his help during the intervention was vital. The researcher had ten years of science teaching experience in biology and chemistry plus experience with two NOS professional development classes and one NOS doctoral course.

Research Design

The mixed-methods approach involved multiple sources and types of data. To assess NOS knowledge levels and the use of Type 1 and Type 2 thinking, data were collected from an open-ended survey that determined the pre and post levels of NOS knowledge. Follow up face-to-face interviews for the NOS surveys were conducted to elicit further clarification for some of the students' responses. A chi-squared data analysis of the pre and post was conducted to observe if there is any statistical significance to the possible changes in NOS levels. The comparison between NOS level changes was also compared.

Reading sessions and discussions were assigned with question prompts following the NOS intervention. All class sessions were audio and video recorded to evaluate the type of thinking being used during instruction. These data were transcribed and coded in order to interpret the type of processing.

Explicit-Reflective Nature of Science Instruction

The course involved an intensive five-day session strictly on the concepts of NOS following the planned AP exam. The final weeks of the AP Environmental course are open since those students that take the AP exam do not have to take the final exam. The AP test was administered on a Monday, so Tuesday through Friday, and the following Monday (a total of 5 hours), involved the NOS aspects introduction and targeted pedagogical concepts. The major NOS aspects include: empirical, inferential, creative, subjective, tentative, experiment (science

methods), law vs. theory, sociocultural, bounded, and collaborative (Deniz, 2013). See Appendix A.

The NOS activities presented were "Tricky Tracks", "Rabbit? Duck?", "Young Woman? Old Woman?", "The Bottle", "The Tube", "The Cubes", and "The Water-Making Machine". These activities were explained in detail in Lederman and Abd-El-Khalick (1998). Not explained in Lederman and Abd-El-Khalick (1998) included a NOS introduction presentation PowerPoint with a poster displaying the ten different NOS tenets, a presentation of atomic theory followed by a mystery box activity based on making inferences about the shape of the unseen object. A reading presentation centered around the myths of nature of science (McComas, 1998). The students were assigned to groups and given certain myths of NOS. They were then instructed to write those myths on a poster board with markers and present them to the class. The timeline and NOS aspects are noted in Table 1.

Table 1

NOS Intervention Activities and Target NOS Aspects

Day	Informative activity	Inquiry activity	Target NOS aspects
1	NOS intro PP and poster	Rabbit? Duck? Old woman? Young woman? Tricky Tracks The Botttle	Empirical, inferential, creative, collaborative, and subjective
2		The Cubes The Tube	Empirical, inferential, creative, collaborative, experiment, and subjective
3	Atomic theory presentation	Black box activity	Empirical, inferential, creative, collaborative, and subjective
4		The water-making machine	Inferential, collaborative, creative, and subjective
5	Myths of the Nature of Science jigsaw presentation		Collaborative, subjective, theories vs. laws, empirical, and creative

Following the five-day explicit-reflective NOS activities, *The Double Helix: A Personal Account of the Discovery of the Structure of DNA* (Watson, 1968) was read during the remaining class periods of the study. The chapters were broken up each day and prompting questions were assigned to promote discussion about the content. See Appendix D for an example of the prompting questions. The final class reading and discussion involved “Women’s Brains” (Gould, 1980). Once the reading was discussed, the last class period of the study was a discussion on what

was learned during the study, and the post VNOS was administered. See Table 2 for the study timeline.

Table 2

Study Timeline

Dates	Direction
4/21	Pre-NOS survey is given with IRB consent and assent forms to the students
5/5-5/8, 5/11	Nature of Science intervention
5/12	Double Helix day 1
5/13	Double Helix day 2
5/14	Double Helix day 3
5/15	Double Helix day 4
5/18	Double Helix day 5
5/19	Double Helix day 6
5/20	Double Helix day 7
5/21	"Women's Brains" reading
5/22	Conclusion-Post VNOS questionnaire

The basis for the data was to provide a direct NOS intervention to observe the influence on student discourse during the readings and group discussion. While the intervention was being conducted, student conversations were recorded to discern the influence of Type 1 and Type 2 thinking on their NOS learning.

Data Collection

Student NOS Questionnaire VNOS Version C

The Views of Nature of Science Version C (VNOS-C) questionnaire was used to assess students' NOS views at the beginning and at the end of the NOS intervention. The validity of this open-ended NOS questionnaire was established by Lederman, Abd-El-Khalick, Bell, and Schwartz (2002), and its validity was later supported with subsequent studies (e.g. Koksal &

Cakiroglu, 2010). This questionnaire allowed the researcher to elicit students' NOS views across target NOS aspects (e.g., empirical, inferential, creative, tentative, and subjective NOS) before assessing them according to a predetermined evaluation rubric. The evaluation rubric that was used in this study included five categories: (a) informed, (b) informed-no example (informed-NE), (c) pre-informed, (d) mixed, and (e) uninformed.

Informed views provide explicit reasoning and accurate examples. The answer to the question is clear and concise, and is backed up with an example that helps define what components of NOS are being evaluated. Informed-NE is explained coherently and appears to be well informed on the question, but does not provide an example to back up their explanation. Pre-informed lacks the depth and clarity that informed answers provide, but seem to be on the verge of competency and is close to a logical explanation of the question. Mixed views may provide some insight into a supported concept of NOS, but also has some conflicting information. Thus, the explanation has both properties of comprehension about the question, but also contains contrasting views. Uninformed fails to appropriately explain the answer to the question, or lacks any true insight into their response. The follow-up interviews may help confirm if the given score to a question is justified, or if more explanation is needed to warrant a change from one level to another.

Within the limits of this study, the VNOS was administered two weeks before the start of the study. The VNOS is comprised of ten questions, with some of the questions asking to provide examples or defend their answers. Each question of the survey is aimed at observing one or more aspects of NOS. It took participants between 45-60 minutes in the Lederman et al. (2002) VNOS reliability and validation study, excluding the time needed for the follow-up interviews. The participants were provided the appropriate amount of time to complete the form during class. Once the forms were collected, the researcher conducted follow-up interviews by arranging times before

or after school for the next few weeks. At the conclusion of the study, the students were given the same VNOS questionnaire to complete during class. The researcher and co-chair examined the responses to see if students improved their NOS views. See Appendix B for the VNOS-C questionnaire.

Follow-up Interviews

During the interview process, the researcher examined the VNOS responses to appropriately determine each participant's NOS responses as being informed, informed-NE, pre-informed, mixed, or uninformed. Eight students volunteered to be interviewed by signing up on a roster sheet.

Follow-up interviews provide an examination into their answers to adequately explain if their views are consistent with how they were scored by the researcher. The label given for each answer may change if their verbal response helps elaborate or explain their written responses. The mixed views may also be supported and changed to informed or pre-informed if proper examples are provided, or demoted to uninformed if the student does not provide enough evidence to show they have some knowledge about that particular nature of science.

The interviews were provided outside of the classroom in a separate classroom, and audio recorded. Once these had been conducted, the transcriptions were written, and compared to the previous student's responses in their initial VNOS. Any clarification was added to the conclusion of whether the student understood the question, or added further examples to support their claims. See Appendix G for an example of a student VNOS interview and evaluation.

Guided Reading Discussions

A one-page reading question handout was provided to each student. This specified which pages they would need to read, and asked some open-ended questions about the content in *The*

Double Helix. The students were requested to tie in their discussions with the NOS content they learned about during the intervention. The students did not need to complete these questions as a grade; they were meant to direct the conversation of each group so that they stay on task, and can discuss the main points within the pages each day of the study.

Audio and Videotaping of the Class

The class sessions during the study were video recorded. Three groups were audio recorded during their discussion of the readings, and the other two groups had the video camera placed near them. One camera was placed near the front of the room facing the audience, and another was placed on a counter in the back of the room. The recordings were designed to capture the dialogue of all five groups during the NOS intervention, and following reading reflections. The audio and videotaping were stored each day on an external hard drive to be transcribed.

Data Analysis

Views of NOS Version C Questionnaire and Follow up Interviews

Amidst the ten open-ended questions of the VNOS-C, each question could present multiple tenets of NOS. Some of the questions were aimed at drawing out attention to some specific NOS aspects, but there was no certainty that question would elicit a particular type of response. For example, question four of the VNOS asks the participant to explain how scientists develop a scientific theory, and whether a theory ever changes. This question aims to elucidate the tentative and law/theory aspects of NOS. If the response states that "theories become laws when they are proven true", then the response was scored as uninformed, exemplifying a more naïve view of this aspects of NOS. If the response states that theories may change over time, but no examples are provided, then it is difficult to determine if the response had an informed tentative NOS view.

Therefore, it would be scored as informed-NE or pre-informed. The follow-up interview provided a more thorough explanation of the participant's views to make a sound conclusion.

The main areas that the VNOS assessed are empirical, inferential, creative, subjective, scientific methods/experiment, bounded, sociocultural, tentative, collaborative, and theory/law (Sweeney & McComas, 2012). Each response for the pre and post VNOS were put into a Microsoft Excel document depending on what aspects of NOS are being examined. Key phrases were identified within the students' responses, and one of the five levels of NOS knowledge is applied. See Appendix E for examples of each level of the rubric.

The eight volunteer students were interviewed, and their responses were determined by what questions were asked to support or clarify their written responses. If the student answered that science is sometimes creative, a follow-up example helped determine why this response was selected. If the interviewee was not fully informed, and couldn't provide adequate support to their claim of why it was creative, a pre-informed or mixed label was issued. The pre interview and post interview results were added to the students' VNOS answers, possibly changing their NOS evaluations. The same students that volunteered were used in the post interviews. See Appendix F for an example of each NOS domain.

One of the main benefits of utilizing the open-ended approach of the VNOS is that is doesn't tally up the numerical scores and completely label a participant as having an overall informed or uninformed NOS views; each question of the form can assess a particular area of NOS content knowledge.

Reliability

The NOS data was coded with the researcher's chair until an agreement on the students' NOS levels was achieved. The chair has an extensive background in VNOS research and analysis,

so the interpretation of the students' answers was conclusive once a mutual evaluation was accomplished. This provided support to the qualitative data analysis portion provided from the VNOS-C.

Chi-Square Analysis

The data were compared quantitatively using a chi-square test. This test was selected since it is nonparametric; it is able to evaluate if there is statistical significance within the deemed numbers provided from the VNOS scores. The total numbers were also evaluated, showing a percentage deviation from the pre and the post VNOS. This is aimed at showing a representation of any possible change from the NOS intervention in addition to the chi-square test. This information was then applied to the Type 1/Type 2 qualitative analysis.

Audio and Videotaping of the Class

Each class session was audio and videotaped in order to analyze the type of thinking being used. A coding scheme was applied to determine if Type 1 or Type 2 thinking is being used during the NOS and reading reflection discourse. Discourse analysis has a special and interesting problem since the same words can have different meanings in different contexts (Gee, 2011). "Everyday people solve the Frame Problem by making judgments about how much of the context is 'relevant' to what a person has just said, that is, they bring to communication standards of relevance" (Gee, 2011, p. 32).

In order to observe the type of thinking being used, he applied the Evidence-Based Reasoning (EBR) framework to the transcriptions (Brown, Furtak, Timms, Nagashima, & Wilson, 2010; Furtak, Hardy, Beinbrech, Shavelson, & Shemwell, 2010). Elements of reasoning include a premise, a claim, and backing (backing a claim). A *premise* is stated information about the activity (problem or question) or general expression. A *claim* includes what something will do in the

future, what is happening in the present, or what happened in the past. It is an isolated statement that is not used as backing.

Backing is a particular type of claim that is divided into three areas: (a) Data- provides a personal anecdote or prior knowledge is support of a claim, (b) Evidence- describes a contextualized relationship between two properties supporting a related set of data in support of a claim, and (c) Rule- supporting statement that is expected to hold in contexts and circumstances not previously observed in support of a claim.

From analysis of the discourse provided in the transcription, each claim (or backing claim) could be further be interpreted as quality of reasoning: (a) unsupported, (b) phenomenological, (c) relational, or (d) rule-based. Unsupported goes directly from the premise to the claim; it has no reasoning to support it. Phenomenological applies data to the claim. It may use senses or observations as data to support the claim. Relational applies data to provide evidence, and may include analysis of the data to support a claim. Rule-based claims provide either inductive or deductive reasoning. It applies data to create evidence, and then uses that evidence to create a rule in support of a claim. See Table 3 and Table 4 (Furtak et al., 2010) for descriptions of the coding scheme.

Table 3

Coding Scheme

Elements of Reasoning (General)	Elements of Reasoning (Specific)	Definition
Premise	Premise	A statement describing the relevant characteristics or properties of the object about which the claim is made. The "given" information from whence the claim derived upon. Includes object, state of object, general expression (subject reasoning), point of reference.
Claim	Claim	A claim about a specific premise. Includes either future prediction or presumption, present conclusion, or past outcome. Could be expressed as a relationship among data points (evidence), statements about single data points (data), or statements of generalized relationships (rules). An isolated statement, however, that is not used as backing.
Backing	Data	A supporting statement describing the outcome of a single specific experiment or a single observation in a personal anecdote or prior knowledge, books, or test in support of a claim.
Backing	Evidence	A supporting statement summarizing a related set of data in support of a claim. Evidence is specific to the context in which the data were collected. Describes a contextualized relationship between two properties, a property and a consequence of that property, or a finding rather than a general principle or law.
Backing	Rule	A supporting statement describing a generalized relationship, preinciple, or law in support of a claim. General in the sense that it is expected to hold even in contexts not previously observed.

Table 4

Quality of Reasoning in Science Discourse

Quality of Reasoning	Definition	Description	Diagram
Unsupported	No reasoning	Elements of reasoning present but no processes of reasoning; Pseudo, circular, tautological reasoning	Premise↔Claim
Phenomenological	Data-based reasoning	Data applied to a claim	Premise↔Claim ↑ Data
Relational	Evidence-based reasoning	Evidence applied to a claim including analysis of data	Premise↔Claim ↑ Evidence ↑ (Data)
Rule-based	Inductive or deductive rule-based	1. Deductive reasoning applying a rule to make a claim with respect to a new Premise 2. Inductive reasoning from data to rule 3. Applying a rule with new evidence (analogy) 4. Complete reasoning structure (whole framework)	Premise↔Claim ↑ Rule ↑ (Evidence) ↑ (Data)

The EBR framework allowed the discourse to be coded and broken down into evaluation for the Type 1 and Type 2 thinking. Since Type 1 is fast, intuitive, and experiential, all claims presented that are determined to be unsupported are making a supporting claim that is has no evidence of true reasoning. This could be defined as Type 1 thinking. Phenomenological can also be categorized as Type 1 if the backing claim is experiential and does not apply empirical data to the claim. This would be a student informing a group of a past story of how something happened, and how that could be applied to the current situation. Type 2 is slower, analytical, and rational, so backing elements of reasoning which include data that leads to evidence should show

phenomenological (with supporting empirical information), relational, or rule-based quality of reasoning. Since some phenomenological, relational, and rule-based processing requires supporting claims that contain more rational thinking, Type 2 would be dominant in these claims.

