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High School Students' Views of Science in a University Science Internship with Cogenerative Dialogues

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HIGH SCHOOL STUDENTS' VIEWS OF SCIENCE IN A UNIVERSITY SCIENCE INTERNSHIP WITH COGENERATIVE DIALOGUES

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Chapter 1: Introduction

High school student's acquisition of science knowledge is a critical focus of education through science, technology, engineering, and math (STEM) initiatives at local, regional, and national levels. National science standards, including the Next Generation Science Standards (2013), state that "students should develop an understanding of the enterprise of science as a whole—the wondering, investigating, questioning, data collecting, and analyzing" (p. 96). However, science education requires more than students just being able to understand basic science concepts at the high school level. Beyond knowing the basic *knowledge in science* or methods and content, students further require *knowledge about the nature of science* or how scientific knowledge is used and developed (Ryder, Leach, & Driver, 1999, p. 201). Understanding knowledge about the nature of science (NOS) is a critical component to provide complete science education for high school students.

There are grave consequences if students do not learn informed views about NOS. Research shows that:

> Citizens who do not understand how scientific research is done, and how scientific research is questioned on its own terms, have little recourse but to (a) ignore arguments grounded in scientific studies, and bow instead to the recommendations of their favorite experts, marketing campaigns, or personal friends; or (b) follow the recommendations of the most recent scientific study they encountered that appeared convincing (O'Neill & Polman, 2004, p. 238).

There is widespread consensus that NOS learning is essential for high school students, while current education efforts are limited in their abilities to improve student's NOS conceptions (Lederman, Abd-el-Khalick, Bell, & Schwartz, 2002). Research demonstrates that few people have even a basic view of NOS. This is detrimental to societies where citizens have a large role in making decisions about policy, funding, and legal matters involving science. Naïve views of NOS lead directly to illogical uninformed decisions that affect society (McComas, Clough, & Almazroa,

2000, p. 3). Therefore, successfully teaching improved NOS concepts to high school students is an important step in ensuring scientific literacy. “One fundamental goal for K–12 science education is a scientifically literate person who can understand the nature of scientific knowledge. Indeed, the only consistent characteristic of scientific knowledge across the disciplines is that scientific knowledge itself is open to revision in light of new evidence” (NGSS Lead States, 2013, p. 96). Without a working understanding of NOS, students will be unable to understand science’s interconnectedness with other disciplines. “Humans have a need to know and understand the world around them. And they have the need to change their environment using technology in order to accommodate what they understand or desire” (NGSS Lead States, 2013, p. 96). Without NOS knowledge, students will lack the ability to understand the natural world (National Research Council [NRC], 1996). Possessing inadequate NOS conceptualizations has a direct negative impact on people’s ability to make informed decisions that impact their lives and those around them. There are multiple beneficial outcomes when students gain adequate NOS views. Three key outcomes include:

> (a) developing social values such that a person can act in a responsible manner within the community, system, nation, or, as in the school situation, at a smaller group level;
>
> (b) being able to function within the world of work at whatever the skill or responsibility level; and
>
> (c) possessing the conceptual background or skills of learning to learn to cope with a need-to-have, relevant public understanding of science and technology in a changing society (Holbrook & Rannikmae, 2007, p. 1352–1353).

Students graduate and enter the workforce across a wide spectrum of occupations, many which will require them to perform duties entailing NOS knowledge. Providing high school students with sufficient NOS knowledge is vital to providing them the tools necessary to participate in our society (Ryder et al., 1999). Furthermore, moral and ethical issues need to be included as core components of NOS to ensure that the populace is well grounded in scientific

literacy, able to relate issues to scientific principles, and capable of making informed democratic decisions that affect society (Ziedler, Walker, Ackett, & Simmons, 2002). When students receive adequate NOS conceptual knowledge in high school, they are far better prepared to live fulfilling lives and provide positive contributions to society.

There are many approaches to improving high school student's NOS conceptions. Current conventional methods include traditional science classroom teaching, as well as inquiry based classroom laboratory instruction. Research continues to demonstrate that current and historical science teaching methods are unsuccessful in developing desired levels of NOS knowledge in secondary students and educators (Lederman et al., 2002). A key criticism of current science teaching methods is that current teaching methods focus almost exclusively on content recall while omitting the knowledge-generation process (McComas et al., 2000). Knowing this, we must look for alternative instructional methods to improve secondary student's NOS views. Therefore, the knowledge-generation process becomes an important area of focus for improving NOS views in secondary students.

Traditional classroom science instruction does not develop adequate NOS understanding in students because the practice of science is a foreign concept, beyond their everyday experiences (Ryder et al., 1999). An alternative instructional method to classroom teaching, is out of school science internships. Participation in authentic science research through internships with practicing scientists, develops student's understanding of nature of science through their experience of real science and discourse with scientists (Bell, Blair, Crawford, & Lederman, 2003). Students acquire a deeper understanding of science through their discreet experiences, and develop understanding beyond factual recall. Social representation theory states that these new and specialized experiences provide a basis for internal and external discussions about science which leads to evolution of student's NOS views (Ryder et al., 1999). Science internships provide a means of engaging the knowledge-generation process in students that is lacking in current factual recall based education.

However, there is a gap in science internship research. Though there have been many studies on the effects of research internships on student NOS conceptualizations, there is little research that includes full immersion in science inquiry for student interns. Full immersion in science inquiry requires immersion in all five features of science inquiry. All five features are present when the "learner engages in scientifically oriented questions…gives priority to evidence in responding to questions…formulate[s] explanations from evidence…connects explanations to scientific knowledge…communicates and justifies explanations" (Center for Science, Mathematics, & Engineering Education [CSMEE], 2000, p. 29). A review of 16 research studies of authentic research apprenticeships for secondary students, revealed that 13 did not fully situate their apprentices within all five features of science inquiry as they did not allow apprentices to engage in their own, original scientifically oriented questions. That is, most of the studies e.g. Abraham, 2002; Barab & Hay, 2001; Bell et al., 2003; Bleicher, 1996; Burgin, McConnell & Flowers, 2015; Burgin & Sadler, 2016; Burgin, Sadler, & Koroly, 2012; Charney et al., 2007; Hsu et al., 2010; McMiller, Lee, Saroop, Green, & Johnson, 2006; Ritchie & Rigano, 1996; Richmond & Kurth, 1999; and Templin, Engemann, & Doran, 1999 did not situate apprentices within all five features of science inquiry, while only a few of the studies did situate them in all five features e.g. Grindstaff & Richmond, 2008; and Stake & Mares, 2005 (See details in Chapter 2). Conducting a study that situates students within all aspects of science inquiry is critical to demonstrating the full potential of research internships for NOS development.

The purpose of this thesis is to examine the impact of authentic immersion in science research on high school student's conceptions of NOS. Students are situated in a long term (over one semester) science research internship where they are immersed within all five features of science inquiry. Pre and post interviews are used to determine student conceptualizations of NOS both before and after the program to show the impact of the intervention.

Chapter 2: Literature Review

2.1 Nature of Science

What is nature of science (NOS)? Within the field of science there are wide ranging and often conflicting claims about what NOS entails. Philosophers and science education researchers have long debated different views of NOS with resultant differing views between philosophers and practicing scientists (Smith & Scharmann, 1999). However, research points to accepting a common view of NOS that can be applied to secondary students without delving into the higher-level debate over epistemologies and philosophies (Bell et al., 2003; Holbrook & Rannikmae, 2007; Smith & Scharmann, 1999; Zeidler et al., 2002). Understanding NOS requires a simplified definition that can be applied to the secondary student level. Lederman (1992), defines this level of NOS as “the values and assumptions inherent to science” (p. 331). This early definition provides a framework from which to develop definitions that encompass student needs while avoiding epistemological issues. It is “the intersection of issues addressed by the philosophy, history, sociology, and psychology of science as they apply to and potentially impact science teaching and learning” (McComas et al., 2000, p. 5). This simplified definition still requires further explanation in order to show what aspects of NOS apply to students. The critical NOS components that apply to the secondary student are that: scientific knowledge is dynamic; experimental; theory based; partly based on reasoning, originality, and ingenuity; and embedded with social and cultural practices. Three defining aspects include: the differentiation between inference and observation, the understanding that there is not a single scientific method, and the separate functions and interplay of scientific laws and theories (Holbrook & Rannikmae, 2007; Lederman et al., 2002). These criteria demonstrate the basic knowledge that students need to know in order to gain adequate NOS conceptions. The social nature of NOS is an important aspect that is often overlooked in the rush to ensure students understand the scientific aspects of NOS. However, understanding how NOS is socially constructed is vital to student learning. It is through internal discourse and reasoning, and discourse with the scientific community that student understandings of NOS are constructed. Their representations of new or different NOS concepts are grounded within the contexts of the

community they understand. Therefore, their participation in a group of scientists gives them improved contexts by which to understand unfamiliar NOS knowledge (Ryder et al., 1999). Understanding how understandings of NOS are socially constructed is important to devising improved means of developing student NOS conceptions.

2.2 NOS Measurement

Fully understanding NOS is impossible without effective measurements of views. Calls for measures of student NOS conceptualizations go back as far as 1907 (Hogan, 2000; Lederman, 1992). Historically, efforts have focused on objective instruments to measure student's NOS knowledge. A number of quantitative standardized tests, such as the Test of Understanding Science [TOUS] (Cooley & Klopfer, 1961), Nature of Science Test (Billeh & Hasan, 1975), Nature of Scientific Knowledge Scale (Rubba & Anderson, 1978), and the Conceptions of Scientific Theories Test (Cotham & Smith, 1981), have been used to measure NOS knowledge (Hogan, 2000; Khishfe, 2008). These instruments generated initial knowledge about student conceptualization of NOS.

The first quantitative measure that is reviewed is one of the earliest attempts to categorize NOS views in students. The Test of Understanding Science [TOUS] was developed as a research tool to better understand student views of science (Aikenhead, 1973; Cooley & Klopfer, 1961). This test was the most prevalent early measure of NOS understanding in students. It was a sixty question multiple choice exam which was divided into three sub groupings: understanding scientific enterprise (18 questions), the scientist (18 questions), and methods and aims of science (24 questions) (Aikenhead, 1973). The TOUS content was oriented on information from a wide range of science educators, as well as history and philosophy of science professors. Some of the main criticisms of this instrument are that it can be too difficult for some students to understand, places scientific enterprise in a negative connotation, and contains bias concerning science stereotypes (Aikenhead, 1973). Despite its critiques, this test provides a good starting point for measuring student views of NOS.

A second instrument is the Nature of Science Test [NOST] designed by Billeh and Hasan. This is a 60-question multiple choice test divided into four categories: scientific assumptions (8 questions), science products (22 questions), science processes (25 questions), and science ethics (5 questions) (Billeh & Hasan, 1975). Two sample questions from the instrument include:

'Bodies falling in space from the same height fall with the same acceleration.' This statement is accepted by scientists because:

(a) It has not been proved false.

(b) It is true.

(c) It is derived theoretically.

(d) It has been empirically tested.

Scientists use classifications in science to:

(a) Explain scientific observations.

(b) Organize scientific observations.

(c) Predict scientific observations.

(d) Favor scientific observations (Billeh & Hasan, 1975, p. 218).

This instrument has a similar focus to the TOUS, and largely undergoes the same critiques. One area where there is difference is that this instrument was measured by a panel of science educators, scientists, and supervisors where the TOUS had history and philosophy professors involved. The outcomes of this instrument focus more on student scientific knowledge than on student understandings about science.

The Nature of Scientific Knowledge Scale [NSKS] was designed to better measure NOS knowledge in secondary students. The test contained 48 questions which were divided into the following six categories: amoral, creative, developmental, parsimonious, testable, and unified. Each category had four positive themed items and four negative themed items in the test. Rather than using a multiple-choice format, this test utilizes a 5 position Likert scale from "strongly agree" to "strongly disagree" to elicit a wider range of responses about student views of NOS (Rubba & Andersen, 1978). Two example statements from the instrument include:

- The applications of scientific knowledge can be judged good or bad; but the knowledge itself cannot.
- The truth of scientific knowledge is beyond doubt (Rubba & Andersen, 1978, p. 456-457).

This instrument differs from the first two examined in that it focuses more on student views and perceptions of NOS to provide a better representation of their NOS understandings. There are still shortcomings with the instrument as it still forces answers to fit within a yes or no dichotomy for scoring rather than showing what views a respondent may actually hold about each item.

The Conceptions of Scientific Theories Test [COST] was designed to give a clearer picture of NOS views based on philosophy rather than of single interpretations of NOS. The 40-question instrument utilizes a four point Likert scale from "strongly agree" to "strongly disagree" to measure views of statements from four subcategories. These categories include: ontological implications of theories, theory testing, theory generation, and theory choice (Cotham & Smith, 1981). One example statement from the instrument is:

> Plate tectonics is a new theory. Given enough time it's likely that enough evidence will be accumulated to prove it conclusively.
>
> Strongly agree agree disagree strongly disagree
>
> (1) (2) (3) (4)
>
> (Cotham & Smith, 1981, p. 390).

The key differences between this test and previous ones is that it provides a means of limiting the assumptions forced upon test takers. The instrument is sensitive to the fact that respondents may hold alternate positions that are still valid and provides a means to show their true views.

The critical issue with these quantitative and closed question assessments of NOS is that they do not give students the ability to freely voice their views and beliefs. Lederman et al., (2002) identifies two critical shortcomings of paper and pencil instrument's validity. First is that the tests are predicated on researcher's assumptions that students understand the questions in the same

contexts as the test creators, rather than having original views that may not be captured by the closed ended questions. Second, closed ended answers often impart researcher bias on student responses as they are forced to answer in line with the researchers views and philosophies without regard for their own images of NOS. These shortfalls limit the ability for closed ended assessments to provide true representations of student views of NOS. These quantitative measures limit the ability to measure how students interpret their NOS understandings.

As a result, qualitative measures based on open ended questionnaires along with interviews about their responses were designed starting in the 1990s to elicit answers from students about their personal interpretations of NOS concepts, such as the Views of Nature of Science Questionnaire (VNOS) (Khishfe, 2008; Lederman et al., 2002; Lederman & O'Malley, 1990). These qualitative assessments allow researchers to see what students believe about NOS, as well as a means of understanding how they developed those views (Khishfe, 2008).

The VNOS-A was developed as a seven-question open ended instrument with follow on interviews for participants in order to elicit not only student views of NOS, but their reasoning and justifications as well. The instrument was based on the seven "dichotomies" presented by Cotham & Smith in 1981 (Lederman & O'Malley, 1990). Two questionnaire questions include:

- What does an atom look like? How do scientists know that an atom looks like what you have described or drawn? [Realist/Instrumentalist]
- Is there a difference between a scientific theory and a scientific law? Give an example to illustrate your answer. [Induction/Invention] (Lederman & O'Malley, 1990, p. 227).

Follow on interviews asked participants to elaborate on their answers with a range of six questions including the following two examples:

- When did you first learn/believe the answer you wrote?
- Did you always believe this? (Lederman & O'Malley, 1990, p. 228).

This system allows NOS beliefs of students, as well as the underlying reasons for those beliefs to be understood by researchers. An identified shortcoming of the VNOS-A was that three

of the seven questions did not elicit answers from participants referencing their tentative and revisionist views of science, as the questions were either too vague or the students did not interpret the same meaning from those questions as the researchers. (Lederman & O’Malley, 1990). These questions include:

- How are science and art similar? How are they different?
- Scientists perform scientific experiments/investigations when trying to solve problems. Do scientists use their creativity and imagination when doing these experiments/investigations?
- Is there a difference between scientific knowledge and opinion? Give an example to illustrate your answer (Lederman & O’Malley, 1990).

The omission of these questions reduced the amount of data that could be used to measure student views of NOS. However, interviews allowed researchers to gain a more accurate understanding of student views as they minimized critical misunderstandings in the use of words, such as prove, that occurred on written instruments. Where researchers thought students used prove in an absolute sense, interviews showed they were giving it the meaning of scientific proof, or supporting evidence of a law or theory (Lederman & O’Malley, 1990). This finding paved the way for future improved interview based instruments.

The Views of Nature of Science (VNOS-C) was developed to continue building on the VNOS-A and VNOS-B while attempting to garner better understanding of student views of social and cultural components of NOS as well as universal scientific method beliefs (Lederman et al., 2002). The VNOS-A and VNOS-B instrument was revised and expanded to 10 questions to provide a better means of probing student views and beliefs about NOS. Two examples of the updated questions on the instrument include:

- Some claim that science is infused with social and cultural values. That is, science reflects the social and political values, philosophic 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. Defend your answer with examples.
- If you believe science is universal, explain why. Defend your answer with examples.
- 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 you believe 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 (Lederman et al., 2002, p. 509).

Additionally, an interview protocol was adopted to ensure sufficient analysis was conducted of different statements from participants. The aim of the interview process was to identify participant views and beliefs of structure and goals of experimentation, logic based theory testing, and observation versus experimental based theories and practice (Lederman et al., 2002).

The Five Interview Questions approach NOS assessment in students from an interview only perspective. Rather than have participants complete an open ended questionnaire and then interview them about their answers, participants are interviewed to learn their beliefs and views of NOS. Open ended interviews build on the questionnaire model by improving the information gathered from the students about their ideas and beliefs about NOS as well as their understanding of the contexts by which they understand NOS (Ryder et al., 1999). The five questions are:

- How do scientists decide which questions to investigate?
- Why do scientists do experiments?

- How can good scientific work be distinguished from bad scientific work?
- Why do you think that some scientific work stands the test of time whereas other scientific work is forgotten?
- How are conflicts of ideas resolved in the scientific community? (Ryder et al., 1999, p. 204-205).

The interview process with these questions allowed science to be discussed at length without having to overly steer the discussion towards student views of science. Interviews provide researchers the ability to give a context to participants who then define what that context means to them as well as clarifying any statement made that may seem ambiguous (Lederman & O'Malley, 1990; Ryder et al., 1999). Interviews allow student views and beliefs of science to be explored to their fullest extent as researchers are able to ask follow on questions to better understand student views.

Many NOS studies have focused on an adequate versus inadequate framework of NOS views. Understanding NOS views require the ability to differentiate knowledge beyond this yes or no framework (Khishfe, 2008). Using a tiered measurement system allows change to be shown for students as their conceptions develop. Several studies use three tiered measures based on naïve (science is absolute with no distinction between evidence and opinion, and no social aspect is involved), basic (science is tentative, but only in changing existing claims; evidence is limited to concrete examples with social components limited to sharing results), and informed (science is tentative; theories can be disproven and replaced based on evidence both concrete and inferred; social aspects of science including negotiations and discourse are equally as important as experimentation) views (Khishfe, 2008; 2015; Yacoubian & BouJaoude, 2010). With this framework, conceptual change can show the effects of instructional methods using pre and post-tests.

2.3 Current Instructional Methods to Teach NOS

There are many approaches to improving high school student's NOS conceptions. Traditionally, science instruction and textbooks have focused on facts based content, while ignoring processes of knowledge creation. This system of factual recall and cook book lab activities explains the low levels of NOS comprehension in students and society (McComas et al., 2000). As such, traditional classroom instructional methods limit the ability to impart informed views of NOS in students. Research shows that cookbook lab activities have been replaced with open inquiry through the constructivist reform movement. Inquiry based classroom laboratory instruction enhances student interest as they are invested in seeking answers to their own questions rather than answers to questions with which they cannot relate. From this they learn the pleasure of inquiry and ownership of their problems and answers (Ritchie & Rigano, 1996). The shortcoming of classroom inquiry is the limited ability to immerse students in scientific communities and contexts. Research demonstrates that conventional methods continue to impart less than desired levels of NOS in secondary students (Lederman et al., 2002).

Recognition of this limitation has led to increased interest in supplementary means of improving student's NOS conceptions, such as authentic science research internships. Authentic science research internships have been identified by national science education organizations as a means of supplementing classroom instruction to improve student NOS conceptions through immersion. "The American Association for the Advancement of Science (Project 2061, 1993) and the National Research Council (NRC, 1996) suggest that K-12 science education needs to engage students in practicing science more authentically rather than providing didactic instruction" (Hsu et al., 2010, p. 1244). Research has shown that there is value in allowing students to experience scientific practices beyond standard curriculum (Burgin & Sadler, 2016). According to Bell et al. (2003), participation in authentic science research in inquiry based learning, or through internships with practicing scientists, develops student's understanding of nature of science through their experience of real science and discourse with scientists. "Out-of-school research apprenticeship experiences offer a uniquely authentic context with the potential to impact participants'

understandings of the epistemological roots of science" (Burgin & Sadler, 2016, p. 33). These contexts give richness and meaning to the scientific knowledge imparted to students. Working with scientists allows students to develop expertise in science by conducting science (Hodson, 1993). Immersion in the practice of science provides opportunities for students to learn science by conducting it, rather than only learning facts in a classroom setting. Research has shown there are positive learning gains about social contexts of science and tentativeness due to participation in research apprenticeships (Burgin & Sadler, 2016; Richmond & Kurth, 1999; Ritchie & Rigano, 1996). Furthermore, research demonstrates that students improve their understanding of scientific practice through truly authentic science experiences (Hsu et al., 2010). Therefore, authentic science research apprenticeships provide a means for students to improve their NOS conceptualizations beyond the classroom.

NOS development has been approached with two techniques in authentic science research internships. Explicit/reflective approaches include explicit teaching about NOS within internships to ensure NOS understandings are improved. Meanwhile, implicit approaches consider the engagement in inquiry activities sufficient in improving students' NOS understandings (Burgin & Sadler, 2016; Khishfe & Abd-El-Khalick, 2002). Research has shown that explicit and reflective methods of covering NOS concepts within research apprenticeships have led to higher levels of NOS understandings for students involved (Yacoubian & BouJaoude, 2010). The benefit of reflection is paramount. "Reflective group discussions contribute to students' learning from each other, thus making NOS instruction even more explicit" (Yacoubian & BouJaoude, 2010, p. 1232). Meanwhile, implicit methods rely on the student's immersion within science activities to develop NOS knowledge in students. Implicit instruction within research apprenticeships has been shown to have limited impacts on student NOS conceptions. Despite these limited impacts, some students did benefit from the implicit program as they related the questions asked in their pre interviews to what they practiced in their apprenticeship (Bell et al., 2003). Though there is a greater preponderance of evidence supporting explicit/reflective approaches, research points to implicit methods having potential when combined with reflection.

2.4 Gender Effects on NOS Learning

In order to understand how students learn NOS, there needs to be an understanding of the role gender can play in learning. Unfortunately, there is not a large body of research on gender effects on NOS learning. However, two comprehensive reviews of literature concerning NOS learning and gender provided some clear findings. Brotman and Moore (2008) was a review of research surrounding girls in science. What they found as a critical theme from the studies they looked at was that there was not clear evidence that male or female students learned NOS differently. According to Brotman and Moore (2008), "these studies provide evidence that laboratory experiences may in fact be beneficial for both girls' and boys' science achievement" (p. 982). However, the study did state that more rigorous research was needed to provide true confirmation. The next review, Deng, Tsai, and Chai (2011) found inconclusive evidence that gender played a role in views of NOS. These findings support the claim from the Brotman et al. (2008) review that additional rigorous research targeted on gender is required to provide conclusive links between gender and NOS views. However, one interesting finding was that "several studies have reported that male students show more constructivist orientation than female students on certain dimensions of VNOS, such as the changing and creative nature of science" (Deng et al., 2011, p. 973). This is supported by de la Rubia, Lin, and Tsai's (2014) study of undergraduate student views of NOS, that found that male Taiwanese students tended to have more constructivist views of NOS than female Taiwanese students. These findings point towards male students as possibly improving their NOS views more than females with regards to constructivist theories. The findings are not conclusive though, and de la Rubia et al. (2014), also call for more rigorous research to provide conclusive proof of this trend.

2.5 Gaps on NOS research

One gap in research about NOS development through internships is the level of immersion experienced by students. There is a lot of research on authenticity of the science that students experience, but little research about the effects of full immersion that requires students to be

involved in the entire process of science. Immersion is where students are involved in authentic science across the entire spectrum of the research process. "It is generally believed that the more authentic the research experience, such as an apprenticeship guided by a science professional, the more likely students will learn about aspects of scientific inquiry" (Bell et al., 2003, p. 488). Part of this immersion is sufficient time for interns to be situated in the discourse. Research shows that, "over time [students] learn discourse, a set of skills rooted in an understanding of the content and culture that shape professional practice" (Richmond & Kurth, 1999, p. 678). This immersion leads to developing improved NOS conceptions from situated learning, through their discussions with mentor scientists and their conduct of actual science in contexts which mirror real life science contexts (Burgin & Sadler, 2016; Richmond & Kurth, 1999). An integral part of science immersion is to ensure authenticity to the scientific research process. "Is merely being embedded in an authentic context enough, or do participants need to be truly and meaningfully participating in the research to see desirable impacts on outcomes such as career aspirations and science identity?" (Burgin et al., 2015, p. 417). The five essential features of science inquiry listed in Table 2.5.1 provide a clear means of measuring the level of immersion that a student experiences in a science internship program. The essence of these features include engagement in original scientific questioning, evidence driven research, evidence based reasoning, hypothesis testing, and communication and justification of their findings (CSMEE, 2000). When all of these features are present, with adequate time to fully process and comprehend the process, it increases the level of immersion to the same levels as those experienced by practicing scientists.

Table 2.5.1. Essential features of science inquiry (CSMEE, 2000, p. 29).

Essential Feature
1. Learners are engaged by scientifically oriented questions.
2. Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions.
3. Learners formulate explanations from evidence to address scientifically oriented questions.
4. Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding.
5. Learners communicate and justify their proposed explanations.

Research on immersion becomes a logical next step to determine how it affects student NOS gains in practice. 16 student science internship or apprenticeship programs were reviewed for their levels of immersion. These studies were selected based on being peer reviewed studies found in either the Web of Science or Academic Search Complete (EBSCO) databases. Keywords of “Research Apprenticeship” or “Research Internship”, Science, and “High School” or Secondary were searched to identify studies that covered the area of inquiry. Each study was reviewed through the published paper to determine if each of the five essential features of inquiry were present, and the length of the program. The findings are tabulated in Table 2.5.2 to show which features were identified in each study.