An example evaluation of this coding breakdown can be observed in Appendix C. The transcription was copied from the audio and video recordings, and the discourse evaluated as either a premise or a claim. When coded as a claim, the type of backing was applied. From there, the quality of reasoning coding was determined as to what type of claim the student is producing. This column is used to observe if Type 1 or Type 2 thinking is being used during the classroom discourse. Further analysis of what actions are occurring during the dialogue may help show what type of processing is being experienced by the students during the NOS intervention and subsequent reading reflections.

Reliability

The framework for the qualitative research ensures reliability through the *inter coder agreement* (Creswell, 2014). The transcripts were compared with the researcher's methods committee member to see if there is a common theme that arises from the data. The EBR framework was agreed upon as a potential method in to which assess the type of thinking that was being exhibited by the participant. The coding applied was the active premise or claim being said, and then if a claim was being made, the elements of reasoning were introduced. Once the element of reasoning was proposed, the quality of reasoning was used to determine the level of processing. This coding scheme aimed to observe if Type 1 of Type 2 thinking was being conducted during the dialogue.

The researcher set up the given student numbers and participant letters for clarification purposes. The agreement on the usage of the coding system from the examples helped assure the

qualitative interpretation was being applied appropriately. All documents and data obtained in this study were collected and stored in a digital folder. This data included (a) all pre and post VNOS survey answers, including any students selected for the follow-up interviews, (b) all transcriptions conducted during the study, and (c) the breakdown of how the EBR coding system was applied to Type 1 and Type 2 thinking. This access will be provided to independent researchers or investigators if requested.

CHAPTER 4

RESULTS

NOS Data and Chi-Square Analysis

According to the hypothesis, the study intervention should have changed in the nature of science (NOS) levels. A chi-square test was performed to determine whether NOS scores changed during the study using the pre and post VNOS scores. The *N* was 29 students, but the analysis varied from their responses to the ten questions provided by the VNOS-C form. An alpha level of .05 was selected for significance. The informed and informed-NE columns were collapsed into one category to compact the data. The other levels could not be merged because they were more distinct than the two informed levels. The four NOS levels are shown below in Table 5.

Table 5

Totals

NOS level	Pre	Post	Total number
Informed (combined)	64	73	137
Pre-informed	23	27	50
Mixed	50	36	86
Uninformed	92	70	162
Total	229	206	435

The expected numbers and pre-post calculations are shown below in Tables 6 and 7. See Appendix H for calculations.

Table 6

Expected Numbers

NOS level	Pre expected values	Post expected values
Informed (combined)	72.12	64.87
Pre-informed	26.32	23.67
Mixed	45.27	40.73
Uninformed	85.28	76.71

The expected values were put in the equation

$$x^2 = \Sigma\ (f_o - f_e)^2.$$

The calculations are presented in Table 7.

Table **7**

Calculations

NOS level	Pre	Post
Informed (combined)	.91	1.02
Pre-informed	.42	.67
Mixed	.49	.12
Uninformed	.53	.59

With the chi-square goodness of fit test performed, the relationship between pre and post NOS scores was not significant, X^2 (3, N = 29) = 4.78, p <*05*. The critical value was determined to be 7.815, so the null hypothesis was accepted, stating there would be no change in the pre and post NOS scores.

Table 8 illustrates any percentage change in overall NOS levels from start to the conclusion of the study. A positive value for the informed and pre-informed indicates an increase from the pre and post. Since informed and pre-informed show a higher competency of knowledge of the ten aspects of NOS, these are the desired levels for each question from the survey. A positive value for mixed and uninformed indicates there was a decrease in the numbers from the pre and post surveys. A reduction in these responses is expressed as a positive value, insinuating there are fewer mixed or uninformed response evaluated in the post surveys. While the pre survey has a total response number of 229, and the post had less with 206, the students' explanations were still evaluated with the same criteria. Thus, not having the same number of responses for the pre and post is a possibility with an open-ended survey like the VNOS-C.

Table 8

NOS Pre/Post Change

NOS level	Pre	Post	% Change
Informed (combined)	64	73	+14%
Pre-informed	23	27	+17%
Mixed	49	36	-26%
Uninformed	92	70	-24%

The informed and pre-informed responses increased (14%, 17%) in frequency, while the mixed and uninformed decreased (26%, 24%) in numbers from the pre to the post. The individual aspects of NOS were not compared separately because this study was based on an overall change in NOS levels.

Dual Processing Data

Type 1 and Type 2 Evaluation

Qualitative data analysis. The students were organized into five groups with five to eight members per group. A purposeful sample of students was selected for Type 1/Type 2 analyses based on their discourse during the intervention and reading reflections. The students chosen were from groups two, three, and four. See Appendix I for seating chart. These groups were selected based on the amount of participation, engagement during the discussions, and the attendance of the students. Two students per group were chosen based on the richness transcribed during the study. The student numbers were changed to initials for clarity purposes. Group two (Group A) contained five members (students 9-13). Students 11 (AA) and 13 (AB) were selected for coding. Group three (Group B) contained five members (students 13-17). Students 14 (BB) and 16 (BC) were the students with regular attendance and participation. Group four (Group C) also contained five members (students 18-22). Students 21 (CC) and 22 (CD) were chosen as participants, and are assessed according to the EBR framework (Furtak et al., 2010). All other students participating in the conversation will be known as their student (S) and their student number (e.g. student 12 will be given the initials S12). Refer to Tables 3 and 4 for descriptions of the elements of reasoning and quality of reasoning on pp. 57-58 of this paper. The elements of reasoning are premise, claim, backing data (BD), backing evidence (BE), backing rule (BR). The quality of reasoning for the claims is unsupported (UN), phenomenological (PH), relational (RL), and rule-based (RB).

The six students are provided examples of the participants, selected based on the previous criteria. Each student grants examples of coded transcriptions during the intervention, and through the reading assignments. While each student displayed all of the quality of reasoning and elements of reasoning at one point in the study, the primary examples are displayed of Type 1 and Type 2

interactions during their conversations. Along with the EBR coding framework, the vocabulary of NOS is underlined to demonstrate the application of these principles. The key NOS terms used in this study are empirical, inferential, subjective, tentative, law vs. theory, experiment, collaborative, bounded, sociocultural, and creative.

To recall the difference between Type 1 and Type 2, Table 9 lists descriptions from Kahneman (2011) and a brief explanation is provided by Evans (2010):

> Nevertheless, they all draw upon a broadly similar distinction between two types of mental process, which we can summarize as follows:
>
> Type 1 process: fast, intuitive, high capacity
>
> Type 2 process: slow, reflective, low capacity
>
> Even with this minimal level of description, we see that we have now a technical addition to the lay meaning of the term *intuition*. Compared with Type 2 processes, Type 1 thinking can handle larger amounts of information or process it in parallel." (Evans, 2010, p.313)

Table 9

Descriptions of Type 1 and Type 2 Taken from Kahneman (2011)

Descriptions	Type 1	Type 2
Characteristics	Fast Effortless Unconscious Associative Creates stories to explain events Looks for patterns	Slow Effortful Conscious Logical Can handle abstract concepts Deliberate
Advantages	Speed of response in a crisis Easy completion of routine or repetitive tasks Creativity through associations	Allows for reflection and consideration of the "bigger picture", options, or consequences Can handle logic, math, statistics Good for reductive thinking
Disadvantages	Jumps to conclusions Unhelpful emotional responses Can make errors that are not detected or corrected Can make wrong assumptions, poor judgments, or false causal link	Slow and requires time Requires effort and energy May lead to decision fatigue

Elements of the NOS vocabulary, in conjunction with Type 1 and Type 2 thinking, were examined in the group dialogue for the six students. The dates are in chronological order; not all dates are listed. Examples of Type 1 are depicted first for each group of students. The first column displays the date and activity or action. The second column examines the elements of reasoning, and below it, the quality of reasoning (abbreviated). The third column shows if it displays T1 or T2

thinking, and if an aspect of NOS is witnessed. If there is a NOS aspect to display, then that is underlined in the fourth column where the discourse is shown. All six students presented will be referred to by the student identification letters, or as females to support anonymity.

Student AA and Student AB. Tables 10, 11, and 12 demonstrate Type 1 thinking for students AA and AB during full group discussions from the reading reflections, including the use of NOS vocabulary in most examples.

Table 10

Type 1 Example for Students AA and AB

Date Activity	Elements of reasoning Quality of reasoning	Type 1 or Type 2 NOS aspect	Transcript (student or teacher participating and transcription line numbers)
5/13			
Double	Claim	T1	AA: 011 And they're just like taking sides. So much drama
Helix	UN		AB: 012 They're not very collaborative
discussion	Claim	T1	
day 2	UN	Collab.	AA: 013 No. And there are a lot of differences
	Claim	T1	014 between…with their empirical and inferential…
	UN		S12: 015 It's very tentative right now
		Emp.	AA: 016 Very tentative…
		Infer.	S12: 017 like they're trying to find the shape of it
		Tent.	AA: 018 and creative-ish. They're just trying…
	Premise	Tent.	
		Creat.	

In Table 10 through this dialogue, the students mention many aspects of NOS, including collaboration, empirical data, inferential, tentative, scientific method (experiments), and creativity. Many of the claims by students AA and AB lacked any logical explanations for their expressions, so they were unsupported Type 1 comments. While their claims seemed to be quick and looked for a simple causation, the NOS terminology did not show any logical advantage for using these terms. The vocabulary isn't necessarily used improperly during this discussion for the reading. However, the effortless NOS language barely showed what the students were trying to explain. The students in Table 11 debate about the proper NOS terminology used in these chapters.

Table 11

Type 1 Example for Students AA and AB

Date Activity	Elements of Reasoning Quality of Reasoning	Type 1 or Type 2 NOS aspect	Transcript (Student or teacher participating and transcription line numbers)
5/14 Double Helix discussion day 3	BD PH	T1 Collab.	AB: 029 I think it's all of the above because…yeah Maurice and Roselyn…they collaborated and that's for sure
	BD PH	T1 Socio	AA: 030 Yeah, I feel like this is where the sociocultural issues come in…
		Subj.	031 Yeah the description is very one sided. It really doesn't leave room for other interpretations
	Claim UN	T1	AB: 032 It's his way or the high way

The NOS vocabulary was abundant in this vignette, since almost all of the tenets were mentioned, but students AA and AB merely made claims that had no backing or very little evidence to support why the reading was regarding that NOS tenet. For example, student AA mentioned sociocultural issue in line 030, and supported their reasoning by saying it doesn't leave room for other interpretations. This was backing with data, but only with an experiential explanation for the reasoning. This could have been better analyzed with subjective descriptions, or how it pertained to sociocultural aspects.

Student AB made claims about collaboration in line 029, and backed it up with an explanation. However, there was no clear evidence to why they were collaborating, and thus used the quick shortcut to end their point. Type 2 elements could have been exposed in these ideas, but Type 1 was primarily observed during this discourse. Table 12 illustrates an improved examination of some key NOS concepts, but there is still limited depth into what these claims actually mean.

Table 12

Type 1 Example for Students AA and AB

Date Activity	Elements of Reasoning Quality of Reasoning	Type 1 or Type 2 NOS aspect	Transcript(Student or teacher participating and transcription line numbers)
5/17 Double Helix discussion day 5	Claim UN	T1 Infer.	AB: 026 Following any major tenets of nature of science here, um I'm pretty sure he's adhering to that inferential one because he is inferring
			AA: 027 What number is this?
			S10: 028 number two?
	BD PH	T1 Exper.	AA: 029 He kind of used scientific method cause he's messing with his little models
			AB: 030 True
	BD PH	T1 Tent.	AA: 031 Tentative because he already like doubting himself
	BD PH	T1 Emp. Infer. Creat. Tent.	AA: 056 I thought empirical and inferential could be interchangeable kind of 057 And then creative and tentative. So you could do like empirical and tentative and then creative and tentative
			AB: 058 Yeah. Very important concepts

Student AA at the end of this vignette (line 056) mentions many aspects of NOS, but they do not explicitly explain how these concepts relate to the reading. Student AB made claims about adhering to the inferential tenet in the beginning at line 026, yet simply backed up their ideas by saying the scientists were inferring. This does not suggest any logical type of processing, and while the students in the group used the NOS key words often, and show forecasting of Type 2 thinking, there was not a significant amount of cognitive evidence to support their claims during this discussion.

The discussion on 5/22 provides an example of Type 1 thinking that occurred during the reading of "Women's Brains" and includes two excerpts from students AA and AB. Both had valid arguments against the article, but used more experiential thinking and aimed to seek causation, rather than support their opinions beyond the phenomenological (experiential and only one piece of data) level. Student AB, because of the society and time they lived in, dismissed the argument that some scientists thought that women had inferior intelligence because they had smaller brains. For example, Student AB did supply an example of Type 2 thinking by relating the size of the

brain and intelligence as not correlational when she said that, “Initially, I was like ok they’re stupid cause you can’t…just because your brain size is smaller doesn’t mean that you’re any less intelligent or what ever.”

However, the claim supporting this looked for causation, which is an element of Type 1 thinking. She stated, “But at the end of the article I kind of thought about it, and I was kind of like they’re in the 1800s, do they really know any better? That’s the kind of society they were brought up in.” No further descriptions of why society tolerated these ideas were supported in her argument; hence she exhibited more Type 1 processing.

Student AA in lines 028-029 was close to presenting some Type 2 processing when she mentioned, “The things that they kept thinking had been true, like women were always inferior. They were just trying to prove, but they weren’t looking to disprove it.Yeah, they were still looking to prove it which is wrong that the scientists were trying to prove, not disprove the theory.” This would have been considered Type 2 if she expanded on why trying to disprove the idea was better, rather than prove it with a limited explanation. She defaulted to simply expressing it was wrong, which displays more of a quick Type 1 thinking pattern, rather than a more logical process like Type 2.

Type 2 Thinking for Students AA and AB

Table 13 gives an individual example of Type 2 thinking for students AA and AB. These examples are presented in chronological order. Table 13 uses a combination of Type 1 and Type 2 thinking to infer during a NOS intervention.

Table 13

Type 2 Example for Students AA and AB

Date Activity	Elements of Reasoning Quality of Reasoning	Type 1 or Type 2 NOS aspect	Transcript(Student or teacher participating and transcription line numbers)
5/6 Blocks lab Students contemplate the unknown side of the block	Claim UN	T1	AB: 021 Ok so the number in the top right hand corner is how many letters are in each name 022 Ok. I don't know what the number in the bottom corner means
	BD RL	T2	AA: 023 Ok I see where you're going there, but yeah like what's at the bottom? 024 It's like they all add up 025 there's 2,3,2,3 AB: 026 Maybe it's…um no
	Claim UN	T1	AA: 027 Maybe it would be 5,4 again. And then up here AB: 028 What?
	BD RL	T2	AA: 029 Maybe it would be 5,4 and then another name starting with F. Then it would be 5,1

Through this discourse, students AA and AB were trying to figure out what numbers and name was on the bottom of the blocks based on the information from the other sides of the cube. While there was a deducing process present and some elements of Type 1 thinking involved during the conversation, most of the ideas were structured to logically figure out the unknown question. The students made claims that were initially unsupported, using Type 1 thinking, but eventually used rational, Type 2 thinking to make inferences to what could be on the unknown side. Both students eventually came to the final conclusion of through the process of applying heuristics (Type 1) to making an educated decision (Type 2) for what should be found on the bottom of the block.