Only three of the 16 studies reviewed gave interns the option to develop their own research projects, separate from their mentor scientists. The common theme of the studies is that the students were working in a laboratory as assistants to the scientists. They did not reach complete immersion as a result of working for, rather than with scientists. They were unable to fully research and develop their individual research questions and become engaged with their own scientifically oriented questions (Abraham, 2002; Barab & Hay, 2001; Bell et al., 2003; Bleicher, 1996; Burgin et al., 2015; Burgin & Sadler, 2016; Burgin et al., 2012; Charney et al., 2007; Hsu et al., 2010; McMiller et al., 2006; Richmond & Kurth, 1999; Ritchie & Rigano, 1996; Templin et al., 1999). There were only three studies that did provide interns with the first feature of inquiry in that they were able to ask their own original research questions rather than having to work on someone else’s ongoing project (Grindstaff & Richmond, 2008; Stake & Mares, 2001, 2005). Allowing interns to create their own authentic scientific questions drives them towards discourse to better understand their data and increase their learning potential (Grindstaff & Richmond, 2008). Moreover, only two of the sixteen studies reviewed in Table 2 were longer than eight weeks. Some research identifies that any length of program can benefit NOS development, stating that even short term internships can give students access to the culture of science (Burgin, McConnell, & Flowers, 2015; Burgin & Sadler, 2016). However, there are still questions regarding how program length impacts NOS change. “Chief among these are questions regarding the nature of the

experience. How much time is needed?" (Burgin et al., 2015, p. 417). "Out of the 20 studies that were designed for high school students and reviewed by Sadler et al., only in two studies high school students engaged in authentic scientific inquiry for an academic semester or longer" (Aydeniz, Baksa & Skinner, 2011, p. 404). Longer internships likely allow discourse to mature as students have more exposure to the cultures of real science. When students entered the lab as technicians or assistants, rather than equal research partners with the scientists, they lost the ability to conduct discourse about their research and the process. Supervisor driven research projects limited intern's engagement with research as the research was not tailored to their interests and knowledge base (Ritchie & Rigano, 1996). Without equal status as researchers, they lack the agency required to develop their research in meaningful ways that improve their understanding of NOS.

Table 2.5.2. Internship projects' levels of immersion and length.

No	Internship	Feature 1	Feature 2	Feature 3	Feature 4	Feature 5	Project Length
1	Bleicher, 1996	-	Yes	Yes	Yes	-	6 Wks
2	Ritchie & Rigano, 1996	-	Yes	Yes	Yes	-	6 Mos
3	Richmond & Kurth, 1999	-	Yes	Yes	Yes	Yes	7 Wks
4	Templin et al., 1999	-	Yes	Yes	Yes	Yes	6 Wks
5	Stake & Mares, 2001	Yes	Yes	Yes	Yes	-	4&6 Wks
6	Barab & Hay, 2001	-	Yes	Yes	Yes	Yes	2 Wks
7	Abraham, 2002	-	-	-	-	-	-
8	Bell et al., 2003	-	Yes	Yes	Yes	Yes	8 Wks
9	Stake & Mares, 2005	Yes	Yes	Yes	Yes	Yes	6 Wks
10	McMiller et al., 2006	-	Yes	Yes	Yes	Yes	8 Wks
11	Charney et al., 2007	-	Yes	Yes	Yes	Yes	4 Wks
12	Grindstaff & Richmond, 2008	Yes	Yes	Yes	Yes	Yes	7 Wks
13	Hsu et al., 2010	-	Yes	-	-	-	6 Mos
14	Burgin et al., 2012	-	Yes	Yes	-	Yes	7 Wks
15	Burgin et al., 2015	-	-	-	-	-	2 Wks
16	Burgin & Sadler, 2016	-	Yes	Yes	Yes	Yes	7 Wks

(Yes) indicates this step was identified in the review of the literature about the study.
(-) indicates this step was not found in the review of the literature about the study.

2.6 Using Communities of Practice and Cogenerative Dialogues to Enrich Student NOS Views

There are two theoretical models the apprenticeship program is based upon. First, communities of practice (CoP) is a theory that creates inclusion for apprentices by allowing them full access to the scientific process as they become full partners in the program. Second, cogenerative dialogues (cogen) is a pedagogical tool for providing conversational equity to all parties involved to allow more complete immersion. Combined, they allow the program to be framed in such a way that apprentices move beyond apprenticeship and become fully vested researchers in the program.

Participation in research communities gives students a sense of belonging that increases their agency in the research process. A “community of practice is a set of relations among persons, activity, and world, over time and in relation with other tangential and overlapping communities of practice…an intrinsic condition for the existence of knowledge, not least because it provides the interpretive support necessary for making sense of its heritage (Lave & Wenger, 1991, p. 98). There are seven principle requirements for a successful community of practice. First, the community must be a dynamic construct that can evolve to meet changing interests, members, and

goals. Second, dialog channels both within and external to the community must be opened to meet goals. Third, welcome all levels of participation, including: core level (leaders of the group), active level (no leadership role), and peripheral level (passive members who still benefit from group learning). Fourth, create spaces both public and private for members to collaborate on ideas and best utilize resources and build relationships. Fifth, maintain a focus on the value of participation and what each member's participation contributes to the community. Sixth, create a learning environment that blends expected learning with collaboration opportunities that expand knowledge of the community's focus. Finally, coordinate a schedule of activity for the community that maintains an ongoing cycle of group interaction to sustain the community, but does not overwhelm members through over intensity (Wenger, McDermott & Snyder, 2002). These guiding principles allow for a successful community of practice to be established and maintained.

Full participation in a community of practice takes time. Communities of practice immerse apprentices within research where they work directly on research with peers, experts, and knowledge holders, rather than learning about the discipline through lectures with little context (Barab & Hay, 2001). In order for apprentices to gain full access as equals in a community of practice, they must reach legitimate peripheral participation. Legitimate peripheral participation consists of three aspects: level of legitimacy, location within the community, and level of participation. These aspects are intertwined and must be viewed as a whole to be understood. The form of legitimacy defines how someone belongs to the community, conditions their learning, and controls content. Location within the community is how actors are socially engaged in different forms of the community. The periphery is actually ideal as there is no true center, therefore being on the periphery gives access to the entire community. Finally, level of participation leads up to full participation, where actors have access to the full breadth of knowledge and resources within the community (Lave & Wenger, 1991). As students spend time in an apprenticeship, they develop their community roles over time. Once they have achieved legitimate peripheral participation, they achieve full access to their community of practice.

Creating an environment where students experience and participate in deep and meaningful dialogue about their work and the issues surrounding it is critical for their success. Cogenerative dialogues are defined as "a process of collective, all-stakeholders-involving, democratic sense making (Stith & Roth, 2010, p. 363). This process builds collaboration with others as they work together to better understand scientific meanings through their social lens. Students gain agency in science through collaboration in cogen (Tobin, 2006), which allows them to improve their NOS conceptualizations, as they see their inputs to the process accepted as valid and correct. "One of the common goals of the participants in cogen is to create solidarity that is grounded in deep respect for differences, and willingness to learn from others (Shady, 2015, p. 1027). This form of discussion is vital to providing the means for students to fully discuss what they are learning throughout the apprenticeship process and reach critical understanding of their topic.

The key purpose of cogen is to set aside and protect sufficient time for group dialogue throughout the entire process. According to Tobin (2006),

> The emphasis in these cogenerative dialogues is on conversations in which each participant is free to express honest opinions of his or her experiences in the lesson. Active listening is considered to be a characteristic of the cogenerative dialogues, as is an acceptance of collective responsibility among all participants for the unfolding events of the classroom. The expected outcomes from cogenerative dialogues are phenomenological accounts of events that all participants can agree to, identification of contradictions and agreements on how to resolve them and, as necessary, consensus on new goals and roles for the community (p. 139).

These discussions allow students to become full members of their research communities and reach shared understandings of the research they are conducting. Gaining participant access to research communities through cogen, is an important step in improving student NOS conceptualizations.

Combining communities of practice with cogen opens up the ability for students to reach immersion in a science apprenticeship. They allow students to access the community of practice,

and resultant knowledge, of their research groups. Cogen ensures that they continually reflect on what they have learned, and compare it to other's interpretations in order to reach shared understandings that give all participants a say in what the research means. Together, these theories tie implicit learning through practice to explicit reflection to achieve improved NOS conceptualizations.

Sufficient NOS conceptualizations are an important educational goal for secondary students. Without adequate NOS conceptions, citizens are unable to make informed decisions about issues that affect all of society (McComas et al., 2000; O'Neill & Polman, 2004; Ryder et al., 1999; Ziedler et al., 2002). As a result, there have been calls for additional and improved NOS education for secondary students to become citizens, capable of making informed scientific decisions which affect the country (NGSS Lead States, 2013; NRC, 1996). Current methods for teaching NOS include traditional factual recall and cookbook style laboratory activities, and inquiry based lab activities (McComas et al., 2000). Due to the failure of traditional methods to impart improved views of NOS, constructivist theorists developed inquiry based lab methods that give students contexts which they can better understand, and gives them investment in the questions they are answering (Ritchie & Rigano, 1996). These methods still lack the ability to provide students with complete immersion in science, therefore limiting how well they can improve NOS conceptualizations. Authentic science research apprenticeships allow students to be fully immersed in the community of science and provide a means of supplementing classroom instruction to reach desired levels of NOS conceptualizations (Hsu et al., 2010; Burgin & Sadler, 2016). Previous authentic science research apprenticeship studies have limited the level of immersion, forgoing some of the five steps of scientific inquiry. Therefore, the gap present is one of immersion. Situating students in research apprenticeships that immerse them in all five steps of inquiry is critical to providing data to fill the gap. The current gap in research on how authentic science research apprenticeships affect changes in secondary student's NOS conceptualizations is how immersion affects improvement. Many studies have been conducted on authentic science research apprenticeships, but few have positioned apprentices within all five elements of scientific

inquiry (CSMEE, 2000) throughout their apprenticeships. Communities of practice and cogenerative dialogues are two theoretical frameworks which have the potential to enhance development of NOS views in secondary students, by setting up an environment that provides true immersion within a scientific research community.

Chapter 3: Research Methods

3.1 Research Context

This thesis was conducted using existing data. The data is from the Transforming Students' Partnership with Scientists Through Cogenerative Dialogues project, a National Science Foundation Project No. DRL 1322600, also known as the Work with a Scientist Program (WWASP) at the University of Texas at El Paso. The WWASP is a research-based and theory grounded internship program that allowed students from Amber, Copper, and Indigo High Schools (pseudonyms) to study in university science laboratories at the University of Texas at El Paso. The students partnered with UTEP scientists in their research laboratories to learn from them, gain a sense of belonging in their laboratory, and then develop and conduct their own research projects. The program consisted of three years of student involvement. Each program year began in January when students attended orientation and then attended three-hour long Saturday laboratory sessions twice a month for ten sessions. In year one, they met Monday through Friday, 9:00am to 1:00pm for four weeks in June and July, and in year two and year three they met Monday through Friday, 9:00am to 4:00 pm for six weeks in June and July. In these summer sessions, they conducted their research projects, cogen, and presented their proposals and findings. Cogenerative dialogue sessions were scheduled to regularly coincide with laboratory research meetings, which were used to develop conversations between the students and scientists that situated them as equals in research. Year one cogen sessions were facilitated by the science research assistant from each lab where the students were working. In year two and year three, cogen sessions were facilitated by education research assistants who had received additional training from the program director in order to improve the quality of the cogenerative dialogues. This continual dialogue formed the basis for developing a community of practice between the students and scientists.

3.2 Connections to CoP

The program is based on the seven principles of the CoP theory. These principles were integrated throughout the WWASP to create a vibrant community that develops apprentice's

knowledge and understanding of science and research methodology. Fulfilling these seven principles of CoP creates an environment within which students can thrive as scientists. They have the background knowledge and support to develop scientific research that answers gaps in current scientific knowledge.

First, the community should be designed in such a way that it can evolve naturally. The program is scheduled so that students have time over the course of a semester to gain a good understanding of ongoing research in the laboratory, and determine where their own interests lie. This time allows the community to naturally evolve to meet community needs, rather than having a shortened timeline that requires strict adherence to a preordained schedule of events.

Second, avenues of open dialog both inside and outside of the community are necessary. The use of cogen creates channels of dialogue both within the community and outside as well. Students have time allocated every other week throughout the semester to discuss their research and science with the scientists with whom they are working, allowing for continual internal dialogue. They have both the research proposal presentation and research final presentation that provide opportunities for dialogue outside of their CoP. They also have meetings every other week with their teachers of record, which provides an outlet for discussion about their work with science professionals outside their communities of practice. This framework ensures that students are continually discussing their research and the greater scientific understandings both within and outside of their CoPs.

Third, all levels of participation, including leaders, active participants, and passive participants should be encouraged and cultivated. The program encourages participation from all levels, including students, scientists, and facilitators. Students collaborate with scientists both inside and outside of the laboratory to maximize ideas and resources. The program is designed so that students have continued interactions with university PhD scientists, graduate research assistants, other student interns, and teachers and faculty from their parent schools and UTEP. A key facet of this is that students work in small groups where they regularly transition between the

different levels of participation as they work together towards a common goal. This collaborative framework allows open sharing of information and creates a sense of belonging for all involved.

Fourth, both public and private spaces for community interactions are offered. Students participate in private community spaces such as their small laboratory groups of two to three apprentices and their cogen groups. This setting creates a feeling of familiarity and belonging as students become equals with their mentor scientists. Laboratory meetings, research proposal presentations, and final presentations create public spaces where students and scientists are able to discuss ongoing research as well as allowing others to see what they have been conducting within their individual CoPs through research presentations. These public spaces give students a voice and a sense of ownership in their research.

Fifth, value of participants to the community is a key focus. Community value is an important aspect of the WWASP. Students create end of course presentations where they present their research findings. This presentation is student generated and conducted. This gives the students a sense of value in their CoP as they are the ones responsible for conveying the important findings from their research, rather than the university scientists. This structure demonstrates the participation and value that the students brought to the CoP.

Sixth, excitement and routine are combined to promote continued learning, while promoting collaboration on new breakthroughs. The semester long program allows students to learn by working with scientists, and then expand on that learning by conducting their own research project. This extended timeline gives students the chance to become comfortable with their research content. Student familiarity with the subject gives rise to excitement as they are able to bring new and novel ideas to the community as they develop their research project ideas and integrate new community ideas from their proposal presentations.

Finally, establishing a schedule of meetings and interactions that maintains engagement levels that drive community vibrancy, without overwhelming participants with too much interaction (Wenger et al., 2002). There are meetings about twice a month during the spring semester where students meet and work in their laboratories. They then have an intensive six-week

period in the summer where they conduct their final research projects and present their findings. This schedule nurtures the growth of their CoPs through ongoing engagement, but they do not meet so often that they become disillusioned. This schedule allows the community to develop to a point that it can sustain ongoing interaction for the summer period as they have established roles and responsibilities within the group, and all participants are able to focus on research rather than attempting to create a new community.

3.3 Participant Background/Demographics

The participants in the program are all juniors in high school from Amber, Blue, Copper, and Indigo High Schools (pseudonyms). These four high schools are all Title I schools from the same district in in a west Texas city. Amber High School's 2014-2015 demographics include 1722 total students, with the key ethnicities being 11.7 percent African-American, 73.9 percent Hispanic, and 10.3 percent white. 57 percent of enrolled students are considered economically disadvantaged (The Texas Tribune, 2015). Blue High School's 2014-2015 demographics include 1415 total students, with the key ethnicities being 3.0 percent African-American, 90.1 percent Hispanic, and 5.4 percent white. 65.8 percent of enrolled students are considered economically disadvantaged (The Texas Tribune, 2015). Copper High School's 2014-2015 demographics include 1920 total students, with the key ethnicities being 9.5 percent African-American, 69.9 percent Hispanic, and 15.5 percent white. 47.9 percent of enrolled students are considered economically disadvantaged (The Texas Tribune, 2015). Indigo High School's 2014-2015 demographics include 1443 total students, with the key ethnicities being 3.8 percent African-American, 91.5 percent Hispanic, and 3.6 percent white. 80.8 percent of enrolled students are considered economically disadvantaged (The Texas Tribune, 2015). These demographics are illustrated in Table 3.3.1. Student participants were recruited from those entering their junior year who had a minimum 3.0 grade point average. The no internship group was recruited from junior advanced placement physics students who had a minimum 3.0 grade point average at Blue High School for each of the three program years. The internship group for year one of the study were

recruited only from junior students at Indigo High School. Due to a limited number of applicants in program year one, recruitment was expanded to applicants from Amber, Copper, and Indigo high schools in program years two and three.

Table 3.3.1. Participant high school demographics (The Texas Tribune, 2015).

School Pseudonym	Total Students	Hispanic	African American	White	Economically Disadvantaged
Amber	1722	73.9%	11.7%	10.3%	57%
Blue	1415	90.1%	3.0%	5.4%	65.8%
Copper	1920	69.9%	9.5%	15.5%	47.9%
Indigo	1443	91.5%	3.8%	3.6%	80.8%

Recruitment was initiated through presentations by the program staff at all four high schools each year for all incoming junior students. These presentations gave an overview of the program, application requirements, a copy of the syllabus, and explained the stipend and transportation plan to all students. Science teachers at all four schools who were partnered with the WWASP were points of contact who provided additional information to interested students. They distributed program flyers and placed posters around each school to ensure all applicable students were aware of the program and had a chance to apply. Students that met program criteria and displayed interest were able to fill out an application form that was submitted to the program staff through their science teacher. All applications were collected and reviewed by the evaluation committee with a minimum of two committee members reviewing each application. A rubric was used to identify all student applicants that met the criteria to include a 3.0 GPA and interest in science. Those applicants were then scheduled to conduct individual interviews with the program staff, where final decisions were made to accept students into the program for that respective year. There are four scientists and their laboratories that participate in the program each year. Up to 36 students can be placed across the four laboratories, where they are grouped into small groups of two to three students per group. Students that are accepted to the program are randomly placed into WWASP lab groups for that program year.

3.4 Data Source

There are 75 participants who completed the entire program including both pre and post interviews in the internship group across all three program years. There are 52 participants who complete both pre and post interviews in the no internship group across all three years. Program year one consisted of 26 complete participants in the experimental group. 13 were female and 13 were male. 13 of these participants were in labs three and four, which did not conduct cogen as part of their program. The other 13 apprentices in labs one and two, conducted the cogen treatment. There were 16 students in the no internship group in year one who completed both pre and post interviews, nine were female and seven were male. Program year two consisted of 20 complete participants in the experimental group. 11 were female and nine were male. All 20 conducted the cogen treatment. There were 17 students in the no internship group in year two who completed both pre and post interviews, 10 were female and seven were male. Program year three consisted of 29 complete participants in the experimental group. 16 were female and 13 were male. All 29 conducted the cogen treatment. There were 19 students in the no internship group in year three who completed both pre and post interviews, 12 were female and seven were male. The participant information is captured in Table 3.4.1.

Table 3.4.1. Participant information.

Program Year	No Internship Female	No Internship Male	Cogen Female	Cogen Male	Sharing Female	Sharing Male
1	9	7	6	7	7	6
2	10	7	11	9	-	-
3	12	7	16	13	-	-
Totals	31	21	33	29	7	6

The data source for this study are the interview responses provided by all participants to the following five questions from Ryder et al. (1999):

1. How do scientists decide which questions to investigate?
2. Why do scientists do experiments?

3. How can good scientific work be distinguished from bad scientific work?

4. Why do you think that some scientific work stands the test of time whereas other scientific work is forgotten?

5. How are conflicts of ideas resolved in the scientific community (p. 204-205)?

All participants were interviewed before the program year for their pretreatment interviews. All no internship group students were administered their posttreatment interviews in April and May of the program year, after they have completed their AP Physics coursework. All internship group participants were administered their posttreatment interviews in July and August after they complete their research project presentations. All of the responses were recorded during the interviews. Interviewers were trained and instructed to prompt participants to elaborate on their answers beyond their initial responses using semi-structured interviews, by asking for elaboration or more information about responses, without providing additional suggestions of ideas. Semi-structured interviews are open ended, but have a framework of themes that keep the interview focused while maintaining the interviewer's freedom to fit questions to the context of each separate interview (Edwards & Holland, 2013). This was done to provide equal opportunity of response for all participants. It ensured that responses provided a clear picture of each participant's conceptions of NOS at the time of the interview. All responses were transcribed to text files to prepare them for analysis.

For the interview process, all male and female interviewers attended several training meetings with the primary researcher prior to beginning each iteration of interviews. These meetings focused on creating friendly and non-intimidating interview environments, and eliciting full and complete responses from all participants. A key component of this process was that all interviewers were introduced to participants before their scheduled interviews. The friendly and non-intimidating environment was critical, to ensure an atmosphere that would help eliminate gender stereotype confirmation bias in the interviews. It assisted in preventing interviewees from feeling uncomfortable or intimidated, increasing their willingness to provide their true responses

to each prompt. This calibrated interview process provided constancy to the responses, ensuring an accurate representation of each participant's interview responses.

3.5 Data Analysis

There are two forms of data analysis in this study, including a question-by-question analysis looking at student responses to individual questions, and a framework analysis comparing student's total responses against a framework of three NOS aspects. The question-by-question analysis yields information about student's NOS views with relation to discreet NOS concepts, while the framework analysis yields information about student's understandings of NOS as a total concept. Together, these analyses provide the means to better understand student conceptualization of NOS and how it changes as a result of an authentic science research apprenticeship.

3.6 Question-by-Question Analysis

The question-by-question analysis examines changes in individual responses to Ryder et al.'s (1999) five questions. The pre and post-interviews from each participant are analyzed against the multiple categories of response for each question (Ryder et al., 1999; Wilson, 2014). These responses are coded on a scoring system of no response, basic, or developed (Khishfe, 2008, 2015; Yacoubian & BouJaoude, 2010). Basic responses are statements that demonstrate a basic or rudimentary understanding of the concept, and developed responses demonstrate views of the concept that have justification or support beyond the basic understanding. The change between the pre and post-interview is given an analysis score for each category of response as listed in Table 3.6.1. These scores are compiled to give a total change score for each question.

Table 3.6.1 The scoring system for the question-by-question analysis to show the change of views on Nature of Science between pre- and post- interviews.

Pre-Interview	Post Interview	Analysis Score
None, Basic, Developed	None	0
Basic	Basic	0
Developed	Developed	0
None	Basic	1

Basic	Developed	4
None	Developed	5
Developed	Basic	0

Question one, "How do scientists decide which questions to investigate?" has six categories of response: (1) curiosity led: scientist investigate questions which they are personally curious about, (2) extending knowledge: scientists seek to increase and improve the knowledge of the discipline and previous hypothesis, (3) utilitarian: scientists work to help preventing and solving medical or environmental problems for the benefit of humanity, (4) financial benefit: scientists working areas for which they know they can get funding, or which may lead to financial reward, (5) personal recognition: To be recognized: scientists want to gain recognition for their job and contributions, it can be by prizes or awards, and (6) feasibility: Length of research, feasibility to reach correct results. The definitions of basic and developed for all six categories of response are listed in Table 3.6.2.

Table 3.6.2. Basic and developed definitions for question one categories of response "How do scientists decide which questions to investigate?" (Ryder et al., 1999; Wilson, 2014).

Category of Response	Basic Definition	Developed Definition
Curiosity Led	Statement that scientists are curious. Statements are short with little definition, support, or justification.	Statement that scientists are curious. Minimum of one statement with definition, support, or justification that demonstrates clear evidence that curiosity is a driver.
Extending Knowledge	Statement that scientists seek to increase and improve the knowledge of the discipline and previous hypothesis. Statements are short with little definition, support, or justification, though scientifically grounded.	Statement that scientists seek to increase and improve the knowledge of the discipline and previous hypothesis. Minimum of one statement with definition, support, or justification that demonstrates clear evidence that extending knowledge is a driver.
Utilitarian	Statement that scientists work to help the greater good. Statements are short with little definition, support, or justification, though scientifically grounded.	Statement that scientists work to help the greater good. Minimum of one statement with definition, support, or justification that demonstrates clear evidence that helping the greater good is a driver.
Financial Benefit	Statement that scientists work for financial gain. Statements are short with little definition, support, or justification, though scientifically grounded.	Statement that scientists work for financial gain. Minimum of one statement with definition, support, or justification that demonstrates clear evidence that financial gain is a driver.
Personal Recognition	Statement that scientists work for personal recognition. Statements are	Statement that scientists work for personal recognition. Minimum of one statement with

	short with little definition, support, or justification, though scientifically grounded.	definition, support, or justification that demonstrates clear evidence that personal recognition is a driver.
Feasibility	Statement that scientists decide based on feasibility. Statements are short with little definition, support, or justification, though scientifically grounded.	Statement that scientists seek to increase and improve the knowledge of the discipline and previous hypothesis. Minimum of one statement with definition, support, or justification that demonstrates clear evidence that feasibility of research is a driver.

Question two, "Why do scientists do experiments?" has four categories of response: (1) knowledge: to extend their knowledge, and the general knowledge on their field by obtaining helpful results on their experiments, (2) empirical: to find answers to particular questions, test their ideas or prove their hypothesis, (3) interest: focus on a particular hypothesis or topic due to personal interest and curiosity, and (4) utilitarian: to obtain results that help to solve or prevent problems in the society. The definitions of basic and developed for all four categories of response are listed in Table 3.6.3.

Table 3.6.3. Basic and developed definitions for question two categories of response "Why do scientists do experiments?" (Ryder et al., 1999; Wilson, 2014).

Category of Response	Basic Definition	Developed Definition
Knowledge	Statement that experiments are done to obtain knowledge. Statements are short with little definition, support, or justification, though scientifically grounded.	Statement that experiments are done to obtain knowledge. Minimum of one statement with definition, support, or justification that demonstrates clear evidence that knowledge acquisition is a driver.
Empirical	Statement that experiments are done to test hypotheses and answer questions. Statements are short with little definition, support, or justification, though scientifically grounded.	Statement that experiments are done to test hypotheses and answer questions. Minimum of one statement with definition, support, or justification that demonstrates clear evidence that hypothesis testing or specific answers is a driver.
Interest	Statement that experiments are done based on personal interest in their outcomes. Statements are short with little definition, support, or justification, though scientifically grounded.	Statement that experiments are done based on personal interest in their outcomes. Minimum of one statement with definition, support, or justification that demonstrates clear evidence that personal interest is a driver.
Utilitarian	Statement that experiments are done to help the greater good. Statements are short with little definition, support, or justification, though scientifically grounded.	Statement that experiments are done to help the greater good. Minimum of one statement with definition, support, or justification that demonstrates clear evidence that helping others is a driver.