There are four examples that demonstrate student AA's ability to explain the components of science, and relate it to aspects of NOS taught during the intervention. During student AA's 5/7 discussion on the myths of the scientific method, she relates the idea that science cannot answer all questions, especially the ethical ones that attempt to solve issues pertaining to society. She states,

“Number eight says that science and it’s methods can answer all questions, but this is only true when the ideas can be falsified or scientific. So topics kind of like abortion and things like that, where it’s more of society’s ethical question. Scientists cannot really be asked to answer that.”

On 5/8, the student continues to explain the steps of forming a hypothesis, and then potentially being able to falsify the experiment or data with new evidence. “Once you make that inference, you can make a hypothesis if you do the steps. But, you do something to confirm it. Even then, there is still something; some evidence that could come up that, I guess, falsifies the evidence.” This was brought up during a classroom discussion of what defines science, and being able to falsify an experiment is a logical step in determining if the data is credible. This involves Type 2 processing, since it is a conscious effort to explain how anything in science could be deemed valuable.

During the first Double Helix discussion on 5/12, student AA utilizes the NOS terminology properly and is able to relay how the sociocultural aspect is important in science. For example, she mentions, “We realized on this umbrella, that this is sociocultural because lots of the social trends and the cultures play a big role in how they believe things, and how they react to other people when they present their theories.” The influence of society’s impact on how science is perceived accurately during this discussion.

On the fourth discussion of the book on 5/15, student AA applies a Type 1 unsupported claim with further evidence of their point, using associative culture as the keystone word. She then supports the claim with five NOS aspects, stating they apply to associative culture, and make the author’s point stronger. “He’s like I’ve already figured that out why do you need to waste more time? So that would be associative culture I think…um tentative, creative, empirical, inferential, and subjective; the elements that already support his argument, and make it strong.” This indicates

Type 2 thinking, since it is deliberate and conscious of how those particular aspects help integrate into the culture. The word association is a characteristic of Type 1 thinking, but student AA is not presenting it in that manner to establish their message.

The final discussion displays Group A's presentation of the blocks lab summary to the class. Student AB demonstrates a logical process of making an inference to what is found on the unknown side of the cube. Her explanation uses Type 2 thinking to support her inference, rather than making an unsubstantiated claim.

> Professor: ok, I understand that one so, what about this one?
>
> AB: umm.. well we thought that the number was supposed to be seven because that's how many letters are in the name.
>
> Professor: Ok so you want to change this one?
>
> AB: Yeah. Then we put Frances because that is a girl version of Frank and we looked for, I don't know, similar letters
>
> Professor: Ok, similar letters we have another Francesca?

During day 4 of the Double Helix discussion on 5/15, the student integrates a Type 1 claim with a Type 2 point, stating that the scientists knew it was a genetic material rather than a protein that transfers genetic information between generations. "Yeah, that they can move on to something that will…Cause they know it's genetic material so they know more of what they're working with now, as opposed to thinking it was a protein and do whatever protein testing." Although this claim doesn't express a completely logical and coherent message to the group, she is able to make a deliberate claim as to what the chapters contained; that DNA was not a protein, and had to be something different from the tests being performed.

On the final day of discussion on 5/22, student AB focuses on some of the "sexist" parts of the book and the "Women's Brains" reading, mentioning that her perspective on science and men had not changed. "I think that with the nature of science, I never really thought about it with the whole umbrella thing, and all that stuff. I didn't know you could be tentative or any of that. I think

it puts that into perspective a bit more." This quotation demonstrated a brief reflection of the overall study. One of the components of Type 2 thinking requires a slow, reflective process, thus her ideas about the readings were backed with data and were relational. Student AB also pointed out that she wasn't aware of certain aspects of nature of science, such as things being tentative, and could put things into perspective a bit more often.

Type 1 Type 2 Summary of Students AA and AB

Students AA and AB both started out with a fair background in science in general, and were able to demonstrate proper use of the NOS vocabulary throughout the study. Through the blocks lab intervention example, the students combined Type 1 claims with Type 2 backing data and evidence to support their inferences. During the individual group discussions, student AA relayed that science can be supported by trying to falsify a theory or experiment. She stated, "But, you do something to confirm it. Even then, there is still something; some evidence that could come up that, I guess, falsifies the evidence." If the evidence cannot be refuted, then it strengthens the theory.

Student AB's reflection on learning about new aspects of NOS exemplifies that there was some education in this area, but did not use the NOS terminology as often as student AA. That doesn't necessarily mean that student AA learned more about the NOS concepts, but she did provide more Type 2 thinking when using these words. See Table 12 for an example.

It appears that the students used both Type 1 and Type 2 thinking during the study. The effortless transition of Type 1 thinking during the reading discussion, followed by reflection, allowed the participants the ability to converse freely. The analysis of the text allowed for conscious and slow participation, allowing Type 2 processing to follow some initial Type 1 claims.

Students BB and BC

The first section describes Type 1 interactions for students BB and BC. These are group transcriptions, and were coded in chronological order. On 5/12 of the first Double Helix discussion, students BB and BC had a brief conversation about the concept if viruses were considered naked genes. Student BB hinted at the NOS aspects of sociocultural and subjective, but wasn't able to effectively show how these tenets applied to their claims. For example, "…so if the scientists that were in it to win it, does it feel like these viruses were naked? Then the public would view it that way too, and there was no room for different opinion, because most of the scientists thought that they were naked genes." While this demonstrated the influence of public views on the subjectivity of science, the student was not effectively showing how society perceived what naked genes were. This exhibited Type 1 thinking in that she attempted to explain the societal perception of viruses effortlessly, lacking the logical aspect of explanation in her claim.

Student BC discussed the concept of women in science, but this was a quick and effortless demonstration of processing. Her thoughts made conclusions rather quickly, with limited evidence, supporting that Type 1 processing was predominant in their review of the chapters on this date. "Yeah because women aren't really seen as superior, well not superior but what's the word…equal? In like the word field of science, I think that was part…not even equal. They're, like, less." The student attempted to make a strong point in the defense of women in science, but failed to elicit any valuable evidence to support the claim. This seemed to be a fast, and intuitive response to the reading material.

On day 2 of the Double Helix discussion, this conversation includes students BB and BC discussing how the scientists were trying to construct the possible structure of DNA. Student BC claimed that Watson didn't want to get into trouble and had to note that incident, which looked for

causation of his motives for studying in a foreign country. “I also think he didn’t want to get into trouble, so he kind of had to note that just in case they ever found out that he wasn’t really involved.” While this sentence seems fairly innocuous, this was an effortless statement, and didn’t have any substantial input in the group discussion.

Student BC also made a claim with some data to support it. “I thought it was cool, well it wasn’t cool, but it was smart of them to use the plant thingy, instead of like going in for what he really wanted; which was kind of deceiving.” This data was described as the plant thingy, and didn’t support any logical conclusion to suffice as Type 2 thinking. The limited description of the data did not support the claim in an effective manner, and therefore was a faster attempt to explain the scientist’s motive in the reading.

Student BB reported the findings from the reading, which was a premise since it didn’t contain any form of a claim. When it came time for the student to expand upon the premise, she was able to use the NOS terms empirically and collaborate, but didn’t have a definite grasp on how the terms were being applied. “Like…umm…the nature of science, using what they know about crystals, like empirically. Try and see if they can collaborate.” This was the extent of her claim. It was a conscious effort to try and explain how the myoglobin crystals were being used in the research, and thus could have been considered a Type 2 example. However, it was fairly rapid in sequence, and lacked any depth into the conversation, making it effortless. Hence, it was more appropriate to look at it as Type 1 thinking.

Day 4 of the *Double Helix* displayed a conversation where group B examined Watson’s collaboration with other scientists. Student BB used components of Type 1 and Type 2 thinking, and they used the NOS terms empirical and creative accurately. Her claim was backed with data, but it was experiential and opinionated in context. “Right, so he’s being a little arrogant, and if she

has empirical data, which I don't think she did. She was just being creative with the data that she has, then he should be able to believe her. But since she's a woman, and she was using...like…the creative nature aspect of nature of science, he didn't really." The added comment, "since she's a woman and she was like the creative nature aspect of nature of science," did not support the logical process of Type 2 thinking in their overall statement, relying on a faster approach to explaining their point of view. Therefore, the claim favored the Type 1 processing towards the end.

Student BC looked for significance and used the terms empirical, collaborative, and subjective.

> Let's see… Chargaff's work was not proven by empirical natures. He said that no explanation for his striking results was offered, and, but Chargaff thought they were significant. So he's basically just saying that…like…his findings were…like…they just didn't matter to him. The overall meeting, the collaborative part of it, was very…umm…I can't read that. But I think that subjective.

The attempt to display logical processing was evident, but it appeared to be more associative in nature. In addition to this, the lack of support as to why the collaborative and subjective terms should be used in their ideas was effortless, which is a defining component of Type 1 thinking.

Type 2 Thinking for Students BB and BC

Tables 14, 15, 16, and 17 demonstrate Type 2 thinking for group B. Table 14 shows Type 2 thinking for student BB, vignettes and examples are used for student BC, and the final Type 2 example is a combined conversation of student BB and BC displaying Type 2 processing. Furthermore, Table 14 shows student BB examining the blocks lab on 5/6 and illustrating a slow, logical explanation for the inference on the bottom. This NOS intervention was a typical example of the elements of higher order. On 5/12 during the first Double Helix discussion, the student showed a competent usage of the NOS terms creative, empirical, and experiment. These terms were used in appropriate context, supported her point about the reading, and showed a deliberate

attempt to describe the scientists' opinion of what identified a naked gene. See Table 14 for 5/6 and 15 for 5/9 examples.

Table 14

Type 2 Example For Student BB

Date Activity	Elements of Reasoning Quality of Reasoning	Type 1 or Type 2 NOS aspect	Transcript (Student or teacher participating and transcription line numbers)
5/6 Discussion on the blocks lab	BR RB	T2 Infer.	BB: 154 and, um, the..between Alma and Alfred 155 the top right number is even 156 and then between Rob and Roberta 157 the top right numbers are odd 158 so, the <u>inference</u> is that Frank's top number is five 159 then the top right number of Francesca would be nine 160 because that's odd as well 161 so that's just the pattern

Table 15

Type 2 Example For Student BB

Date Activity	Elements of Reasoning Quality of Reasoning	Type 1 or Type 2 NOS aspect	Transcript (Student or teacher participating and transcription line numbers)
5/12 Double Helix discussion day 1	BE RL	T2 NOS Creat. Exper. Empir.	BB: 068 and that ties into the nature of science by like creativity 069 because these scientist formulated 070 off of experiments using empirical data 071 they formed their opinion of what 072 the virus was which was 073 in their opinion a naked gene

During Day 4 of the *Double Helix* discussion, student BB expressed the notion of attempting to disprove data empirically, and taking ownership of any evidence that isn't supported with science. Her explanation was very logical, identifying with Type 2 thinking. See Table 16 below for this discourse.

Table 16

Type 2 Example For Student BB

Date Activity	Elements of Reasoning Quality of Reasoning	Type 1 or Type 2 NOS aspect	Transcript (Student or teacher participating and transcription line numbers)
5/15 Double Helix discussion day 4	BE RL	T2 Law vs. theory Empir.	BC: 022 Cause not that they proved that it's not what they thought 023 they have to… BB: 024 reformulate BC: 025 yeah, they have to come up with like a whole new plan BB: 026 That relates to science in general 027 because when a <u>theory</u> is obviously 028 disproven by <u>empirical</u> natures or 029 like data that you can actually see 030 scientist have to be willing to say 031 "yeah we were wrong" 032 and they have to admit their mistakes.

On 5/21, during the reading of “Women’s Brains”, lines 006-012 show a conscious demonstration of processing from student BB. They point out three NOS tenets in lines 009-010, supporting their claim that men at that time were already very sexist. This communication was aptly applied to the scenario, making it an educated and effortful claim. See Table 17 for this example.

Table 17

Type 2 Example For Student BB

Date Activity	Elements of Reasoning Quality of Reasoning	Type 1 or Type 2 NOS aspect	Transcript (Student or teacher participating and transcription line numbers)
5/21 Students discuss the article “Women’s Brains”	BE RL	T2 Empir. Infer. Empir. Subj. Socio.	BB: 006 Without reading the last two pages 007 you really feel like he’s sexist. He is using Brock as empirical data 008 and touching on the inference that scientists of that time made about the data 009 saying that girls brains are smaller so they’re inferior because they’re smaller. 010 That’s a way of interpreting empirical data 011 but it’s very sociocultural because the men at that time were already very sexist 012 so they had that view point in their mind that- BC: 013 Yes, it was just confirming their stereotypes for them.
	BD PH	T1	BB: 014 They’re trying to find a way to prove their on point.

Student BC displayed Type 2 reasoning during the presentation of the Myths of Science to class on 5/7. This presentation to the class used many components of NOS, but the student did not read from a paper. She was able to explicitly show the class what myths their group examined, using deliberate verbal descriptions through their explanation.

> BC: Ok, so myth nine was scientists. That scientists are particularly objective, and basically, it talked about how scientists, depending on their past experiences, and expectations, have a different outlook on the experiment. So, for example, if someone is doing an experiment and they have prior knowledge about it, they might think that something is unimportant when actually, to somebody else, it would be something that they didn't even know, and they would think it's spectacular. And then, there was this other thing called para-dig..I don't know how to say that.
>
> Mr. Jackson: Is it paradigm? I can't see from here
>
> BC: P-A-R-A-D-I_G. Yeah, it said it can provide direction for the research, but it can also struggle or limit investigations and anything that requires research endeavors necessarily limits objectivity.

Later in the same presentation, student 15 introduced another example of the ten myths in science. Following student 15's lead, student BC supported the group's argument with evidence of a real theory, like evolution, that is influenced by society. While student 15 read her thoughts from a note card, student BC informed the class without any notes, demonstrating the sociocultural NOS tenet effectively. For example, "…and we also saw that, in society, with like the evolution theory, a lot of people didn't even want to teach it in schools and stuff. Because, it didn't go with the belief; the traditional beliefs of humans." With the conscious example to defend her reasoning, Type 2 thinking was applied to the presentation.

The two students were able to deliberately express their opinions of the paper using evidence to support their claims, as well use components of NOS, during the discussion of "Women's Brains" on 5/21. Student BB used evidence directly from the text to show the fallacy of the size of brains and intelligence. She quoted, "And there was one point he made where the same

difference...113 grams after he calculated out 181.13, and was the same difference from a 5’4” man and a 6’4” man; so is that saying that none are affected by the mass of their brains, because that’s the difference between them. With the same logic, are tall men smarter than large men? That just doesn’t really make sense.” She was able to refute the idea with reliable information instead of jumping to conclusions.

Student BC referenced sociocultural values to defend her arguments against the author’s opinions, which was also highly supported with an effortful form of processing. “And that’s simply empirical and if you look at the data with no social or cultural viewpoints and you just look from a scientific standpoint, obviously that theory goes out the window." She is defining her interpretation about women’s brains with NOS terminology and conscious, logical processing in the discussion.

Type 1 Type 2 Summary of Students BB and BC

Students BB and BC were able to progress within the study with proper usage of the NOS terminology, as well as defend their claims with evidence as the reading discussions progressed. Student BB was effective in improving the thesis of their arguments, and also learned the concept of trying to disprove data as a form of theoretical support. Student BC showed a high ability to use proper examples during the Myths of Science presentation to the class without any notes. The Type 1 thinking from both students came primarily using comments that aimed to show NOS terms effectively, but lacked in depth on why they used those words. The Type 2 group discussion towards the end of the study included a very logical conversation about false data and the subjectivity of it by both students BB and BC. This displayed a maturity of how to use their NOS terms during discussions from the study.

Students CC and CD

The following section demonstrates examples of Type 1 thinking for group C. All dates are in chronological order. The first example includes the students' conversation focused mainly around stories from the reading to explain the events, or capture the essence of the text. Their claims were mostly opinion based, with limited evidence to support their assumptions.

On the first day of the *Double Helix* discussion on 5/12, student CC made a claim about Watson's selfishness, exemplifying a behavior without establishing ideas for which this bias was suggested. "Yeah. I said Watson wanted to become more familiar with genes, so he learned more about it without telling anyone else, so it was kind of again, selfish." This was an unsupported claim; making an assumption without any argumentative support. Student CD displayed the same form of explanations about the relationship between the scientists, which was primarily effortless and impulsive. "Yeah. Like his knowledge and insight and stuff? I put, like, there's kind of a weird tension. Like, they weren't friends, but they weren't not friends." While there was some insight into the reading discussion, the students demonstrated opinions in the form of what they felt, rather than with any visceral evidence to back it up.

Students CC and CD expressed emotional and experiential points in the fourth day of the discussion on 5/15, as did the rest of the group. Student CD argued that the scientists had the right to scorn each other when you have been around someone for a long time. "But they have the right to scorn each other, because when you've been around someone for so long, you argue and stuff." This sentiment was based on her experiences, and automatically made the conclusion it's normal to argue when you are around someone for long period of time.

Student CC claimed that the two scientists should have collaborated better, and it was unprofessional to scream at each other. "Yeah. Well anyway, I feel like it was kind of

unprofessional in a way because they should have been able to, in the nature of science, be able to collaborate better, instead of screaming at each other." Some of the NOS tenets were used as backing for their opinion; nevertheless, the discourse revolved around how the student felt about the chapter, and how the scientists were reacting to one another. The phrase, "in the nature of science", wasn't used appropriately during their interpretation of the context. This showed both of the students were responding to emotional processing during this discussion.

On 5/21 during the discussion on "Women's Brains", student CC displayed the dialogue that wavers between Type 1 and Type 2 thinking throughout the conversation. While many of the claims were supported with evidence and may have been valid, much of the support was highly experiential. The influence of her own beliefs looked to create stories to explain the events in the reading, or looked for causation. The vignette below shows one of the experiential Type 1 thinking examples from Student CC:

> Well, you're just hammering the same nail and, like, you think that it is so easy, and you don't have to be educated, because you really don't. You don't even need a high school diploma sometimes. When you're a construction worker, but because they were communicating with people, and because they were learning and discussing everything, they have the chance to go out and be social. While women have to sit there with children, and children have no intellectual thought.

Student CD exhibited emotional Type 1 thinking during this discourse as well in this discussion:

> And that's what he said, like gossiping. As stupid as that is, they had to create a language, and like a system. Men follow the same routine every single day. They have their set of rules that they follow to go hunting.

She backed her claim with support, so it was coded as a backing-evidence element of reasoning. However, the quality of reasoning was deemed as phenomenological. The statement was based on her personal beliefs and assumptions, and it leaning more towards Type 1 processing.

Type 2 thinking is effortful and logical, so there were elements to suggest the reader could evaluate this in that format. The overall consensus displayed was back and forth between the elements of Type 1 and Type 2, but with following one of the disadvantages of Type 1 thinking, the students jumped to many conclusions based on their own stories to explain the reading. In addition to this, an advantage to Type 1 thinking is creativity through associations, so this was portrayed in this vignette.

Type 2 Thinking for Students CC and CD

The following examples demonstrate individual Type 2 thinking for student CC. Student CD also exhibits individual examples of Type 2 processing. A vignette shows examples of combined Type 2 thinking for both students CC and CD during a debate on a reading reflection. All examples are in chronological order.

During the discussion of the mystery bottle on 5/5, student CC was conscious of backing up her analysis of the unknown bottle with logical steps to address the conclusions. The claim was made initially, and then supported with observations and reasoning behind why she suggested how the mystery bottle functioned. “Ok, I think there’s a ball inside of the bottle. And, first you put the string in obviously, and when you turn it upside down, the ball constricts the string from coming out so that’s when you pull on it. But you have to keep pulling on it before you turn it upside down, so it keeps the ball stuck in the tube of the bottle.”

On 5/7, the researcher conducted a brief discussion with the class. There was some prompting and facilitation with student CC, but her arguments expressed a coherent, thoughtful reference to the components of nature of science. Student CC suggested that she formed the models based on the observations, which led to an inference. The structure of the conversation lead the student to decide her own mediated conclusions, based on the previous NOS intervention.

CC: "Ok, the inferential. It talks about inferences and observations, and with the bottle and the rope activity, we have to distinguish which one we really think by saying that we see that there are two ropes. And that's our observation. But, we have to make an inference on what's going on inside of it. And that's how we got to make our models."
Mr. Jackson: "Your inference?"
CC: "Well, yeah we had to make an inference."
Mr. Jackson: "How did you make your inference?"
CC: "By using the observations we saw by pulling the ropes to see which ones moved."

During the 5/11 class discussion, student CC elaborated on how experimentation operates, pertaining to the mystery bottle and contents inside. "Experiments usually have the goal of identifying cause and effect, which again is what we did. And, that's kind of how they figured out how the rope and the tube worked. Because you have to do experiments to figure out what is actually going on under the black box as you explained earlier." The expression of using formal models to test unknown phenomena utilizes the logical processing, and is expressed here to the class during the examination of myth 10 of the reading.

Student CC continues to demonstrate a logical approach to the process of science, including the use of the terms analysis, speculation, observation, and experimentation. "Ok. Students are encouraged to associate science with experimentation, yet knowledge comes in a variety of ways including observation, analysis, speculation, and experimentation. Because, umm, how myth 10 is talking about how experiments is the way you kind of learn science." While the student may not completely aware that not all science requires experimentation to function, she is able to effectively portray Type 2 thinking in their reasoning behind how to infer what may be contained inside the mystery bottle.

On 5/15 during the Double Helix discussion on day 4, student CC examined the idea that bacteria may have two different sexes since they are able to reproduce sexually at times. This

notion was discussed with aspects of NOS, including that the assumption was inferential and collaborative since the scientists had to work together.

> I thought that it wasn't really possible when I first read it, but then when I continued to read more about it, I discovered that it was possible to have two different sexes because bacteria can mate. Also, how I thought this related to nature of science was it was inferential, because based on observation and inference. Also, it was collaborative because the scientists had to work together.

This processing was able to handle abstract concepts; the student mentioned she didn't believe it at first when they read the chapter, but was able to check her initial feeling with Type 2 processing. She supported her argument with backing evidence for the reasoning, showing a conscious effort to comprehend the idea of bacteria mating.

Student CD discussed the Myths of Science on 5/11 with the class. She evaluated the myth that science is procedural rather than creative, in which her group argued that creativity permits scientists the laws and imaginative theories. "The majority of laboratory exercises are verification activities. Instead of creating new things. Creativity of the scientist permits the laws and the imaginative theroies. Many students reject science as a career because they are not given opprotunities to see this as creative and exciting; only as following in other's footsteps."

Her opinion stated that it may turn students away from science and reject science as a career if it isn't seen as creative, which has elements of Type 1 thinking since this message looks for causation. However, both sides of procedural and creative are compared, which shows a reductive thinking approach. This aims to challenge both sides of the question, and shows the fallacy of one of the sides. This element of processing in an advantage of Type 2 thinking, which student CD exhibits during this discussion.

During the discussion of Women's Brain on 5/21, student CD opened up the argument that science is subjective and may be used to try and support a theory with inappropriate data.

> You can almost take any evidence of science and kind of skew it your way. It's just like when we had racism in America, they found genetic markers that suggested that black people were from apes or monkeys. And that's why they could use that, but they used science to be racist. Science didn't prove that they were lessor or different. It just showed that they weren't lessor; just that they were different, but that doesn't mean that one is better than the other. Just a less subjective point of view utilizing science to drive that.

The NOS terms used here were empirical and subjective, and supported her expression that science didn't prove that they (black people) were lessor or different. The quality of reasoning was rule-based, since student CD supplied a complete framework on the subjectivity nature in science, how it may be skewed, and the validity of empirical data when making an argument. The conscious decision to make a statement, provide an example, and conclude with how it affects science constitutes a slow and deliberate form of Type 2 processing.

The following examples demonstrate students CC and CD providing several instances of complete conversations that used Type 2 thinking. On the first day of the Double Helix discussion 5/12, student CD used sociocultural terms to deliberately examine how women weren't often accepted in the scientific community during the times of the DNA search. Student CC continued on with this idea, and added collaboration to the sociocultural debate. Both of the claims were supported with evidence from the book, and the conversation was able to develop in an organized manner, without rushing into conclusions not bolstered with information from the book.

> CD: "I don't know if this would work, but it's like sociocultural. Like men and women of many societies and cultures contribute to science, but then they like called that one girl Rosie, like a feminist, and said that she couldn't work with them. It was just because she was just a woman, and it's like not usually accepted, or it is now, but usually women weren't accepted as, like, intellectuals."
>
> Mr. Jackson: "That is sociocultural. That's good."
>
> CC: "And collaborative is because he, well, people kind of try to feed off of each other and figure out everything. And then in question #8, they're talking about social as well as academics. I was talking about how scientists kind of have to be social when they work together; to communicate about what they discovered in

order to help each other out."

On 5/18 during the Double Helix discussion day 5, the students were promoted with questions from the researcher. Student CC provided claims that were Type 1 based thinking, using NOS term appropriately, but jumped to her conclusions rather quickly. For example, she stated, "There would be no creativity or originality, or anything, so I think that we need to all think differently." This stimulated student CD to examine most of the aspects of NOS. She claimed, "If everyone were agreeing then, the nature of science thing, there is no nature of science. It would be like… cause creativity is gone. Collaboration is kind of gone. Sociocultural is gone, so basically, just empirical. Nothing would change so, it's all the same." With further questioning from the researcher, student CD continued to analyze other NOS tenets, finalizing the combination of logical and effortful processing to observe how the NOS terms could be applied to the conversation. While student CC didn't demonstrate any Type 2 examples in this conversation, she was able to support the group thinking, and guide student CD to evaluate most of the NOS terms.

With the reflection class on 5/22, student CC collectively discussed the readings, her opinions on the sexism in the text, and the NOS terms.

> "Yeah. It was good to learn about all the different types of nature of science. Like collaborative. I would have never have figured that, or sociocultural. I would have never have thought of that as a nature of science aspect. We learned about empirical and inferential and stuff like that that also helped out a lot. To, like, conduct experiments and see science differently. Creativity has always been like a really big thing in science, and it was kind of cool to see how different people use science and like use it differently."

Student CD reflected on how the students were able to learn about the different levels of science, and not just the scientific method commonly taught in class. "I'm happy we learned about the different levels of science. Not just, like how we're commonly taught, like, scientific method is, like, the only way to connect experiments. Like, it was good to see there was other

(differences)." Both of the students used Type 2 thinking because they were able to see the bigger picture of what the study involved, and briefly interpret the NOS terms they had learned. Students CC and CD also agreed that certain terms would never have been part of nature of science, considering an alternate form of previous science knowledge associated with Type 2 thinking.

Type 1 Type 2 Summary of Students CC and CD

Students CC and CD were very opinionated, and liked to discuss the topics in depth. Student CC was especially argumentative and verbose, often displaying quick Type 1 thinking when making her claims. Student CC did provide several moments of evidence-based reasoning and Type 2 thinking, especially as the discussion days progressed through the study. Student CD used more of a logical approach to her arguments, but did not provide as many Type 2 examples as student CC. The group Type 2 discussions were larger in volume than other groups because of their propensity to discuss the readings in depth, and display any NOS terms that were prompted from the reading questions. The reflection and analysis of what they learned summarized their experiences during the study.

Conclusion

The six students chosen were actively engaged in the multiple days of reading reflections. These students were a sample of the total *N* of 29 students. Other students did show areas of Type 1 and Type 2 thinking within the transcriptions, but the purposeful sample represented the elements of reasoning and quality of reasoning that the EBR framework aimed at displaying the two forms of processing. The readings were designed to engage the students with a framework for discussing the readings, and support the NOS intervention by using NOS terms when appropriate. The overall quantitative and qualitative data will be connected in the research questions to observe any findings from the study.

Research Question 1

Do the experiential processing (Type 1) and the logical processing (Type 2) influence the development of students' NOS views?

The chi-square analysis did not show any statistical significance in presenting that the students' NOS levels were improved during the study. The percentage change from the informed and pre-informed responses increased (14%, 17%) in frequency, while the mixed and uninformed decreased, i.e. improved, (26%, 24%) in numbers from the pre to the post. This indicates that while no statistical significance was achieved, the levels of NOS responses changed during the study. Having a higher number of informed and pre-informed responses in the post study, as well as seeing a lower number of mixed and uninformed responses, suggests that the students did expand their NOS scores from pre to post.

With the six students and their analysis of Type 1 and Type 2 thinking, Table 12 below shows their individual changes from the pre and post NOS survey. The ten aspects were evaluated for each student, and their levels are shown below. Since the levels go from (a) Informed, (b) Informed-NE, (c) Pre-informed, (d) Mixed, and (e) Uninformed, an improvement of one level is indicated as a +1 (e.g. mixed to pre-informed). A decrease in levels of -2 indicated two levels were dropped (e.g. Informed-NE to Mixed). If there was no change, or a pre and a post response were not provided, then a 0 will be shown. See Table 18 below.

Table 18

Students AA, AB, BB, BC, CC, and CD Individual NOS Changes.