Question three, "How can good scientific work be distinguished from bad scientific work?" has three categories of response: (1) quality of the work/results: quality of the research process, testable conclusions of scientific ideas that rest on highly reproducible data, then it will last, (2) utilitarian: good scientific work helps to solve or prevent problems in society; good scientific work benefits the greater good, and (3) extending knowledge: good scientific work increases and improves the knowledge of the discipline and previous hypotheses. The definitions of basic and developed for all three categories of response are listed in Table 3.6.4.

Table 3.6.4. Basic and developed definitions for question three categories of response "How can good scientific work be distinguished from bad scientific work?" (Ryder et al., 1999; Wilson, 2014).

Category of Response	Basic Definition	Developed Definition
Knowledge	Statement that good scientific work is distinguished from bad due to quality of work or results. Statements are short with little definition, support, or justification, though scientifically grounded.	Statement that good scientific work is distinguished from bad due to quality of work or results. Minimum of one statement with definition, support, or justification that demonstrates clear evidence that quality of work or results are a deciding factor.
Empirical	Statement that good scientific work is distinguished from bad due to utilitarianism. Statements are short with little definition, support, or justification, though scientifically grounded.	Statement that good scientific work is distinguished from bad due to utilitarianism. Minimum of one statement with definition, support, or justification that demonstrates clear evidence that utilitarianism is a deciding factor.
Utilitarian	Statement that good scientific work is distinguished from bad due to extending knowledge. Statements are short with little definition, support, or justification, though scientifically grounded.	Statement that good scientific work is distinguished from bad due to extending knowledge. Minimum of one statement with definition, support, or justification that demonstrates clear evidence that extending knowledge is a deciding factor.

Question four, "Why do you think that some scientific work stands the test of time whereas other scientific work is forgotten?" has five categories of response: (1) Revolutionary: if scientific work solves long lasting problems in a revolutionary way, (2) Coherent field: if scientific work builds on previous work and is consistent with it, then it will last, (3) Inherent quality of work: Quality of the research process, testable conclusions of scientific ideas that rest on highly reproducible data, then it will last, (4) Utilitarian: if the work has many particular benefits to humanity or it affected the quality of life, then it will last, and (5) Untestable: if predictions from

the scientists are difficult to test then the idea may last a long time. The definitions of basic and developed for all five categories of response are listed in Table 3.6.5.

Table 3.6.5. Basic and developed definitions for question four categories of response "Why do you think that some scientific work stands the test of time whereas other scientific work is forgotten?" (Ryder et al., 1999; Wilson, 2014).

Category of Response	Basic Definition	Developed Definition
Revolutionary	Statement that revolutionary work stands the test of time. Statements are short with little definition, support, or justification.	Statement that revolutionary work stands the test of time. Minimum of one statement with definition, support, or justification that demonstrates clear evidence that revolutionary work stands the test of time.
Coherent field	Statement that coherence allows work to stand the test of time. Statements are short with little definition, support, or justification, though scientifically grounded.	Statement that coherence allows work to stand the test of time. Minimum of one statement with definition, support, or justification that demonstrates clear evidence that coherence allows work to stand the test of time.
Inherent quality of work	Statement that quality of work allows work too last. Statements are short with little definition, support, or justification, though scientifically grounded.	Statement that quality of work allows work too last. Minimum of one statement with definition, support, or justification that demonstrates clear evidence that quality of work is a deciding factor.
Utilitarian	Statement that scientific work lasts due to utilitarianism. Statements are short with little definition, support, or justification, though scientifically grounded.	Statement that scientific work lasts due to utilitarianism. Minimum of one statement with definition, support, or justification that demonstrates clear evidence that utilitarianism is a deciding factor.
Untestable	Statement that scientific work lasts due to untestable nature. Statements are short with little definition, support, or justification, though scientifically grounded.	Statement that scientific work lasts due to untestable nature. Minimum of one statement with definition, support, or justification that demonstrates clear evidence that untestable nature is a driver.

Question five, "How are conflicts of ideas resolved in the scientific community?" has three categories of response: (1) Individualist: Scientists use logic and debate among individuals and groups from the scientific community to solve conflicts, (2) Empirical: Scientists use empirical verification of theories and hypotheses to solve conflicts in science, and (3) Appeal to Authority: Scientists will appeal to recognized experts to resolve conflicts in their field. The definitions of basic and developed for all three categories of response are listed in Table 3.6.6.

Table 3.6.6. Basic and developed definitions for question five categories of response "How are conflicts of ideas resolved in the scientific community?" (Ryder et al., 1999; Wilson, 2014).

Category of Response	Basic Definition	Developed Definition
Individualist	Statement that logic based debate between individuals and groups are used to solve conflicts. Statements are short with little definition, support, or justification, though scientifically grounded.	Statement that logic based debate between individuals and groups are used to solve conflicts. Minimum of one statement with definition, support, or justification that demonstrates clear evidence that logic based debate between individuals and groups are used to solve conflicts.
Empirical	Statement that empirical verification is used to solve conflicts in science. Statements are short with little definition, support, or justification, though scientifically grounded.	Statement that empirical verification is used to solve conflicts in science. Minimum of one statement with definition, support, or justification that demonstrates clear evidence that empirical review is a deciding factor.
Appeal to Authority	Statement that appealing to recognized experts in the field can resolve conflicts. Statements are short with little definition, support, or justification, though scientifically grounded.	Statement that appealing to recognized experts in the field can resolve conflicts. Minimum of one statement with definition, support, or justification that demonstrates clear evidence that appealing to authority is a deciding factor.

3.7 Framework Analysis

The framework analysis examines student's total responses based on Ryder et al.s' (1999) three aspects of NOS. These aspects are:

> The relationship between scientific knowledge claims and data, is strongly epistemological, representing students' discussions of how knowledge claims arise from and interact with experimental and observational data…The nature of lines of scientific enquiry, focuses on the extent to which scientists are seen as following a coherent line of scientific enquiry, either individually or as a community…The social dimension of science, captures students' discussions about science as a collaborative and institutionally regulated activity (Ryder et al., 1999, p. 207).

This analysis lends insight to changes in student's conceptualizations of NOS as a whole. The relationship between scientific knowledge claims and data, nature of lines of scientific enquiry, and the social dimensions of science are the three critical areas of analysis. Based on Ryder et al.'s (1999) secondary analysis, there are three subcategories for each aspect of NOS.

The three subcategories for the relationship between knowledge claims and data are knowledge claims as description, knowledge claims as provable, and knowledge claims go beyond the data. The three subcategories for the nature of lines of scientific enquiry are location in individual

interests of scientists, internal location in epistemology of discipline, and external location. The three subcategories for the social dimension of science are individualist view, recognition of a community of scientists, and recognition of institutions of science (Ryder et al., 1999; Wilson, 2014). Student's total responses are analyzed to determine where statements have been made that meet these criteria. These responses are coded on a scoring system of no response, basic, or developed (Khishfe, 2008, 2015; Yacoubian & BouJaoude, 2010). Basic responses are statements that demonstrate a basic or rudimentary understanding of the concept, and developed responses demonstrate views of the concept that have justification or support beyond the basic understanding. The changes between pre and post-interview statements are compiled into aspect scores to show how student's NOS views have changed. The three aspect scores are combined to give an overall framework score that shows how much NOS conceptual change students have undergone. Table 3.7.1 shows the scores for changes in basic and developed statements between pre and post-interviews.

Table 3.7.1. The scoring system for the framework analysis to show the change of views on Nature of Science between pre- and post- interviews.

Pre-Interview	Post Interview	Aspect Score
None, Basic, Developed	None	0
Basic	Basic	0
Developed	Developed	0
None	Basic	1
Basic	Developed	4
None	Developed	5
Developed	Basic	0

The definitions of basic and developed for the subcategories of the relationship between knowledge claims and data are listed in Table 3.7.2.

Table 3.7.2. The definitions of basic and developed for the subcategories of the relationship between knowledge claims and data (Ryder et al., 1999; Wilson, 2014).

Subcategory	Basic Definition	Developed Definition

Knowledge claims as description	Statement that knowledge claims result from descriptions of scientific observations. Statements have no elaboration.	Statement that shows that knowledge claims result from descriptions of scientific observations. Minimum of one statement with definition, support, or justification that demonstrates clear evidence supporting claims as description.
Knowledge claims as provable	Statement that knowledge claims result from empirical data, social acceptability, and/or do not require absolute proof to be true. Statements have no elaboration.	Statement that knowledge claims result from empirical data, social acceptability, and/or do not require absolute proof to be true. Minimum of one statement with definition, support, or justification that demonstrates clear evidence supporting claims as provable.
Knowledge claims go beyond the data	Statement that knowledge claims result from prediction from incomplete data or coherence with other claims. Statements have no elaboration.	Statement that knowledge claims result from prediction from incomplete data or coherence with other claims. Minimum of one statement with definition, support, or justification that demonstrates clear evidence supporting claims beyond data.

The definitions of basic and developed for the subcategories of the nature of lines of scientific enquiry are listed in Table 3.7.3.

Table 3.7.3. The definitions of basic and developed for the subcategories of the nature of lines of scientific enquiry (Ryder et al., 1999; Wilson, 2014).

Subcategory	Basic Definition	Developed Definition
Location in individual interests of scientists	Statement that scientific enquiry is influenced by personal curiosity or interest. Statements have no elaboration.	Statement that scientific enquiry is influenced by personal curiosity or interest. Minimum of one statement with definition, support, or justification that demonstrates clear evidence supporting individual interest of scientists.
Internal location in epistemology of discipline	Statement that scientific enquiry is influenced by theoretical ideas and hypotheses within the discipline. Statements have no elaboration.	Statement that scientific enquiry is influenced by theoretical ideas and hypotheses within the discipline. Minimum of one statement with definition, support, or justification that demonstrates clear evidence supporting epistemology of the discipline.
External location	Statement that scientific enquiry is influenced by external factors such as funding or to benefit humanity. Statements have no elaboration.	Statement that scientific enquiry is influenced by external factors such as funding or to benefit humanity. Minimum of one statement with definition, support, or justification that demonstrates clear evidence supporting influences from beyond the discipline.

The definitions of basic and developed for the subcategories of the social dimension of science are listed in Table 3.7.4.

Table 3.7.4. The definitions of basic and developed for the subcategories of the social dimension of science (Ryder et al., 1999; Wilson, 2014).

Subcategory	Basic Definition	Developed Definition
Individualist view	Statement that scientists can work alone without interactions with other scientists. Statements have no elaboration.	Statement that scientists can work alone without interactions with other scientists. Minimum of one statement with definition, support, or justification that demonstrates clear evidence supporting the individualist view.
Recognition of a community of scientists	Statement that there is a community of scientists with which scientists interact. Statements have no elaboration.	Statement that there is a community of scientists with which scientists interact. Minimum of one statement with definition, support, or justification that demonstrates clear evidence supporting community collaboration and interactions.
Recognition of institutions of science	Statement that there are institutions of science that regulate and direct funding and validation of new claims. Statements have no elaboration.	Statement that there are institutions of science that regulate and direct funding and validation of new claims. Minimum of one statement with definition, support, or justification that demonstrates clear evidence supporting scientific institutions that govern enquiry and knowledge.

Chapter 4: Results

4.1 Introduction

4.1.1 Using Numbers in Qualitative Research

The data analysis construct for this study uses a process based approach to analyze all the data as qualitative data. According to Maxwell (2010), “process theory…deals with events and the processes that connect them; its approach to understanding relies on an analysis of the processes by which some events influence others” (p. 477). Due to the large quantities of rich data, a means of “quantitizing” the data was implemented to better indicate patterns or phenomena in the data (Sandelowski, Voils, & Knafl, 2009). Ascribing numbers to the qualitative data is done to better visualize the data using quasi statistics to justify terms like some, usually and most (Becker, 1970), rather than a method of trying to bring quantitative, statistical analysis into the methods. Understanding the number of each occurrence across the data set can lend insight to how each group performed in the study. According to Maxwell (2010), “If participants in a study repeatedly make a particular claim or perform a particular action, presenting this fact in numbers isn’t necessarily conceptualizing it in terms of variables, but can be seen as simply describing the occurrence and distribution of the claim or action in that setting” (p. 478).

Using numbers in qualitative research analysis provides both positive outcomes and some drawbacks. Maxwell (2010) states that using numbers to provide tallies of responses as Becker’s quasi statistics yields important qualitative data. Numbers also provide a gauge to identify important relationships and show those that are idiosyncratic to that case (Huberman & Miles, 2002). They also provide evidence to support conclusions and counter claims that only data that supported researcher conclusions was selected (Maxwell, 2010). Using the numbers as the only form of data has a significant drawback. “Primarily, as Becker and Hammersley have argued,

numbers give precision to statements about the frequency, amount, or typicality of particular phenomena. However, they do this at the cost of stripping away everything but the quantitative information" (Maxwell, 2010, p. 478). The use of numbers to assist in analyzing data in this study requires them to be used as a supplement to the rich data.