		Emp.	Infer.	Tent.	Creat	Subj.	Exper.	Bound	T/law	Socio	Collab.
AA											
	Pre	Mixed	Unin	Infor	Inf-NE	Pre	Mixed	none	Unin	Unin	none
	Change	+2	+1	-2	-1	+2	+1	0	0	+4	0
	Post	Infor	mixed	Pre	Pre	Infor	Pre	none	none	Infor	none
AB											
	Pre	Mixed	Infor	Infor	Infor	Infor	Mixed	Pre	Unin	Infor	none
	Change	0	-2	0	-1	-1	+1	+2	0	0	0
	Post	Mixed	Pre	Infor	Inf-NE	Inf-NE	Inf-Ne	Infor	Unin	Infor	none
BB											
	Pre	Mixed	none	Pre	Mixed	Inf-Ne	Unin	Inf-Ne	Unin	Pre	none
	Change	+3	0	+1	+2	-1	+3	0	0	+1	0
	Post	Infor	Inf-NE	Inf-NE	Infor	Pre	Inf-NE	none	Unin	Inf-NE	none
BC											
	Pre	Mixed	Pre	Pre	Infor	Inf-NE	Mixed	none	none	Unin	none
	Change	-1	+2	0	-3	+1	0	0	0	+3	0
	Post	Unin	Infor	none	Mixed	Infor	Mixed	none	Unin	Inf-NE	Pre
CC											
	Pre	Unin	none	Unin	Unin	Unin	Unin	Unin	Unin	Unin	none
	Change	0	0	0	+1	+3	0	0	0	+2	0
	Post	Unin	Inf-NE	Unin	Mixed	Inf-NE	Unin	Unin	Unin	Pre	none
CD											
	Pre	Mixed	Pre	Pre	Mixed	Infor	Mixed	Pre	Unin	Infor	none
	Change	+2	+1	+1	+3	-1	+3	+2	0	0	0
	Post	Inf-NE	Inf-Ne	Inf-Ne	Infor	Inf-NE	Infor	Infor	none	Infor	Inf-NE

This sample represents the population of students, so the empirical, inferential, subjective, experiment, and sociocultural aspects improved the most. Bounded, theory vs. law, and collaborative had little or no change from the study.

To connect the influence of Type 1 and Type 2 on any NOS change, the proper use of the NOS vocabulary is valued. The advantages of having creativity through association in Type 1 thinking may have allowed the students to look for repeating patterns in the readings. When prompted to examine the text for themes of NOS aspects, the students were able to quickly

interpret the use of terms like subjectivity in evaluating data, inferences from observations that lead to experimentation, and the influence of society in how ideas are supported. Because this is associative and creates stories to explain events, the students used Type 1 thinking to debate about the reading content openly, without having to peruse back through the pages and find evidence to support their claims. While this is an advantage when having an effortless conversation, the students did often jump to quick biases and opinions. This may have influenced the fast assimilation of the NOS terminology into their discussion, resulting in a moderate increase of the post NOS response scores.

With regard to the students Type 2 responses, some of the prompt questions from the researcher and through the reading questions aimed at facilitating a more rational discussion. In combination of their unsupported claims during the discourse, the students did provide multiple examples of logical ideas, supported with evidence learned from the intervention and readings. Since these terms require a more conscious attention to their explanations, the students had to thoughtfully relay their ideas to the group.

Although there was a slight improvement in the NOS scores, the direct link between the NOS vocabulary usage and Type 1 or Type 2 thinking is speculative. The mixed method approach aimed at showing the influence of Type 1 and Type 2 thinking on the NOS scores. Since using NOS terms during the discussion was primarily prompted based on the reflection questions or from the researcher, there seems to be no formal conclusion on whether Type 1 or Type 2 had any ability to modify these NOS levels. Therefore, research questions two and three are regarded as sub-questions to research question one.

Research subquestion 1a. If there is an influence on students' NOS views, then what is the nature of relationship between experiential (Type 1) and the development of NOS views?

The qualitative demonstrations from the students show that the NOS vocabulary was used in the Type 1 examples. The use of these key terms was commonly impulsive and intended to support their claims, but kept the conversation progressing in a casual sense. Some of their motives to explain the reading using NOS words failed to explicitly relay why they chose to use that term in that specific context. Other times the students would just mention the term, or agree with a classmate that the word was appropriate in that analysis.

AB: "Following any major tenets of nature of science here, um I'm pretty sure he's adhering to that inferential one because he is inferring."

> AA: "What number is this?"
> S10: "Number two?"
> AA: "He kind of used scientific method cause he's messing with his little models."
> AB: "True."
> AA: "Tentative because he already like doubting himself."
> AA: "I thought empirical and inferential could be interchangeable kind of. And then creative and tentative. So you could do like empirical and tentative and then creative and tentative."
> AB: "Yeah. Very important concepts."

The students here are discussing the major NOS aspects, but lack any conscious effort to explicitly relay how the tenets pertain to the reading. The dialogue is conducive to automatic thinking, which is in the pattern of Type 1 thinking. There is very limited substantial dialogue, but the conversation is able to progress openly. Student AB is simply agreeing with student AA, noting that the discourse is one-sided, and lacks any further development in the interpretation of the text.

Students BB and BC also had similar Type 1 examples during the reading reflections. The conversation leaned heavily on fast processing, and failed to examine the context in a deliberative format in order to discuss the NOS aspects thoroughly.

BB: Right. So he's being a little arrogant, and if she has like empirical data, which I don't think she did. She was just being creative with the data that she has, then he should be able to believe her, but since she's a woman and she was using, like, the creative nature aspect of nature of science. He didn't really…

S13: Constant conflict.

BB: "Right…ok…do you have anything to say?"

BC: "I think also he's like more motivated to like do his own research. Kind of, to go out of the way, to like, instead of putting it all on somebody else. He's going to go out of the way, and look for something that is going to benefit him."

BB: "That's good…ok."

The students analyzed the reading very quickly. It's not the speed of the interpretation; it's the quality of dialogue that is established during the conversation. Students BB and BC attempted to use NOS terms to make a point, but it was rushed. They planned on moving on to the next reading question with haste. Students CC and CD argued about the role of women and men in society in the next example:

CD: "And that's what he said like gossiping as stupid, as that is they had to create a language, and like a system. Men follow the same routine every single day. They have their set of rules that they follow to go hunting."

CC: "And back in like the prairie day too, I don't know what era that would be called, but men, they like, build houses and stuff like that. And it's so routine; it's just like an assembly line. You go and you do what you do every day."

S18: "I work in construction and they literally are the same thing every single day. Every job file, if you file through it has the same. Nothing is different. The tests are the same for like a

general contractor."

CC: "Well, you're just hammering the same nail, and like, you think that it is so easy, and you don't have to be educated, because you really don't. You don't even need a high school diploma sometimes when you're a construction worker. But because they were communicating with people, and because they were learning and discussing everything, they have the chance to go out and be social. While women have to sit there with children, and children have no intellectual thought."

The NOS sociocultural word was not used here, but the relevance of the term diffuses throughout the conversation. The students provide examples to support their claims, but they are experiential or opinion based. The students often jumped to conclusions or involved emotional responses, which is Type 1 orientated. These examples show how Type 1 thinking facilitates the conversation, and how NOS aspects were used in an automatic sense. This leads in to where Type 2 thinking is involved in NOS discourse.

Research subquestion 1b. What is the nature of relationship between logical (Type 2) and the development of NOS views?

Type 2 thinking is a more conscious and logical approach to the situation. In this vignette, students CC and CD are having a conversation about the work of Rosalind Franklin with James Watson. The researcher is helping structure the dialogue to observe if the students actually comprehend what is important in the reading as it pertains to NOS aspects.

> CD: I don't know if this would work, but, it's like sociocultural. Like men and women of many societies and cultures contribute to science, but then they like, called that one girl Rosie like a feminist, and said that she couldn't work with them. It was just because she was just a woman, and it's like not usually accepted or it is now, but usually women weren't accepted, as like, intellectuals."
> Mr. Jackson: "That is sociocultural. That's good."
> CC: "And collaborative is because he…well…people kind of try to feed off of each other,and figure out everything. And then in question #8, they're talking about social, as

well as, academics. I was talking about how scientists kind of have to be social when they work together; to communicate about what they discovered in order to help each other out. And that's, like, the collaborative."

Mr. Jackson: "That's good."

The students were able to effectively communicate their ideas along side using the NOS tenets appropriately. This was established with very limited facilitation from the researcher. However, this was a guided process that required cognitive effort and took time to develop to relay their sentiments accordingly.

Students BB and BC had a logical argument to the reading "Women's Brains." This process was initiated with a response question, but the students branched out from the stimulus, and used Type 2 thinking in accordance with NOS tenets.

BB: "What weaknesses or problems were there with this data and their interpretations to Gould's point?"

BC: "The fact of how they all died is different and the heights of all the women."

BB: "And there was one point he made where the same difference. 113 grams after he calculated out 181.13. And was the same difference from a 5'4" man and a 6'4" man. So it is that saying that none are affected by the mass of their brains because that's the difference between them. With the same logic, are tall men smarter than large men? That just doesn't really make sense."

S15: "It kind of just collapses on itself for that one."

BC: "And that's simply empirical, and if you look at the data with no social or cultural viewpoints. And you just look from a scientific standpoint, obviously that theory goes out the window."

The points made in the discussion are supported with data, and the viewpoints make for a firm case against the reading. This can only be accomplished with slower, more analytical Type 2 processing. Students AA, AB, and student 9 also followed the reading questions. It is a brief conversation, but ends with a Type 2 example from student AB. This shows the expression doesn't have to be purely scientific or intellectual. It has to have non-experiential, logical support, whether it is correct or incorrect.

AB: "Yeah proof. Ok Moving on to queston#2?" What is the significance in his research?"

S9: "The timing starts to prove that their theory for DNA is holding more weight cause it's not protein now. They know that."

AA: "So it's completely out of the picture? A more straight forward…you know…I lost my words."

S10: "Oh yeah. It kind of like changed their perspective."

AB: "I think it's significant because eliminating that it's a protein that, like, wipes out like a lot of different, like, theories that they could have had."

AA: "That they…"

AB: "Yeah, that they can move on to something that will. Cause they know it's genetic material so they know more of what they're working with now. As opposed to thinking it was a protein and do whatever protein testing."

The students in all of these examples exhibit a more developed usage and elucidation of the reading context and NOS vocabulary. The role of Type 2 thinking is to allow for reflection, and be cognitively malleable to different scenarios. With prompting from the reading questions or the researcher, the students were capable of expanding on their thoughts. This required more time and cognitive resources, but the thesis was comprehensible for the audience. The role of Type 1 and Type 2 thinking and NOS in science education will be discussed.

CHAPTER 5

DISCUSSION AND IMPLICATIONS

Based on the current methodology, there was no direct relationship found between Type 1 and Type 2 thinking on NOS development. The NOS levels did improve in certain areas (e.g. empirical, inferential, subjective, experiment), and showed limited or no growth in other tenets (e.g. bounded, theory/law, collaborative). Any correlational link between Type 1 (T1) and Type 2 (T2) to NOS seemed to found within the NOS vocabulary and practice during the reading reflections. The interventions provided examples of the dual processing, but it was aimed at assimilation of the terms in preparation for the rest of the study.

Type 1 processing is good for capacious thinking, which is why it can lead to options not presented from the reading prompts or questions from the researcher. The indirect influence of Type 1 on the students' NOS views guided the discourse process to lead to reflections, which is present in Type 2 thinking. The creation of dialogue often requires effortless opinions or views in order to stimulate the conversation. Through this catalyst of information and perspectives, more logical thinking can be observed in Type 2 thinking, which is more appropriate in science education.

Some of the context in the Double Helix readings (Watson, 1968) did suggest sexism towards Rosalind Franklin from scientists likeWatson, and the reading "Women's Brains" was included to observe the subjectivity in science. These discussions elicited personal beliefs in many of the students, triggering emotions, and motivating the use of Type 1 thinking. When promoted to support their ideas with NOS terminology, this emotional response activated the use of NOS aspects; sometimes properly, and other times without much support for their claims. The students were also able to correlate the readings with their own experiences, allowing for processing to

occur more rapidly. The speed of the response is valuable when having a discussion on topics that may be subjective or controversial, so Type 1 thinking is important to ease the discussion along to foster ideas and debates.

The qualitative examples of Type 2 thinking from the students presented some logical processing during the study. Type 1 thinking framed the dialogue to flow smoothly, and the role of Type 2 thinking was to slow down the processing to support their claims. It also checked their Type 1 claims with evidence, and possibly reevaluate why they made that claim. These improvements are vital to de-biasing beliefs.

The Type 2 thinking examples showed not only effective usage of the NOS key words, but also when the students should use that term appropriately. The participants showed an improved awareness of what the meaning of the NOS terms were, and how those terms applied to science. This was noticed as the study progressed, and as the class was able to practice using those terms while reading scientific literature.

The final role of Type 2 thinking on the development of NOS views was reflection on the ideas presented in the intervention and readings. The initial reflex of Type 1 assumptions created the opportunity for reflection, which is important to the accommodation of new information. The NOS vocabulary became more familiar when using Type 2 thinking, but this did not show a direct influence on their NOS scores. Using the appropriate terms in context is important, but Type 2 thinking wasn't essentially the determining factor in guiding the use of those terms. Some of their Type 2 examples came after using Type 1 thinking, displaying the processing became slower and more effortful. Type 2 thinking also allowed for reflections of each reading, incorporating the NOS tenets into their vocabulary as they proceeded through the study. With the prompting from the readings, the students became aware of when to apply some of the key terms, but it wasn't

always logical. It was a combination of how the students discussed the literature with quick, Type 1 thinking, followed by analysis of the questions guided by Type 2.

Promoting scientific literacy involves not just the rote knowledge associated with scientific vocabulary; it requires the proper application and ability to modify the usage of the language when the term is required. “A literate citizen should be able to evaluate the quality of scientific information on the basis of its source and the methods used to generate it. Scientific literacy also implies the capacity to pose and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately" (National Research Council, 1996). Marks and Eilks (2009) examined the teaching approach that promotes reflection on scientific questions by inserting authentic and controversial socio-scientific issues in chemistry. The evaluation and communication associated with this pedagogy helps promote scientific literacy. The association in how T1/T2 thinking might be active during the process could help structure the scientific questioning preparation for the learners.

Abd-El-Khalick and Akerson (2004) suggested that structured reflections and modeling through classroom dialogue were able to help pre-service teachers reconcile their meaning of NOS. This shows that although the prompting by the reading reflection questions or by the researcher was the primary reason why the NOS terms were being used in the discourse, it still modeled practicing of how to apply the terms to the content, and reflect on what had been read each session of the study.

The explicit-reflective approach to teaching NOS is supported as an effective means of pedagogical practices (Abd-El-Khalick, & Lederman, 2000). Therefore, the most beneficial practices to understanding the use of NOS in the classroom is to introduce the major tenets, structure inquiry-based activities that help promote logical thinking and discussion, and allow the

students to reflect back on what they had observed or learned. This may include a guided class discussion by the teacher, a quick group conclusion essay, or questions that tie the NOS vocabulary with the learning activity.