Therefore, using a process based approach supported with numbers is a beneficial means of analyzing the data. A local form of measurement for the abstract variable of the rate of occurrence is required. There is prior precedent for these locally defined measures. "The field work literature contains many examples of…locally restricted measures of abstract variables" (Becker, 1970, p. 58). The focus is on the occurrences within the data that demonstrate change, or lack thereof, in NOS beliefs. The numbers based data is used to identify trends in the data. "Numbers can't replace the actual description of evidence but can provide a supplementary type of support for the conclusions when it's impossible to present all of this evidence" (Maxwell, 2010, p. 480). The numbers data further supports the rich data analysis by providing a means to negate alternate hypotheses (Becker, 1970). The rich data is then extracted to give credibility to the interpretation and conclusions of the data (Maxwell, 2012).

4.1.2 Interrater Reliability

The categories of response and associated definitions were decided on by the primary and secondary rater. Interrater reliability was conducted to ensure the information was valid. The primary rater recruited an individual with a Masters of Education and seven years of high school science teaching experience to participate as a secondary rater. Both raters went through all the definitions of each level of understanding in the question by question analysis and framework analysis. Both raters then looked at each other's coding differences for a sample of each response category and discussed how they had coded differently and what changes needed to be made to

the definitions to reach agreement. From this discussion, agreement was reached on what each definition meant and how to code responses.

There were 62 complete responses from cogen students, 13 complete responses from sharing students, and 52 complete responses from no internship students. A random sample of 10 percent was generated with a random number generator in Excel, of cogen students, sharing students, and no internship students, rounded up to the next whole number, following the rule of thumb that interrater reliability should be based off a random 10 percent sample of the entire group (Elder, Pavalko, and Clipp, 1993). This resulted in seven cogen responses, two sharing responses, and six no internship responses for interrater reliability coding. Each student was assigned a random number through Excel's random number generator, and then sorted from lowest to highest. The lowest numbers were selected based on the calculated number from each group to create the random sample.

The secondary rater analyzed each of the 15 sample responses for both question by question and framework analyses based on the definitions that had been agreed upon between raters. Once both analyses were complete, the resultant codes were compared to the codes given for the same 15 respondents by the primary rater. In the question by question analysis, there were 630 possible coding locations based on a pre and post response for each of the five questions. There were 45 coding locations that were different between the primary and secondary coders. 630-45=585, 585/630=92.9 percent interrater reliability for the question by question analysis. In the framework analysis, there were 270 possible coding locations based on a pre and post response for each of the three dimensions. There were 22 coding locations that were different between the primary and secondary coders. 270-22=248, 248/270=91.9 percent interrater

reliability for the framework analysis. Both measures were above the minimum 90 percent interrater reliability recommended by Elder, Pavalko, and Clipp (1993).

4.1.3 Data Analysis Synopsis

The compiled student responses from three program years was analyzed utilizing both the question by question (Q by Q) analysis and the Framework analysis. Data showing responses for all possible levels of response for the Q by Q and Framework analyses were compiled. This data provides the rich data to support the quantitized data in the following analysis. Table 4.1.3.1 shows examples of all levels of response for Q by Q question one. Table 4.1.3.2 shows examples of all levels of response for Q by Q question two. Table 4.1.3.3 shows examples of all levels of response for Q by Q question three. Table 4.1.3.4 shows examples of all levels of response for Q by Q question four. Table 4.1.3.5 shows examples of all levels of response for Q by Q question five. Table 4.1.3.6 shows examples of all levels of response for Framework dimension one. Table 4.1.3.7 shows examples of all levels of response for Framework dimension two. Table 4.1.3.8 shows examples of all levels of response for Framework dimension three. These excerpts provide the rich data necessary to show how different levels of change in NOS understanding are achieved by participants in the program.

Table 4.1.3.1. Examples of all levels of response for Q by Q question one.

Response Level	Student Code	Question one - How do scientists decide what questions to investigate?
Category		Curiosity Led
Basic	1L3DG	If they...they decide whether they are interested or not.
Developed	3L3JT	I think it affected it to a certain extent, 'cause if I'm in chemistry, I'm not gonna pick something, you know, architecture related or-- so yeah. I guess something I'd specialize in. And then go to specifics… Um, [chuckles] hmm. I don't know [chuckles]… Uh, well, for my team, I think everybody, like, as far as our group members were concerned, enjoyed the idea of, uh, creating power using solar cells and finding, like-- well, our idea was a

		phone case, so I guess what motivates them is their own passion for an idea they made… So-- like, if someone told you, "Uh, do this," you might be less motivated as if you were like, "I wanna do it." Like your own idea versus someone else telling you.
Category		Extending Knowledge
Basic	1L3JS	They could work on it by what they already have and they already know.
Developed	1CYF	Um, I think they look at like the background of what we should learn and what we need to learn and that we don't understand so they know what to teach and what to ask… To know, um, the outcome of what they want to know or just having the motivation to teach others… Mmhm, maybe like in a major event, if they need to know like why something is happening so they have to figure it out.
Category		Utilitarian
Basic	3CEW	Um, I think they decide what questions to investigate by, like, how important they are to society, and, like, what we're doing, and how it will affect us later in the future.
Developed	3L4JB	Maybe the importance for further research, how it could help society or whatever it's going towards, I guess. The relevance of the project and--…Mm-hmm…Yes. Like, say for instance, my project. My project was based on stress and uh sleeping disorders. And so if we do further research for that, we could probably try to manage stress that help with the sleeping disorders so they don't get more stressed, does that make sense?
Category		Financial Benefit
Basic	1L1EM	And if it's worth the money…Right…And if I-it's worth the money, like the funding.
Developed	2CSM	Um, other things could be like - uh I think in the back of the scientist's mind should be like, earnings, how much they are going to earn in a month, ah who are they working for, what company they want to be with, and stuff like that, just like tiny details.
Category		Personal Recognition
Basic	3CJT	Um, I think for some it's just being able to find out like how those things work or like-- and for some others it's kinda like the fame and like the recognition. Like, "Oh, like I'm that person that found this."
Developed	3L3RS	Cause like if you're trying to pump something out or you're coming up with something new, like, like, uh, you wanna get it done before like somebody else does it, or----like somebody else takes credit for it. I'm not sure if that answers the question. Like--
Category		Feasibility
Basic	1CEA	Mmmm… the things they know like what they can work with.

Developed	3L3NR	Hmm. Well, um, teachers would always tell me this, uh, like, there's no such thing as a stupid question. Um, but I guess you can evaluate which question would take more thought and effort to answer. And I guess scientists would decide which question to investigate, um, by seeing if the question makes sense to everyone if they're working in a group. Uh, if it's something they can investigate if they have the right equipment and knowledge, or experience, I should say, to do so.

Table 4.1.3.2. Examples of all levels of response for Q by Q question two.

Response Level	Student Code	Question two - Why do scientists do experiments?
Category		Knowledge
Basic	1L4JJC	To get results.
Developed	2L2MB	Uh, they-- just to, uh, to determine all the, um, unknown things in their environment, the way things work, why they work, uh, how they work, um, why does it matter and stuff like that. Just-just to basically determine any underlying knowledge that hasn't been found before on the workings on the environment around them.
Category		Empirical
Basic	1L4BQ	Ah, to test, like to test what they're actually researching, like I mean, if they didn't test it, how would they know the results.
Developed	2CMV	To prove it. Instead of just saying, "Oh, it happens." Like, to have proof about it. So they can like show that it's, like, accurate that if you do this and this, this is what happens. Because this is like how you do it and then this is like the, what they've observed and how it reacted. So, like, to have more proof…And make sure they like, make sure it's correct. 'Cause if they do it once, then it gives them. But if they did kinda give it like a different result so you do more experiments to see "Okay, if we do this, this would happens." Like they have different outcomes.
Category		Interest
Basic	2CCW	Uhm, scientists do experiments to help-- not only help others but to help themselves. Scientists do experiments just for curiosity sometimes, sometimes they do it for fun.
Developed	2L4AR	They're just kind of, I don't know, they motivate themselves [laughter] I don't know. They just-- Dr. Vines likes to think outside of the box, she-- you know? She's that person that apoptosis is one of those normal things that happens in your body, and she was like, "I wonder how I can trigger this." Why would you want to trigger apoptosis, you're killing your cells here woman? [inaudible] want to try it.
Category		Utilitarian

Basic	1CAR	If it's gonna affect the people and the planets, I guess.
Developed	3L2NO	Um, they do these experiments for the benefit-- I, I, I would think, hopefully, that they do it for the benefit of humanity…Because, um, we're not perfect. We're not a perfect race. There's no such thing as perfection, but there's progression… So they want t-- they want the-- for the future of everyone and of everything, you know, not just e-- the human race, but the whole race in general of life itself, they want it to progress, they want it to get better. They want, you know, they want the environment to be protected; they want to find out how to protect it, how to keep it----safe. A lot of it's due to health reasons, a lot of it's due to safety reasons. Um, they do s-- they do these experiments because they care about, you know, what is provided to them. And if something's provided, they want to use it to their advantage… And once they use it to their advantage, they unlock everything that's, I would say, interesting to even people that are not even interested in science… You know, like at th-the discovery of medicine. You know, a lot of people back then, without the technology, they use medicine in these small tribes or these small, um, little areas - I guess you could say like the cavemen times or whatever - but as soon as, you know, the years went by they found out, "Oh, we could use it this way. This could----help out with this, this could help out with that." And not to say that there weren't a-- many mistakes being made. Yeah [crosstalk]--

Table 4.1.3.3. Examples of all levels of response for Q by Q question three.

Response Level	Student Code	Question three - How can good scientific work be distinguished from bad scientific work?
Category		Quality of the Work/Results
Basic	1CEC	Following the directions as they are. Not making your own or like, you might want to do this before you do this thing but there is always (audio unclear) (???) like seeing the results
Developed	3L1JB	You know, the process of the experiment. The results they acquire, the effort put into it, you know…No, no. That's so you can tell if it's good. That's how you can tell the [difference?] from a bad one… You know, like--…[inaudible]. Like for the good one, you know, you, you come up with the question, you do multiple experiments with different files, and then you get results. You conduct research and try to find, like, the, the best results possible and for the bad one, you just, like, don't even care, you just find the problems. Do one experiment with, like, only one trial, and don't even analyze the data or results…The bad one…Like, a lot of this effort put into it. A lot less thought.

Category		Utilitarian
Basic	1L3LA	bad experiments destroy the world.
Developed	2L2EA	Anything that-- if there's a problem and it's trying to be solved, it's a good scientific work, I guess. If it's something to better the community or better life or anything in our ecosystem, anything that's going to better something or improve its way of functioning or its way of working or living, I think that's good scientific work…Such as, well, like all the experiments that we did in the program, a lot of people did like-- for cancer, they were doing research on that. Or again, with the girls who tried cleaning the air, the girls who said, um, this is all the germs that are on your makeup and stuff and you're putting it on your face. All of that stuff was something that like-- they're like informing you about the negative sides of things or like what we can do to change something, so I thought like all of our experiments were good work.
Category		Extending Knowledge
Basic	1CJM	In my opinion, a good science experiment is anything that gives you new information. Just any kind of new information.
Developed	2L2EA	Scientific work. There you go. There's not really bad scientific work 'cause everything-- everything you do scientifically helps you learn something new or helps you expand on an idea. And the more you expand, the more understanding you have of it, which makes it easier to just-- I can't think of the words I'm thinking of right now. Um, but the-- he was the guy who interviewed me, um, the other day. Um--…Yeah…The more you know about something, the better understanding you have of the thing. And-- do you get my point? I'm sorry.

Table 4.1.3.4. Examples of all levels of response for Q by Q question four.

Response Level	Student Code	Question four - Why do you think that some scientific work stands the test of time whereas other scientific work is forgotten?
Category		Revolutionary
Basic	1L4BA	Umm. probably because some are bigger than others and are more memorable than others ones that … The findings that you get from the work. Like, don’t know how to explain it, I know what I want to say
Developed	3L3RO	I don't know. I mean, there-- I guess the only thing-- the only ones that actually stand the test of time are the discoveries that made the-- they made-- they made a huge, huge impact on the world…Like, I don't know, like discovering the laws of physics whatever. Like, we still use those today, so. That was long-lasting and it's it's a principle for everything else.

		Because everything obeys the laws of physics so. Everything is based on what this one guy discovered…But, like, no discovery is like, I don't know, creating a super strong medal like stainless steel or whatever. And it's not-- [?] that it's still widely used. It's not something that everyone knows. Or everyone like is interested in. So they just forgot it eventually.
Category		Coherent field
Basic	1CJM	Mmmm… if it either has very little to do with any kind of subject that anyone has any interest in then it would be forgotten.
Developed	2L1VR	Possibly, because more and more people, they're conduct- they're conducting like certain experiments that could be similar to that certain experiment [laughter]. I'm being very repetitive. Um--…--but um, and just providing more, um, supporting ideas - adding more ideas to it. Like, for instance, you want to find the cure for cancer. How are you going to do that, you know? You want to-- and in my lab, we used a lot of plants to fight against cancer cell lines. So, more and more people, they're using more and more plants against these cancer cell lines. Even though we haven't found a certain treatment, we want to keep conducting more experiments.
Category		Inherent quality of work
Basic	1L2AG	mmmm It wasn't answered clearly
Developed	2CLH	Of course, there's some things that-- there still hasn't been like-- like let's say, uh, when people thought like-- when people didn't know the planet weren't around-- we went around the sun and stuff like that. Well, of course, those things are forgotten because they were wrong. But now that we know for a fact that the earth goes around the sun, then [?]. Those are kept because those were true…And I guess that's it. Like, either you find something. I guess that's why things are forgotten either because it's like they find it's incorrectly wrong where they find a better way.
Category		Utilitarian
Basic	2L2SP	some work is just forgotten because, um, it's harming people.
Developed	1L4CM	Maybe it's because of the the importance people have put in some of the best work that it's actually brought down into history that people are remembering instead of forgetting, but I'd say that if some scientific work is forgotten it must be re-learned so we can learn from, learn from old researches…I'm not sure about that, do we? One thing would be... I think they were-- a guy here in EL Paso was developing a water vapor engine on a car, and everything went smoothly and he almost patented it, but several petrol companies just decided to end that. I'm not sure if they killed them, but it's sort of a conspiracy but it's something that's really important, it's a very

		good technology because that mechanic needed from here to Las Cruces and back like in two gallons, and it was water vapor, it was just that. It was very good invention that could actually be abroad, not just here, but yeah.
Category		Untestable
Basic	1CCR	I think this is probably because either it was already proved out there haven't been able to prove it yet.
Developed	3CDH	To be forgotten? Hmm. I guess if in that time they don't have the proper equipment or the proper technology to conduct the experiment, they just set it aside. 'Cause they don't know the answer, like they-- they're, they're, they're in the unknown…On hold, yeah, for I guess future generations to test on it, or pick it up.