In classrooms where students are encouraged to make meaning, they are generally involved in "developing and restructuring [their] knowledge schemes through experiences with phenomena, through exploratory talk and teacher intervention" (Driver, 1989). The current study included a five-day NOS intervention, and readings that were aimed at allowing the students to discuss and reflect upon the material. The goal was for the students to apply their newly acquired NOS information to literature that could be viewed from different perspectives. This advocated for scientific literacy, even though there was no causality link between Type 1 and Type 2 thinking and NOS improvement.

Blachnowicz & Fisher (2000) advocated for the use of vocabulary in all classrooms. While most of the NOS words used may not have been foreign to AP students, their application to how the words pertained to science as a whole might not have been clearly developed. Some of the students in this study expressed that they never thought creativity or sociocultural aspects would have been some involved in science.

Word consciousness is a known form of literacy that means having an interest and awareness of words. Reading comprehension and vocabulary are best served by spending time on reading texts on the same topic and discussing the facts and ideas in them. This kind of immersion in the topic not only improves reading and develops vocabulary; it also develops writing skills (Hirsh, 2003).

With the NOS vocabulary being the link to dual processing, the ten aspects used in this study served as a catalyst to promote both Type 1 and Type 2 thinking during the discussions. With

the combination of these forms of processing, the influence seemed to be a scaffolding method of dialogue. Type 1 utilizes the heuristics previously learned to attempt to solve a problem; Type 2 expands on these methods, reflects upon the scenario, and attempts to logically solve the situation. See Figure 1 below.

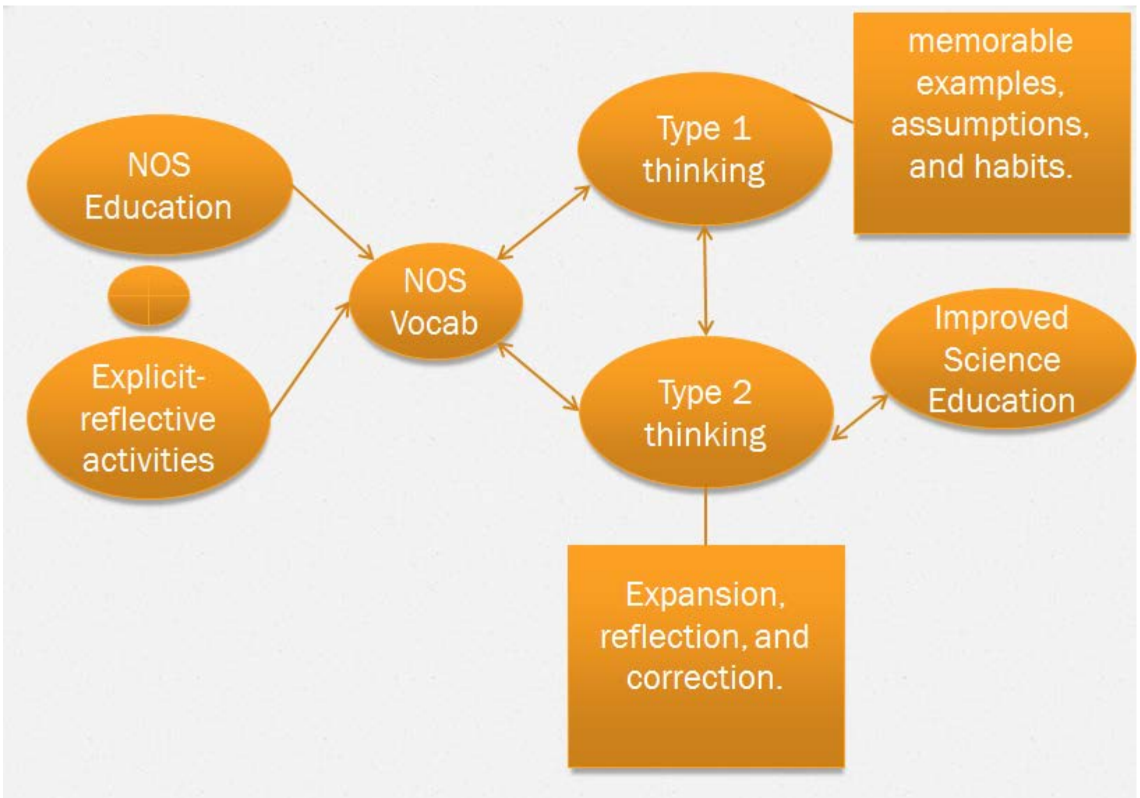

Figure.1. With the addition of NOS education in the classroom, the students may be able to investigate a claim or theory with better comprehension of how to form logical solutions.

This scaffolding is initiated with Type 1 thinking. Shah & Oppenheimer (2008) state that Type 1 thinking is advantageous because: (a) examine fewer cues, (b) reduce the difficulty associated with retrieving and storing cues, (c) simply the weighting principles for cues, (d) integrate less information, and (e) examine fewer alternatives. After each reading session, the results were prompted with questions in order to instigate dialogue about the text. The students,

primarily using Type 1 thinking as a foundation for the conversation, initiated the discourse. The pace of a normal conversation requires memorable examples, assumptions, and habits to exchange ideas or information. These are all characteristics of Type 1 thinking. With the addition of complex questions or ideas, commonly associated with scientific education, Type 2 thinking can correct errors made with Type 1, or expand upon the idea with evidence.

Because Type 1 and Type 2 are not exclusively used during discussions, they often switch back and forth during the process. Type 1 has its advantages in processing, so it is not observed as a weaker form of processing. However, when analyzing a problem, formulating a hypothesis, or making logical claims, Type 2 has the advantage. This is especially important in science education. Type 2 thinking doesn't always have to be correct either; it is the intended form of processing that is significant in pedagogical framework. Misconceptions may be adjusted later, as long as the educator is aware that these claims should be re-examined. The students in this study made several claims that were not completely accurate, but still demonstrated components of Type 2 thinking.

The goal of explicit-reflective NOS education would then be to expose the students to the varying aspects, allow them to process the activity or content in ways that they are accustomed to using Type 1 thinking, and then proceed to foster the use of Type 2 thinking with prompting, inquiry-based experiments, and the promotion of reflection during discussion. The Socratic means of questioning may help influence the switch between quick, experiential dialogue, and focus more on other ways to define a question or topic. Since Type 2 is generally connected to logical processing, the ideal role of the dual processing theory is to allow the dialogue to progress naturally, but ultimately end up with a conscious, effortful analysis. This may connect former ideas, fix any incorrect assumptions, and weigh the consequences of their decisions. Since this is aligned with the goals of scientific literacy, the benefits of allowing both Type 1 and Type 2

thinking to cooperate may lead NOS education effectively.

Future Research

While the study aimed at combining quantitative and qualitative measures to connect Type 1 and Type 2 influence on NOS education, no correlational statistic was applied to the data. Establishing a parameter of how to more effectively quantify Type 1 and Type 2 thinking would benefit this body of research by allowing a test to be performed, possibly linking NOS scores directly with each form of thinking. The EBR framework could still be applied to the dialogue, but the elements of reasoning and quality of reasoning could be given a set number on an established scale. An ANOVA test could look to see if there is any connection between the variables.

Although there is significant research in vocabulary, especially in the primary grades, the research in dual processing theory and science education is scarce. How can we formally and systemically promote and utilize vocabulary or scientific literacy in pedagogy as it pertains to Type 1 and Type 2 thinking? Does Type 1 thinking have a role in how student acquire new science vocab, and how can the educators promote the involvement of Type 2 thinking in literacy?

Finally, how does the awareness of Type 1 and Type 2 thinking impact teacher education? It would be interesting to see if pedagogical practices were influenced if pre-service teachers were exposed to the role of Type 1 thinking and Type 2 thinking in education. This may lead to differently structured group discussion, the incorporation of balanced activities following literature readings, or emphasize the role of how reflections are conducted during class.

Limitations of the Study

The Type 1 and Type 2 processing coding should have examined the individual NOS scores to more formally determine whether there is a clear relationship between the influences of T1/T2 thinking. While the mixed method was aimed at connecting the two, the formal assessment

was not predicated on how to achieve this. A more defined measure is needed in order to address this issue.

The transcription analysis focused only on those students who were most verbal and contributed most to the discussion. While the class size was average at twenty-nine, an analysis of all who participated may have provided more depth and clarification as to the relationship between NOS levels and the dual processing. In addition to this, the audio and visual recording were sometimes indecipherable in large groups. There were two cameras and three audio recording devices during the study. The transcriptions were challenging at times; with practice, the researcher was able to label each student. This would not be possible for an outside researcher.

The study was conducted after the Environmental AP exam. The students had other AP exams during the study, so some students were absent on certain days. The motivation was limited due to the fact that it was voluntary (although there was a party incentive involved). Even though they were advanced placement students, they participated when prompted to read, and completed the discussions as if it were an assignment. There was good participation during the intervention, but the students still got off task at times when in groups.

Finally, the duration of the intervention and activities were limited. As mentioned, some of the students had other AP exams during the intervention, so some of the NOS activities were missed due to this occurrence. The study devoted five days of intervention, and could have incorporated more inquiry-based NOS activities to promote the NOS tenets. Allowing more time and preparing a better-developed and rigorous NOS invention could help improve the NOS associations.

APPENDIX A

DESCRIPTION OF THE NATURE OF SCIENCE ASPECTS

NOS aspect	Description
Bounded NOS	Science is a limited way of knowing. Science cannot answer moral and ethical questions. Scientists do not invoke supernatural explanations when doing science.
Empirical NOS	Scientific knowledge is based on empirical evidence. Knowledge claims in science are made with evidence and observations of nature. However, this empirical base does not provide a secure base for science because observations are influenced by scientists' creativity, and personal and theoretical subjectivity.
Inferential NOS	There is a difference between observation and inference. Observations are descriptive statements about the nature that are available to the senses. Observes can agree upon observation statements with relative ease. Inferences are interpretations of observations. They are not immediately available to the senses.
Creative NOS	Creativity and imagination of scientists play a major role in the scientific inquiry. The role of creativity and imagination is not limited to any specific phase of the scientific inquiry. Creativity and imagination are of importance before, during, and after data collection. Creativity and imagination allow scientist to build theoretical models that inferentially explain the natural phenomena.
Subjective NOS	Scientists try to achieve objectivity, but absolute objectivity is not possible in science. Theoretical orientations of scientists make them unavoidably subjective. In addition to scientists' theoretical orientations their personal characteristics and social and cultural backgrounds contributes to subjectivity of scientists. All these factors influence scientists' choice of research questions, methods of research, observations, and interpretations of their observations.
Tentative NOS	Scientific knowledge is tentative but durable. Scientific knowledge is subject to change with the availability of new evidence and with the interpretation of the old evidence, but this change does not happen on the daily basis. Science is not concerned with finding the final truth.
"Scientific Method"	There is not a general and universal scientific method that is followed by all research scientists to solve scientifically oriented questions.
Social and cultural NOS	Science is a human activity. It is influenced by social and cultural factors. These social and cultural factors include social composition, religion, worldview, political and economic factors. Science is not only influenced by these factors but also it influences these factors.
Social NOS	Science is no longer a solitary pursuit. Scientific knowledge is constructed through social negotiation. Despite their individual differences members of a scientific community of practice share common traditions, values, and theoretical frameworks. This social dimension enhances the objectivity of scientific knowledge. The double-blind peer-review process used by scientific journals is a major component of this NOS aspect.

Theory/ Law	There is no hierarchical relationship between theories and laws. Laws are mathematical descriptions of natural phenomena. Theories do no turn into laws. Different usages of the word theory are problematic. In science, theories are extremely well-supported web of hypotheses that are constructed to explain natural phenomena. However, everyday use of the word theory refers to some sort of a wild idea, which may or may not have an empirical support. From Deniz, H. (2013). Teaching a socially controversial scientific concept: Evolution. In M.S. Khine & I.M. Saleh (Eds.) *Approaches and Strategies in Next Generation Science Learning*. (pp. 52-63). Hershey, PA: IGI Global.

APPENDIX B

VIEWS OF NATURE OF SCIENCE QUESTIONNAIRE VERSION C

Instructions

- Please answer each of the following questions. Include relevant examples whenever possible.
- **There are no "right" or "wrong" answers to the following questions. I am only interested in your opinion on a number of issues about science.**

1. What, in your view, is science? What makes science (or a scientific discipline such as physics, biology, etc.) different from other disciplines of inquiry (e.g., religion, philosophy)?

2. What is an experiment?

3. Does the development of scientific knowledge **require** experiments?

- If yes, explain why. Give an example to defend your position.
- If no, explain why. Give an example to defend your position.

4. Science textbooks often represent the atom as a central nucleus composed of protons (positively charged particles) and neutrons (neutral particles) with electrons (negatively charged particles) orbiting that nucleus. How certain are scientists about the structure of the atom? What specific evidence, or types of evidence, **do you think** scientists used to determine what an atom looks like?

5. Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example.

6. After scientists have developed a scientific theory (e.g., atomic theory, evolution theory), does the theory ever change?

- If you believe that scientific theories do not change, explain why. Defend your answer with examples.
- If you believe that scientific theories do change:

(a) Explain why theories change?

(b) Explain why we bother to learn scientific theories. Defend your answer with examples.

7. Science textbooks often define a species as a group of organisms that share similar characteristics and can interbreed with one another to produce fertile offspring. How certain are

scientists about their characterization of what a species is? What specific evidence **do you think** scientists used to determine what a species is?

8. Scientists perform experiments/investigations when trying to find answers to the questions they put forth. Do scientists use their creativity and imagination during their investigations?

- If yes, then at which stages of the investigations do you believe that scientists use their imagination and creativity: planning and design; data collection; after data collection? Please explain why scientists use imagination and creativity. Provide examples if appropriate.
- If you believe that scientists do not use imagination and creativity, please explain why. Provide examples if appropriate.

9. It is believed that about 65 million years ago the dinosaurs became extinct. Of the hypotheses formulated by scientists to explain the extinction, two enjoy wide support. The first, formulated by one group of scientists, suggests that a huge meteorite hit the earth 65 million years ago and led to a series of events that caused the extinction. The second hypothesis, formulated by another group of scientists, suggests that massive and violent volcanic eruptions were responsible for the extinction. How are these **different conclusions** possible if scientists in both groups have access to and **use the same set of data** to derive their conclusions?

10. Some claim that science is infused with social and cultural values. That is, science reflects the social and political values, philosophical assumptions, and intellectual norms of the culture in which it is practiced. Others claim that science is universal. That is, science transcends national and cultural boundaries and is not affected by social, political, and philosophical values, and intellectual norms of the culture in which it is practiced.

- If you believe that science reflects social and cultural values, explain why and how. Defend your answer with examples. If you believe that science is universal, explain why and how. Defend your answer with examples.