Table 4.1.3.5. Examples of all levels of response for Q by Q question five.

Response Level	Student Code	Question five - How are conflicts of ideas resolved in the scientific community?
Category		Individualist
Basic	2L3FG	I believe that people could work it out themselves--…--but I really wouldn't depend on other people to try to work it out for them but...
Developed	3L1SM	I think a way to resolve it would be, first of all, you know, speak about it, and say, "Well, this is what I think," and then, like, "What do you think?" And then from there on, you know, maybe not spend so much time, like, discussing about it. Maybe, you know, doing more research about it, conducting experiments to see who's actually right--…Yeah, like both conduct experiments, like, you know--…To compare their results, and maybe that's the way you can solve, like, different, like, solve conflicts between different ideas. By talking about it.
Category		Empirical
Basic	1CMB	By experimenting
Developed	3L4JB	I guess-- I guess just running the test again and again until we can get some of the similar data. Because I can't say I'm right, and I can't say I'm wrong…I wouldn't deal with it in, like, a childish way, like arguing with you, like, "Oh, I'm right. I'm right." You know. I mean, I'm stubborn like that, but I wouldn't do it just because of professional matters. I think I would just have both of us, you know, run the test together, and then run it again separately to see if anything would change in two comparison tests, I guess.
Category		Appeal to Authority

Basic	3L2RC	Have somebody else look at it 'cause maybe somebody did something wrong, or maybe somebody didn't do something wrong and there's something weird going on there.
Developed	2L4AR	But, if they both, ah, give you pretty clear results, and your data comes out pretty clean, then I'd say one, you'd have to have a middleman decide, you know, because they're both going to think they're right, 'cause that's human nature. We like to think we're right [chuckles]. But, ah, and if you don't want to try the middleman, trial and error, you know. We're pretty good at doing our errors…Like your middleman.

Table 4.1.3.6. Examples of all levels of response for Framework dimension one.

Response Level	Student Code	Dimension one - Relationship between knowledge claims and data
Subdimension		Knowledge Claims as Description
Basic	1L1IS	And maybe what they got different, um, analyze it again so they could see what went wrong with it.
Developed	3L1DL	I guess those things just deserve to be evaluated some more until you can find either the middle ground or if one of them is actually more right…I suppose more experimentation--…--would be needed, yeah. And if not that, then you would just need to-- there's gotta be a missing piece, you know. Because in my opinion when you're talking about science, there's only one answer to things, and if you think that there's more than one answer, that it's either a matter of opinion, or there's, like, a missing part…Right. Like a right, final answer...Mm-hm…I think if there are, like, two final answers that either there's an inconsistency or there's something, you know, different happening. I think it's possible, but there's always gonna be, like, something missing. Like a link between them perhaps that makes them both right, or maybe they're both wrong and there's another answer. I think that there's always just gonna be some concrete thing.
Subdimension		Knowledge Claims as Provable
Basic	1L2IR	They dissolve by proving one, one and the other and show which one is part of the best.
Developed	2CKW	Because the fact that they're just-- well, they were thought as theories. I mean, not really facts like, uh, for example, I think there's one scientists said that the earth was in the center and then everyone believed it for a long time, until another scientist said that the sun is actually in the center of the, of the, of the galaxy and not, at, the earth one. Everyone remembers the fact-- everyone knows the fact that the sun is

		in the center, but no other had talked about why they thought that the, the earth was on the center…Because it isn't true.
Subdimension		Knowledge Claims go Beyond the Data
Basic	1CAA	Um maybe its that way because someone already discovered why it happened. And so they just leave it and they decide not to keep going. Even if the other person is wrong.
Developed	1L4BQ	I think maybe they get tired of looking studies, studies can take up to like years so maybe they just, they come to a conclusion when they can't find an answer and maybe just stopped working on it other and move on to the next than keep on pursuing what they want to find out

Table 4.1.3.7. Examples of all levels of response for Framework dimension two.

Response Level	Student Code	Dimension two - Nature of lines of scientific enquiry
Subdimension		Location in Individual Interests of Scientists
Basic	1L3LI	I don't know maybe they're curious…to find out
Developed	2CMA	Uh I mean I think just basically depends on what the scientist wants to know. I mean he's got to ask himself a question before he wants to ask a question. He wants to, I mean, he's got to ask himself, "Well, do I want to figure out this today or do I want to test this today?" It just depends on the scientist what he wants to learn.
Subdimension		Internal Location in Epistemology of Discipline
Basic	3CEM	Yes, because they all have different outcomes. And like, some, you expect. Others, it's like, "Whoa, what happened?" Like, you know [chuckles]?
Developed	1L2NDLS	or they wanna be able to find out, um, on their own to make sure - not just rely on somebody else, but to be able to rely on their information in their studies…Because you don't just will-- maybe the first time you think it's good, but you missed a step, but doing it again, it makes you learn more and makes you do it better, helps you do it better.
Subdimension		External Location
Basic	1L4JJC	like to research like things happen and how they can help.
Developed	3L4WB	But also you can think of like things that you can research on, maybe uh somethings that people don't know. Um, pretty much the way a scientist tries to figure out a problem, or just like come up with something to solve…Uh, just looking around or looking at the world around them, seeing if there's like any problems, anything they could approve science-wise. Maybe, like, doing experiments, doing research, um, and finding some sort of way to fix these problems.

Table 4.1.3.8. Examples of all levels of response for Framework dimension three.

Response Level	Student Code	Dimension three - Nature of lines of scientific enquiry
Subdimension		Individualist View
Basic	1L2LV	Um, by doing their own research on it…Uh, not working together.
Developed	3CMD	Uh, then I think what happens is they usually create two different answers to the same question. Cuz they think one would answer the question better then the other…Uh, cuz I mean it-- the questions are variable itself. So, I mean, there's always more then one answer to each question.
Subdimension		Recognition of a Community of Scientists
Basic	3L2KB	or even get a third opinion
Developed	1L2CE	Um, we would basically be discussing it. How we had cogen, we'd always think of the best thing that we could do or, um, how we could fix something. So, it's basically just sitting down and discussing it, um, what can be fixed and what can be changed…Um, it'd probably be the one that makes the best, like, the best sense. The one that has more of a background, more to look into than just a simple answer, the simple--something that doesn't take long to look into…It'd be on the person, actually, 'cause people can always change their opinions, or they can always stay strong…They have to--…--um, convince each other.
Subdimension		Recognition of Institutions of Science
Basic	1L4CF	Umm usually boards speak out about it, resolve it hopefully.
Developed	2L3FG	Um, I think it's based on what the people that are like pretty much at the top choose to bring about. Like, let's say it would help to benefit us, just like some people prefer to do one thing but not the other. But they know, "Okay, well this will actually help me out but this is, like, just kind of there, just to sit." So, I don't know if that made sense but it's kind of like a-- I don't know--…Yeah, pretty much…Yeah. It's exactly that [laughter].

The local measure of rate of occurrence looks at the differences between the average scores for the no internship group across all three program years as the primary control group, with it split into female and male subgroups for the gender based analyses. These averages provide a baseline to identify change or similarity for each experimental group. To demonstrate "more" change, an

internship group must have an average score greater than one above the no internship group average. To demonstrate "less" change, an internship group must have an average score lower than one below the no internship group average. Internship group scores that fall within one of the no internship group score will be said to have "similar" change. These numbers align with the values assigned to the scoring system, in that a change of one indicates going from none to basic based on the coding scores used to identify NOS change in participants. Demonstrating this amount of change, compared to the no internship group shows that the internship group has undergone change. An example of student response coding to a question is included in Table 4.1.3.9. This example applies to coding for both the Q by Q and Framework analyses.

Table 3.1.3.9. Example of one student's responses to Question 2: "Why do scientists do experiments?"

Number	Student: 3L1SM	Pre-interview	Post-interview	Change Score
1	**Knowledge**: To extend their knowledge and the general knowledge in their field by obtaining helpful results on their experiments.	Developed	Developed	0
2	**Empirical**: To find answers to particular questions, test their ideas, or prove their hypothesis.	Developed	None	0
3	**Interest**: Focus on a particular hypothesis or topic due to personal interest and curiosity.	None	Developed	5
4	**Utilitarian**: To obtain results that help to solve or prevent problems in the society.	None	Basic	1
			Total:	6

First, data showing the differences and similarities between students who completed the internship (cogen and sharing) and the no internship group who did not was analyzed. Within this analysis there are four separate data analyses. Initially, the Q by Q scores are analyzed for internship versus no internship change. Next, the Q by Q scores are split into female and male

groups, and analyzed for change between the internship and no internship groups by gender. Then the Framework scores are analyzed for internship versus no internship change. Finally, the Framework scores are split into female and male groups, and analyzed for change between the internship and no internship groups by gender.

Second, data showing the differences and similarities between students who complete the internship with cogenerative dialogues (cogen), students who completed the internship without cogenerative dialogues (sharing), and the no internship group who did not was analyzed. Within this analysis there are four separate data analyses. Initially, the Q by Q scores are analyzed for cogen or sharing versus no internship change. Next, the Q by Q scores are split into female and male groups, and analyzed for change between the cogen, sharing, and no internship groups by gender. Then the Framework scores are analyzed for cogen or sharing versus no internship change. Finally, the Framework scores are split into female and male groups, and analyzed for change between the cogen, sharing, and no internship groups by gender.

4.2 Internship Versus No Internship Responses

The first means of analyzing results looked at the differences between the combined group of cogen students and sharing students, and no internship students. These results are compiled to show how answers varied based on program year, question, and category of question or dimension. Results are further analyzed to show differences based on participants' gender.

4.2.1 Question by Question Analysis

The internship versus no internship question by question analysis resulted in some interesting data. The average combined score of cogen students and sharing students was 19.88 for all three years, while the average combined score for no internship students was 17.76 for all three years. The internship group year three scored more than the no internship control group. The scores

of both groups by year are in Table 4.2.1.1 and Figure 4.2.1.1. The scores of both groups by question are in Table 4.2.1.2. When looked at based on each of the five questions, the internship group scored more than the no internship group for question five.

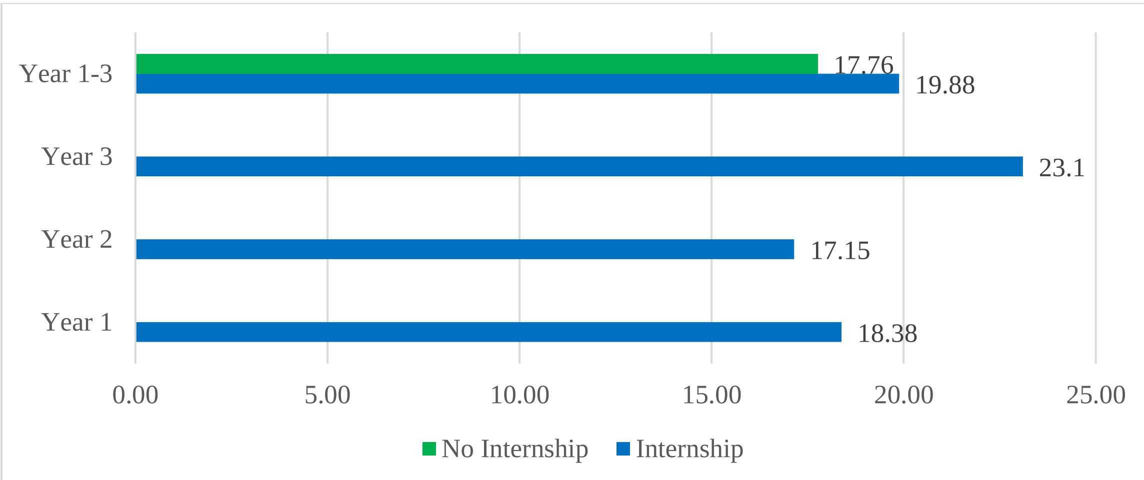

Figure 4.2.1.1 Internship versus no internship question by question average change scores by year. This figure illustrates the combined average change scores for internship and no internship students for all three program years.

Table 4.2.1.1. Internship versus no internship question by question average change scores by year.

Year	Internship	No Internship
Year 1	18.38	
Year 2	17.15	
Year 3	23.1	
Year 1-3	19.88	17.76

Table 4.2.1.2. Internship versus no internship question by question average change scores by question.