APPENDIX C

EVIDENCE-BASED REASONING FRAMEWORK DISCOURSE EXAMPLE

Quality of Reasoning	Elements of Reasoning	Participants	Dialogue in message units	Actions/participant contribution
		13	001 What's that? What's that mean? 002 I mean, what are we supposed to do with the box?	Group 2 5/6 Audio 2 4:22-12:27 Students begin discussion about the blocks
	Premise	11	003 We're supposed to decide what's supposed to be on the bottom	
		13	004 I have no idea…	
Pheno	BD	11	005 Well, if there's R there's A. There's F. I guess you could…it starts to (inaudible) or it's Frank	
		13	006 What?	
Relational	BE	11	007 Well because you know if you think about it. First you have R, then you have F, and then you have R. 008 Then you start with R. Or maybe you start with A, and then RA. I don't know why, but maybe that's like the first 3 letters	
		13	009 Ok	
Unsupp	Claim	11	010 And the last one's like Mikey or something. Because that would totally go	
		13	011 Ok. I kinda hear where you're coming from. Ok why are there numbers?	
		11	012 Ummmm	
Unsupp	Claim	13	013 Frank? Umm Rob? Is it 3 and 3, 2 and 6, 4 and 5	
		11	014 Wait, does that mean 4 (inaudible) 4	
		13	015 No. No	

APPENDIX D

DAY 5-DOUBLE HELIX READING PAGES 149-171

Reference the main components of NOS education during the small group conversation: Empirical, inferential, tentative, subjective, creative, bounded/limits, science methods, sociocultural, and collaborative.

Write down your own questions/observations about chapters 21-23 in addition to my general questions. Each person may bring up what ideas they wrote down in the discussion.

1) What components of NOS was Watson using when he was explaining his belief that DNA → RNA → protein on p. 153?

2) What were your thoughts about the excitement Watson expressed when he read Pauling's new paper on DNA? Is the competition and reveling in the mistakes of others "ethical" in science? Would you react the same way if you were working on a huge discovery like DNA?

3) Rosy and Watson get into a heated debate in chapter 23. Discuss this interaction and if they are being unprofessional or have the right to have scorn for each other.

4) On p. 170, Maurice Wilkens made sure that Watson understood that if we all could agree where science was going, everything would be solved and we would have no recourse but to be engineers and doctors. Explain this statement in terms of nature of science aspects.

5) The author seems to be close on making the breakthrough for DNA research at this point in the book. Describe one point in the book in which there showed EACH one of the NOS aspects. List some notes and discuss with your group.

APPENDIX E

EXAMPLE: PRE AND POST SURVEY CODING FOR STUDENT 8

Pre Survey	Empirical	Inferential	Tentative	Creative	Subjective	Experiment	Bounded	Theory/Law	Socio/ cultural
Student 8	3. Yes, In order to prove something the idea must be repeatedly tested. For example, if someone was trying to prove the type of soil that best supports plant growth, plants would need to be tested in various environments in various soil types. This way, the experiment is tested and their is validity to the scientifc claim. 4. After extensive experimentation. I believe scientists are fairly certain about the structure of an atom. Though I am not certain, I believe scientists break down molecules into atoms, then study each part of the atom (proton, nuetron, electron) 7. People creating groups (called species) is a man made concept. Scientists are very certain about characterizing a species. Scientists use traits, like habitats, appearance, breeding habits, dietary needs, and other factors to determine what a species is and how to categorize animals in the same	9. Because there is no actual documentation from 65 million years ago, scientists have to use fossils to find the truth. However, if all they can indicate is that some massive heat caused the dinosaurs to go extinct, it is logical for some scientists to arrive at two seperate conclusions.	6. Yes, scientists gain more information, such as determining the Earth is actually round, not flat. We learn scientific theories because they are the greatest truth we know of right now. Yet, we can also expand on these theories to find a greater truth; but first, we must know the original theories.	8. Yes; scientists must use creativity and imagination to determine various things about the universe. This can be seen as scientists try to determine factors about evolution. Though scientists cannot always physically watch the process play out, they can use creative methods to determine if evolution happened or not.	9. Because there is no actual documentation from 65 million years ago, scientists have to use fossils to find the truth. However, if all they can indicate is that some massive heat caused the dinosaurs to go extinct, it is logical for some scientists to arrive at two separate conclusions.	2. An experiment is meant to test the validity an argument. This can be done physically using the five sense, including observing various phenomenon. An experiment is trying, inherently, to prove something. 3. Yes, In order to prove something the idea must be repeatedly tested. For example, if someone was trying to prove the type of soil that best supports plant growth, plants would need to be tested in various environments in various soil types. This way, the experiment is tested and their is validity to the scientifc claim.	1. Science aims to study both the theoretical and tangible to try and come to a conclusion. While other disciplines are inherently unable to be proved (like religion), science aims to find an actual, accurate answer.	5. Yes, scientific law has been proved. For example, Newton's Three Laws of motion are undisputed. Yet, theory (like the Big Bang) cannot yet be fully proven, so it remains a scientific theory.	10. I believe science is fairly universal. Because scientists strive for the truth, there does not need t be social influence. For example, if a scientists proves that certain rock has a certain half life this is absolutely universal.
Level	Mixed (Pre)	Informed (Pre)	Mixed (Pre)	Informed-NE (Pre)	Informed (Pre)	Mixed (Pre)	Mixed (Pre)	Uninformed (Pre)	Uninformed (Pre)
Post Survey	Empirical	Inferential	Tentative	Creative	Subjective	Experiment	Bounded	Theory/Law	Socio/ cultural
Student 8	1. Science is the study of how something works based on experimentation observation, and empirical data. While other disciplines rely on opinion and belief science relies on facts. 3. Scientists used experimentation (like the Rutherford Model) adapted various other models (plum pudding). Now scientists are fairly certain because others have repeatedly questioned Rutherford's model and found it true. 7. Fairly certain they define them based off of a strict guideline. These characeristics include size, breeding ability color shape, dietary habits, locations, and niches.	8. Yes; the scientists must imagine theoretical concepts they cannot see such as the subatomic particals of an atom. Thus, they must imagine different kinds of worlds where their theories are correct.	6. Yes, theories such as evolution are constantly changing. More information is present. If theories are learned people will have interest to expand them.	8. Yes; the scientists must imagine theoretical concepts they cannot see such as the subatomic particals of an atom. Thus, they must imagine different kinds of worlds where their theories are correct.	9. Similar evidence such as a massive heat influxation made different scientists conclude different things based at various times and even sometimes conflicting evidence. 10. Yes; scientists are people. Thus prejudices, such as Watson agaisnt Rosalind in our novel, cause scientists to discount other. Others disregarded things like evolution based on their religious beliefs.	2. A way to test a theory or hypothesis through a controlled test that may be repeated by other scientists.	10. Yes; scientists are people. Thus prejudices, such as watson agaisnt Rosalind in our novel, cause scientists to discount other. Others disregarded things like evolution based on their religious beliefs.	3. Yes theories must be proven in order to be deemed accurate or not. 5. Yes, a law is definate and theory is still changing for example the theory of evolution and Newton's Law of motion.	
Level	Mixed	Mixed	Preinformed	Mixed	Informed	Informed-NE	Informed	Uninformed	

APPENDIX F

EXAMPLES OF THE NOS CODING SCHEME

Empirical
Informed: 1. Science is heavily based on empirical data to back something up. Besides that, ones opinions on this data is up to you. 3. Yes, because if no one tries to prove or disprove anything with experiments, scientific knowledge could never be advanced. 4. They used empirical evidence, inferences, and creativity to structure the atom. Scientists can never open the black box, but they try to use the best model that has the most evidence. 7. This is a good enough characterization of a species because there is copious evidence supporting that the species is the most practically specific thing to describe organisms. 9. This is pure influence using the same empirical data. A very common thing to happen in science is, if you have data to back it up and you can't disprove another theory.

Informed-NE: 3. Yes, using observations, inferences, creativity and other NOS aspects to discover and challenge knowledge. 4. They can never be 100% certain. Using observations, creativity, collaboration and more interactions to determine the structure of an atom. 7. Using observations and experiments are used to characterize species along with NOS methods.

Pre-informed: 2. Since the term species was coined by scientists and words have any meaning only because we attribute meaning to them, scientists are pretty sure about how they characterize species. Scientists run observational experiments to determine if something is a species, by comparing it to their already existent database of species' knowledge.

Mixed: 4. Scientists are very certain about the structure of the atom. Several tests have been conducted to help scientists "paint a picture" of how an atom looks. 7. They are very certain over time and progressing technology scientists are able to prove their idea of what a species is.

Uninformed: 3. It does, as nothing can be proved without trial and error. We cannot, for example, figure out how an organism responds to climate change without setting up an experiment. 1. Science is the study of the workings of the world and provides explanations for the way things are. Science in practical and differs from other disciplines in it finitely proves or disproves hypotheticals. 7. Scientists definition of a species seems sound, as grouping the millions of organisms on earth is complex. I believe that another factor for determining a species is that they all thrive in the same climate type.

Inferential
Informed: 7. Well because scientists are susceptible to being bias I think personal interpretation can cause characterization to change and be altered. Scientists most likely use physical characteristics to determine a species. 9. Because there is so little information it is logical that whatever is left can be interpreted very differently. Just like the trails we discussed in class it is almost impossible to tell what could happen since there is so much missing.

Informed-NE: 3. Yes, using observations, inferences, creativity and other NOS aspects to discover and challenge knowledge. 4. They can never be 100% certain. Using observations, creativity, collaboration and more interactions to determine the structure of an atom. 9. Sociocultural, tentative, inferential, and more views can change the interpretation of data.

Pre-informed: 4. Scientists are pretty certain about the structure of the atom. Scientists are certain because there have been no substantial studies done to prove the fundamental structure inaccurate. They have probably used the magnetic tendencies behavior and electronic charge to represent the structure.

Mixed: 8. Yes scientists do. They do when making inferences and hypothesis. That requires a lot of imagination. When creating the experiment, scientists need to be extremely creative. 9. Scientists have their own different personal views of things, so this causes them to make up different inferences

Uninformed: 9. Inferential science is making a guess based on the same data. Different people have unique perspectives and science is subjective.

Tentative
Informed: 6. Yes, theories change because the world is constantly evolving and as humans, our capabilities with experimentation and technology are always advancing, giving us more information than years before. We learn scientific theories to understand the way the world works. We want to know this because science provides room for advancement. IE: anesthesia for surgery, clean air act; surgeon general warning.

Informed-NE: 6. I believe scientific theories do change. Theories change when new information is presented and when the theory is proven to be wrong. We must learn theories to be able to help prove or disprove them.

Pre-informed: 6. New information or discoveries can oppose current beliefs. For example, we thought the earth was round until we got new information and learned the truth.

Mixed: 6. A)Theories change because everything is always changing. B) Because without creative ideas they will never discover anything new.

Uninformed: 6. Theories do not change. To become a theory it has to be correct, proven, and tested multiple times. Theories would not be theories unless they were completely correct so no they cannot change.

Creative
Informed: 4. They used empirical evidence, inferences, and creativity to structure the atom. Scientists can never open the black box, but they try to use the best model that has the most evidence. 8. During data collection investigators should collect data with pure non-bias but in any other aspect of the experiment imagination and creativity with empirical data is the most important part.

Informed-NE: 8. Yes, throughout the whole experiment scientists use creativity. Creativity is needed to develop a hypothesis as well as come up with an experiment and build a model of the data.

Pre-informed: 8. Yes, they use creativity and imagination throughout the whole process. As they need to form a question and use data to draw conclusions. They use it in order to be more revolutionary in their findings.

Mixed: 8. Absolutely, because they are coming up with ideas on how to explain the formerly unexplainable. Creativity allows scientists to propose what it could be, how it could be and why it is.

Uninformed: 8. Scientists do not use imagination or creativity while experimenting or going on investigations. Scientists rely on evidence and proof and not imagination.

Subjective

Informed: 9. I think that both could be true. That's the only hard part above science is that no one really knows because we weren't there. A volcano has lava and could have left a huge hole like a meteorite but either way we know something wiped out the dinosaurs.

Informed-NE: 9. You can interpret the same data in many ways. This is a flow with the experiment because it cannot disprove the other theory.

Pre-informed: 1. Science is heavily based on empirical data to back something up. Besides that, ones opinions on this data is up to you.

Mixed: 9. The different conclusions are possible because the scientists may have different beliefs of the formation of the earth, different religions, interpreting the data. 10. There are different types and interpretations of science, no it is impossible to decide whether science is universal or affected by social and cultural values. 6. New Evidence, science studies, more insight, alternative perspectives. They lead to laws, gravity was once a theory now a law of earth.

Uninformed: 9. The determining conclusions can be derived because they are both probable and plausible, yet cannot officially be identified.

Experiment

Informed: 1. Science is experimental observations and testing of the natural world. It's a study of experiments relating to chemistry, biology, physics, and the environment. Science and the scientific disciplines are different from other disciplines because it requires research and experimentation. 2. The experiment is a period of study that requires understanding of ideas and thoughts. It tests certain things a scientists is studying in order to gain some knowledge and factual evidence in the Science World.

Informed-NE: 1. Science is the study of our world that uses facts, data, and resources to reach plausible conclusions. Science uses legit facts and data to describe and perceive events as opposed

to religion that is based on beliefs. 2. An experiment is a procedure that tests a question or hypothesis with the use of facts and data.

Pre-informed: 2. A test that is made or conducted in an effort to answer a hypothesis or question. Experiments often can tell us data and facts from observations and recordings.

Mixed: 1. Science is a study of how things work, how things are created, and testing to find certain things. 2. A test (series of tests) that are done to conduct information or topics.

Uninformed: 1. Science is the logic behind everything. It is used to challenge the basic knowledge of everything. 2. An experiment is a test where you use different variables to see what works and what doesn't. 3. I believe the development of science requires experiments. For example, even the most basic of evidence, like how hot water needs to be cool before it boils could not be known without experimenting with several different temps.

Bounded
Informed: 1. Science is a subject that uses facts and data about the world around us in order to come up with laws and conclusions about our world. Science is different from other disciplines such as religion because it is almost entirely based on facts and data as opposed to faith or ideas.

Informed-NE: 1. Science is the pursuit of knowledge and is the study of why the things around us are what they are and how they work. It is different because it uses facts and experiments in order to come to conclusions rather than with belief or ideas.

Pre-informed: 1. Science is the study of how the world works. It explains humans, animals, and plants. Religion is faith while philosophy creates thought experiments that are not grounded in the real world.

Mixed: 1. Science is a combination of many factors that combine together to prove or disprove an idea through various types of evidence. However, religion and philosophy have no form of evidence.

Uninformed: 8. I don't think they do because science is evidence and if their imagination generates unicorns. It doesn't mean unicorns exist. I don't think imaginations are required to be a scientist.

Theory vs. Law
Informed: No examples were provided from the data.

Informed-NE: No examples were provided from the data.

Pre-informed: No examples were provided from the data.

Mixed: 5. Scientific theory is a conceptual thought that explains how something works or came to be. Scientific law is a definite fact that illustrates how something is. Scientific theory would be the Big Bang Theory and a scientific law would be Newton's First Law of Motion.

Uninformed: 5. Scientific theory is something widely believed but still possessing the potential to be disproved. There are some things that humans have not yet had the capability to prove scientific laws are grounded and have research / evidence to back them. For example, the laws of Gravity and the Theory of Evolution.

Socio/cultural
Informed: 10. Science definitely reflects traditional values and culture. Experiments and theories reflect religious beliefs and thoughts of scientists, they can be the driving forces behind scientific ambition. 8. Creativity is integral when determining experimental design. Scientists must think outside of the box and have the courage and mental creativity to challenge culture and tradition. Why didn't anyone else during the time ask why the apple actually fell from the tree? No one else did.

Informed-NE: 10. I believe science reflects social and cultural values because all of these things reflect how a person thinks and how it can manipulate his or her thoughts. Because of this experiments may be skewed a certain way.

Pre-informed: 10. Some parts of the world don't believe evolution or the earth revolves around the sun because of their unique social and philosophical backgrounds.

Mixed: 10. I believe in some proven science reflects social and cultural values. For example, people who believe the earth was round got shunned. Now with technology science is more universal.

Uninformed: 10. I believe that science is universal and doesn't reflect society, but people can use the data from science in order to provide evidence for their agenda. Political groups use scientific evidence in order to prove their point but they are really just bending the scientific data to appear as though it supports them.

Collaborative
Informed: 9. Scientists sometimes do no collaborate and as such they interpret evidence in radically different ways. They see things different, which is actually very important.

Informed-NE: 4. They can never be 100% certain. Using observations, creativity, collaboration and more interactions to determine the structure of an atom.

Pre-informed: 4. Scientists are very certain of the structure of the atom. Scientists collaborated and used influences to develop a theory, then they tested their theory to find empirical data. 7. Scientists are very certain of their characterization of what a species is. Scientists have worked together for many years to provide people with enough empirical data to prove their idea.

Mixed: No examples were provided from the data.

Uninformed: 10. I think science is universal because across the world scientists receive the same answers and they use the same measurements and formulas.

APPENDIX G

VNOS INTERVIEW EXAMPLE

Student 20 pre-interview (MJ is Mr. Jackson).

MJ - Hi Student 20

20 – Hi

MJ- Alright we're going to start with question one about what makes science. I noticed from your response, my question to you is what makes science religion so different from pure science And maybe just explain what it means that science is just factual which is one thing you said.

20- I think that science is factual because it can go with between agriculture and different peoples' religion and I say that because when you're reading an article about English you're still using science and with math you use science but religion its more about spiritual stuff it's not really science. Evolution is science.

Comment [L1]: Mixed from VNOS. Still not clear

MJ- What makes evolution science compared to Catholicism?

20- Because you can prove it. I think it is all in your opinion and what you believe because someone could believe that this plant was that way because God made it or this plant was that way because of symbiosis or whatever.

Comment [L2]: Good ideas, but you can't prove science. Still mixed

MJ- Okay so, you're saying that pure science is more evidence based compared to philosophy or religion?

20- Yeah that's what I meant by factual is its more evidence based.

Comment [L3]: No change

MJ- Okay number two is just a simple question on experiments. Could you explain some of the procedures about experimentation? What do you consider an experiment?

20- Well they all have to have a consistent base like they have to have different variables and if you were to test like plants or something and to see what would make it grow better you would still need the same soil and water and everything but you would need different lighting or you have to have something different and that's what makes it an experiment. An experiment is that you're trying different things.

Comment [L4]: Experiment was determined uninformed. No clear change from this response

MJ- So it's a variable, okay perfect. Number three, to develop scientific knowledge does it require experimentation and in your response I just wanted to ask you what is wrong with leaving the learning aspect up to the individual? I think you said something about something is wrong with that?

20- Yeah well I just think that how are you supposed to figure out new things and create things that have been experimented if you haven't been taught that? Does that make sense?

Comment [L5]: Experiment uninformed

MJ- Could you maybe just try to word it a little differently and explain it?

20- Say the question one more time.

MJ- When you responded you said there was something wrong with leaving the learning aspect up to the individual; it's my fault the question is how do experiments support scientific knowledge that's basically a different way to wording that question. How do experiments support that?

20- Oh, well because that's how you figure out new things. You try it and if you come out with a different outcome it's a new result. So by-

MJ- What does that mean though? If you come out with a new result and you tested that several times what does that mean?

20- Then that's your new answer. That's how you find new things like people can't find new things if they keep doing the same experiment. So if you do something different and you get a different outcome then that's how scientists have come so far in finding new things.

Comment [L6]: Not enough evidence to support a change to mixed. You can find new things from repeating an experiment.

MJ- Okay. Number four has to do with the atomic theory and your beautiful cell membrane picture. My question is what specific types of evidence do scientists look at to support what an atom looks like? So basically what type of evidence do they use to show that an atom exists?

20- Well with just what I've learned in science I just think that they use microscopes as a big thing kind of what I pictured. I'm not really super sure on how they figure out how because they're super smart scientists but I think um testing different things with like microscopes and- that's all I can really think about is microscopes because they cut it open and look at it closer and see how it's made.

Comment [L7]: Answer on VNOS and here are uninformed

MJ- are you talking about cells again though?

20- Yeah

MJ- Okay. You're right though, we can view an atom with microscopes.

20- Oh atoms are made out of matter.

MJ- Right. So they use different types of equipment that you may or may not know of to actually view and study the atom.

20- Oh well in certain objects I know everything has to be filled with everything and I think that's how they got the theory of atom is because you can't have just a space of nothing like even in a room of nothing there's still atoms filling the air and so I know that's one way to put it and I think that they just figured it out that you can't have just an empty space because even in that you have oxygen and things filling that room.

Comment [L8]: Nothing to support a change here

MJ- Okay. Alright number five deals with scientific theory and scientific law. You had an explanation but maybe you could just kind of elaborate on the difference between a scientific law and a scientific theory.

20- I think a scientific law can be proven it can be factual if you do an experiment then you show it if you don't have the same results every single time and a theory is kind of like your own opinion. Like it could work sometimes but it could not. So it's kind of like an educated guess. So that's what I think a theory is compared to a law.

Comment [L9]: Clearly uninformed here and on the VNOS

MJ- Number 6 goes along with scientific theory and change. So my question to you is how scientific theories change. My question to you is how do scientific theories change? And maybe you could give me another example about how we bother learning new scientific theories once it's developed

20- Well I think that theories change because everything around them changes and if you stay in one little thought process bubble you're never going to find new things. I think it's important to learn new things and try new things and kind of experiment on what we think theories are because we're like a developing generation and everything changes around us so why wouldn't we change our theories if it's not always going to stay the same.

Comment [L10]: VNOS was initially mixed. Preinformed change from this answer

MJ- How do they change though? Like what is the process of like changing a theory?

20- Well give me an example of a theory.

MJ- Let's go with atomic theory, you were just explaining about atoms and how different atoms take up space and that's how they came up with that. How do we develop upon that theory or possibly change it. You don't have to necessarily give me specific examples or anything, just in your mind how we really change a theory if it's not set in stone what is the process of going through and changing it.

20- Well I'm not sure really what kind of experiments you would do but, you would have to do some sort of testing to figure it out. I don't know what testing that would be but..

MJ- I'm not asking you to but experimentation?

20- Yeah, you definitely have to experiment and figure different things out.

MJ- Seven has to do with how scientists classify different species. My question to your response is what specific evidence do scientists use to classify species? So give me some examples of what you consider scientists and how they organize and classify different species.

20-Different species are all based on DNA and mutations so I think that they figured out that 'this bird goes there this bird goes here' because there is like 150 thousand different bird species and how are they supposed to know they are a bird. I think it's because if you take a bird's cell or matter from them it could be completely different from a bird that looks just like them. So I think that's how they characterize or put them in certain categories, by their DNA and other stuff like that.

Comment [L11]: Question 7 added to empirical. Determined uninformed. The student's response was the same as their response, so no change.

MJ- Excellent. Number 8 has to do with creativity and imagination in science. According to your response what stages of science do scientists use imagination and creativity? So out of those three right there, basically, you pretty much agree that there is at some point some imagination and creativity right? I just want to further clarify at what stages do you think? Or maybe they don't.

20- I think that if I was a scientist I would only use it when results aren't happening. I would result to imagination after I wouldn't get constant results. So like, if I was trying to make a plant grow and it's not growing and I'm doing the same things, that's when I'd have to start looking for what I'm doing wrong or what could I change or what could I think of to do to make my plant grow. So I think that goes with after the data collection and planning.

Comment [L12]: VNOS was preinformed. Almost to informed with their example, except for the part about only using creativity when not getting constant results.

MJ- So you're saying that if something's not working, that's where you could apply that? Saying well what I need to do next and using your imagination.

20-Even if it is working, I mean you can always change it up to see like "well what if I do it this way?"

MJ- Last two, this one has to do with viewing different conclusions based on the same set of data. My question to your response is how are these different conclusions formed by different scientists using the same set of data? Maybe you can clarify that or give an example.

20- Well, I think that every decision that a person makes is based on their own experiences and opinions. I think it has to do with your parents too because if your parents teach you that it was by the dinosaurs and somebody else teaches you it was the volcanic eruptions. I think that every choice you make is based on the opinions that you've gathered through all your years. So one person could say no this is how this is done and another could say no this is how it's done but I think that it's all your own opinion, whatever makes sense to you is going to be the one you understand more. So it's your background.

Comment [L13]: Already informed. Explanation was fine.

MJ- This last one here has to deal with how social, cultural, societal influences, if that's possible according to your opinion. My question is, so science is not universal which is what you wrote and not influenced by cultural and national boundaries. Can you explain a little more about how this is and why this is neither? You said that this is neither universal, and it doesn't reflect that? If you could expand upon that answer a little bit.

20-I think that most scientists I know aren't religious just because of the fact that they're very black and white like, this is why it's happening, and this is why things are the way they are. They're very factual in the way they do things because they need something to prove why it's that way. So I think it's kind of hard to have a cultural or universal kind of science, because again everyone's beliefs are going to be different, no matter what. Unless you're talking about cell phones and being social. That's all I really have to say, people are always going to have different opinions.

Comment [L14]: Uninformed in VNOS. Explanation did not change this level.

MJ- So that's not influenced by your culture?

20- Not really, I mean it just depends. It depends on the person.

MJ- Alright Thanks. I think we're good.

Student 20 Post-interview

MJ- Your answers seemed to change quite a bit from the original which is kind of good, actually. So, number 3 you kind of talked about "how do we prove facts?" and "what is the difference between facts and opinion?" and those are my questions to you. You wrote "we actually are trying to prove facts" what does that mean?

20- If you're trying to prove fact, if you know it's a fact then you already know it's right, but if you can prove if it's wrong then it's not a fact. So if you're trying to prove facts, you already know your right, so you're kind of trying to prove that it's wrong. Does that make sense?

Comment [L15]: Number 3 was tied to empirical and was uninformed. Prove facts did not change from pre. Still uninformed.

MJ- Yes. Kind of what we talked about at the end of the study? Trying to disprove instead of prove?

20- Yes, that is what I was going for.

MJ- So you consider a fact as being 100% true?

20- Yes, fact is 100% true. So like when you're trying to prove facts you're trying to back that up but if something changes then you know that it's not fact.

Comment [L16]: Uninformed

MJ- Right, but is everything in science 100% true?

20- No.

MJ- So is there real facts in science?

20- No then, probably not. I don't think so. I think that they're as close as we can get to a fact.

MJ- It would be nice to say that there are true facts, we use that a lot but I don't know if there's really true.

MJ- You talked a little bit about the double helix, number 4 with the atomic theory, on the next page. You didn't really talk about the atomic theory, but I think I know what you were kind of getting at, you talked about how throughout the book the double helix showed how Watson was building this model. Do you want to touch on that? The question is essentially about atomic theory, but if you want to touch on that.

Student 20 Post-interview

MJ- Your answers seemed to change quite a bit from the original which is kind of good, actually. So, number 3 you kind of talked about "how do we prove facts?" and "what is the difference between facts and opinion?" and those are my questions to you. You wrote "we actually are trying to prove facts" what does that mean?

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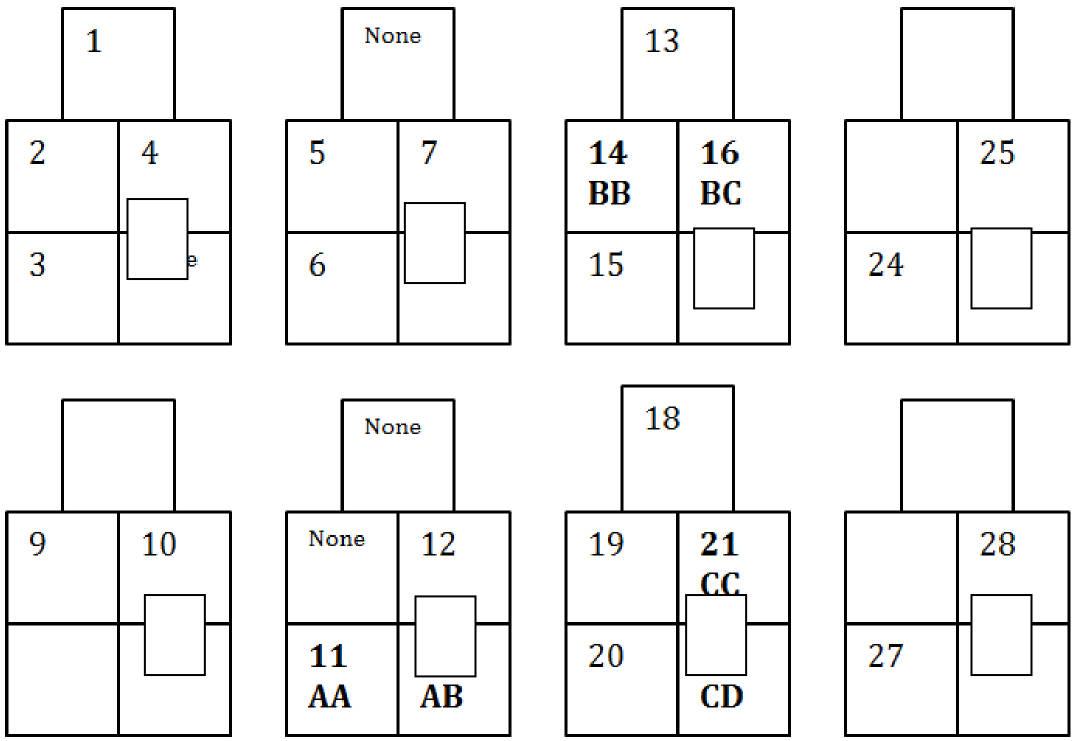
APPENDIX H

EXPECTED CALCULATIONS

NOS level	Pre Expected Values	Post Expected Values
Informed (combined)	229 x 137 435 = 72.12	206 x 137 435 = 64.87
Pre-informed	229 x 50 435 = 26. 32	206 x 50 435 = 23.67
Mixed	229 x 86 435 = 45.27	206 x 86 435 = 40.73
Uninformed	229 x 162 435 = 85.28	206 x 162 435 = 76.71

APPENDIX I

CLASS SEATING CHART



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