Question	Internship	No Internship
1-How do scientists decide what questions to investigate?	4.71	4
2-Why do scientists do experiments?	3.32	3.51
3-How can good scientific work be distinguished from bad scientific work?	3.4	3.45
4-Why do you think that some scientific work stands the test of time whereas other scientific work is forgotten?	4.33	3.71
5-How are conflicts of ideas resolved in the scientific community?	4.12	3.1

Next, scores for each individual question were analyzed. First, question one (how do scientists decide what questions to investigate?) was analyzed in detail. The average combined score of cogen students and sharing students was 4.71 and no internship students was 4. The year three internship group scored more than the no internship control group. Table 4.2.1.3 shows the yearly average change scores for question one. When looked at based on each of the six categories, all internship scores were similar to no internship control scores. Table 4.2.1.4 shows the average change scores for each category of question one.

Table 4.2.1.3. Internship versus no internship question one average change scores by year: How do scientists decide what questions to investigate?

Year	Internship	No Internship
Year 1	4.58	
Year 2	3.75	
Year 3	5.48	
Year 1-3	4.71	4

Table 4.2.1.4. Internship versus no internship question one average change scores by category: How do scientists decide what questions to investigate?

Category	Internship	No Internship
Curiosity Led	1.01	1.27
Extending Knowledge	1.33	0.63
Utilitarian	1.13	1.61
Financial Benefit	0.19	0.04
Personal Recognition	0.11	0.02
Feasibility	0.93	0.43

Second, question two (why do scientists do experiments?) is analyzed in detail. The average combined score of cogen students and sharing students was 3.32 and no internship students was 3.51. The year one internship group scored less than the no internship control group. Table 4.2.1.5 shows the yearly average change scores for question two. When looked at based on each of the four categories, the internship group scored less than the no internship group for the empirical category and the internship group scored less than the no internship group for the

utilitarian category. Table 4.2.1.6 shows the average change scores for each category of question two.

Table 4.2.1.5. Internship versus no internship question two average change scores by year: Why do scientists do experiments?

Year	Internship	No Internship
Year 1	2.42	
Year 2	3.15	
Year 3	4.24	
Year 1-3	3.32	3.51

Table 4.2.1.6. Internship versus no internship question two average change scores by category: Why do scientists do experiments?

Category	Internship	No Internship
Knowledge	0.88	1.70
Empirical	0.8	2.32
Interest	0.81	1.40
Utilitarian	0.83	2.17

Third, question three (how can good scientific work be distinguished from bad scientific work?) is analyzed in detail. The average combined score of cogen students and sharing students was 3.4 and no internship students was 3.45. The internship group scored similar to no internship group for all three years and combined. Table 4.2.1.7 shows the yearly average change scores for question three. When looked at based on each of the three categories, the internship group scored similar to the no internship group for all three categories. Table 4.2.1.8 shows the average change scores for each category of question three.

Table 4.2.1.7. Internship versus no internship question three average change scores by year: How can good scientific work be distinguished from bad scientific work?

Year	Internship	No Internship
Year 1	3.27	
Year 2	2.95	
Year 3	3.83	
Year 1-3	3.4	3.45

Table 4.2.1.8. Internship versus no internship question three average change scores by category: How can good scientific work be distinguished from bad scientific work?

Category	Internship	No Internship
Quality of the Work/Results	1.12	1.08
Utilitarian	1.31	1.69
Extending Knowledge	0.97	0.69

Fourth, question four (why do you think that some scientific work stands the test of time whereas other scientific work is forgotten?) is analyzed in detail. The average combined score of cogen students and sharing students was 4.33 and no internship students was 3.71. The year three internship group scored more than the no internship control group. Table 4.2.1.9 shows the yearly average change scores for question four. The internship group scored similar to the no internship group for the five categories. Table 4.2.1.10 shows the average change scores for each category of question four.

Table 4.2.1.9. Internship versus no internship question four average change scores by year: Why do you think that some scientific work stands the test of time whereas other scientific work is forgotten?

Year	Internship	No Internship
Year 1	4.19	
Year 2	3.75	
Year 3	4.86	
Year 1-3	4.33	3.71

Table 4.2.1.10. Internship versus no internship question four average change scores by category: Why do you think that some scientific work stands the test of time whereas other scientific work is forgotten?

Category	Internship	No Internship
Revolutionary	0.75	0.39
Coherent field	1.28	0.78
Inherent quality of work	1.03	0.86
Utilitarian	1.01	1.27
Untestable	0.27	0.39

Finally, question five (how are conflicts of ideas resolved in the scientific community?) is analyzed in detail. The average combined score of cogen students and sharing students was 4.12 and no internship students was 3.1. The year three internship group scored more than the no internship control group. The year one-three internship group scored more than the no internship control group. Table 4.2.1.11 shows the yearly average change scores for question five. The internship group scored similar to the no internship group for all three categories. Table 4.2.1.12 shows the average change scores for each category of question five.

Table 4.2.1.11. Internship versus no internship question five average change scores by year: How are conflicts of ideas resolved in the scientific community?

Year	Internship	No Internship
Year 1	3.92	
Year 2	3.55	
Year 3	4.69	
Year 1-3	4.12	3.1

Table 4.2.1.12. Internship versus no internship question five average change scores by category: How are conflicts of ideas resolved in the scientific community?

Category	Internship	No Internship
Individualist	1.44	1.53
Empirical	1.74	0.8
Appeal to Authority	0.96	0.76

4.2.1.1 Question by Question Analysis Summary

Q by Q Combined Changes

Criteria for observed change was a difference of more than one from the corresponding no internship group score for each question. A difference of more than five from the corresponding no internship group score was used for the overall combined score since there are five questions combined.

- The year three internship group scored more than the no internship group for the overall Q by Q score. The internship group scored 23.10 while the no internship group scored 17.76.

Question One Changes (How do scientists decide what questions to investigate?)

- The year three internship group scored more than the no internship group for question one. The internship group scored 5.48 while the no internship group scored 4.

Question Two Changes (Why do scientists do experiments?)

- The year one internship group scored less than the no internship group for question two. The internship group scored 2.42 while the no internship group scored 3.51.
- The internship group scored less than the no internship group for the question two empirical category. The internship group scored 0.8 while the no internship group scored 2.32.
- The internship group scored less than the no internship group for the question two utilitarian category. The internship group scored 0.83 while the no internship group scored 2.17.

Question Three Changes (How can good scientific work be distinguished from bad scientific work?)

- No changes were observed in question three.

Question Four Changes (Why do you think that some scientific work stands the test of time whereas other scientific work is forgotten?)

- The year three internship group scored more than the no internship group for question four. The internship group scored 4.86 while the no internship group scored 3.71.

Question Five Changes (How are conflicts of ideas resolved in the scientific community?)

- The year three internship group scored more than the no internship group for question five. The internship group scored 4.69 while the no internship group scored 3.1.

- The year one-three internship group scored more than the no internship group for question five. The internship group scored 4.12 while the no internship group scored 3.1.

4.2.2 Question by Question Gender Analysis

The next data observation for the question by question analysis for the internship vs no internship paradigm is to take students' gender into account. The year three internship group females scored more than the no internship group females. Figure 4.2.2.1 shows average combined score of cogen students and sharing students per year for females and males, and female and male no internship students. The internship group males scored more than no internship group control males for question five (How are conflicts of ideas resolved in the scientific community?). Table 4.2.2.1 shows the individual Q by Q question scores of females and males split into internship and no internship groups.

Table 4.2.2.1. Individual Q by Q question average change scores of females and males split into internship and no internship groups.

Question	Internship-Female	Internship-Male	No Internship-Female	No Internship-Male
How do scientists decide what questions to investigate?	4.23	5.26	3.84	4.29
Why do scientists do experiments?	3.48	3.14	3.55	3.33
How can good scientific work be distinguished from bad scientific work?	3.38	3.43	3.35	3.67
Why do you think that some scientific work stands the test of time whereas other scientific work is forgotten?	4.15	4.54	3.16	4.43
How are conflicts of ideas resolved in the scientific community?	3.75	4.54	3.16	2.9

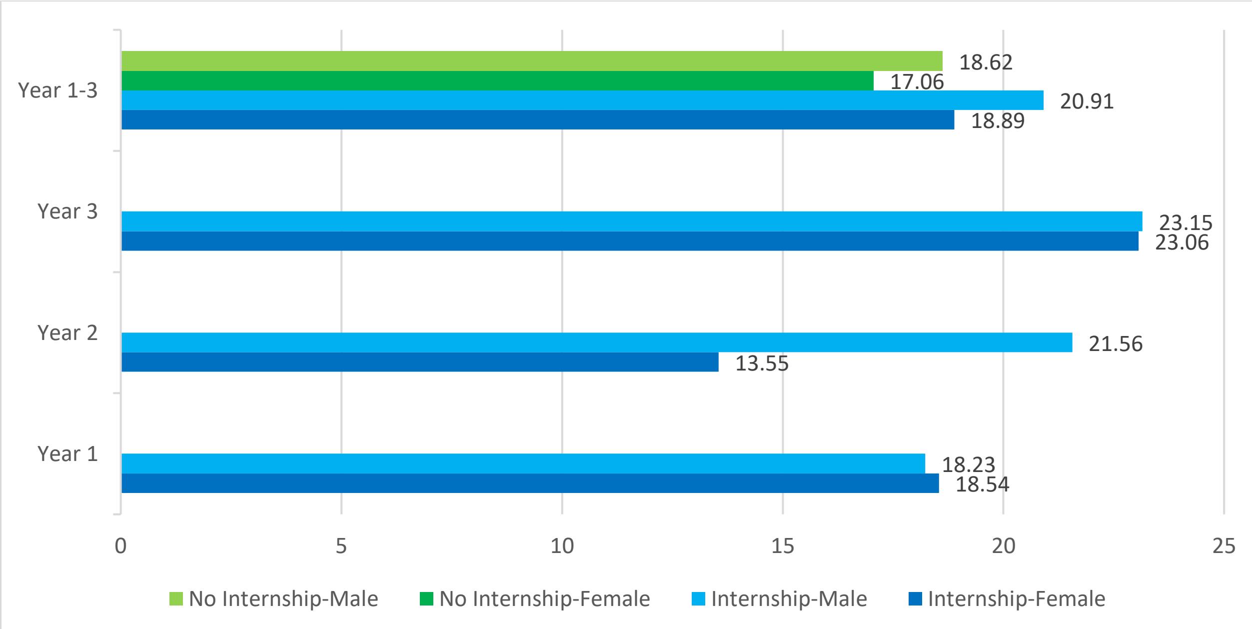

Figure 4.2.2.1. Male and female internship versus no internship combined average change scores for question by question analysis. This figure illustrates the average change scores for male and female internship and no internship students for all three program years.

In question one (How do scientists decide what questions to investigate?), the year three internship group males scored more than the no internship group males. The year one internship group females scored more than the no internship group females. Table 4.2.2.2 shows average combined score of cogen students and sharing students per year for females and males, and female and male no internship students for question one. When question one was looked at from the perspective of its categories, the internship group males scored more than the no internship group males for the category of extending knowledge. Table 4.2.2.3 shows average change scores of females and males split into internship and no internship groups by category.

Table 4.2.2.2. Q by Q question one "How do scientists decide what questions to investigate?" average change scores of females and males split into internship and no internship groups by year.

Year	Internship-Female	Internship-Male	No Internship-Female	No Internship-Male

Year 1	4.92	4.23		
Year 2	3.73	3.78		
Year 3	4	7.31		
Years 1-3	4.23	5.26	3.84	4.29

Table 4.2.2.3. Q by Q question one "How do scientists decide what questions to investigate?" average change scores of females and males split into internship and no internship groups by category.

Category	Internship-Female	Internship-Male	No Internship-Female	No Internship-Male
Curiosity Led	0.75	1.31	1.1	1.48
Extending Knowledge	1.33	1.34	1.03	0.24
Utilitarian	1.2	1.06	1.45	1.76
Financial Benefit	0.15	0.23	0.03	0.05
Personal Recognition	0.05	0.17	0.03	0
Feasibility	0.75	1.14	0.19	0.76

In question two (Why do scientists do experiments?), the year one internship group males scored less than the no internship group males. Table 4.2.2.4 shows average combined score of cogen students and sharing students per year for females and males, and female and male no internship students for question two. When question two was looked at from the perspective of its categories, the internship groups scored similar to the no internship control groups for all categories. Table 4.2.2.5 shows average change scores of females and males split into internship and no internship groups by category for years one through three.

Table 4.2.2.4. Q by Q question two "Why do scientists do experiments?" average change scores of females and males split into internship and no internship groups by year.

Year	Internship-Female	Internship-Male	No Internship-Female	No Internship-Male
Year 1	2.92	1.92		
Year 2	2.91	3.44		
Year 3	4.31	4.15		
Years 1-3	3.48	3.14	3.55	3.33

Table 4.2.2.5. Q by Q question two "Why do scientists do experiments?" average change scores of females and males split into internship and no internship groups by category.

Category	Internship-Female	Internship-Male	No Internship-Female	No Internship-Male

Knowledge	0.8	0.97	0.74	0.48
Empirical	0.8	0.8	1.61	1.05
Interest	1.15	0.43	0.19	0.62
Utilitarian	0.73	0.94	1	1.19

In question three (How can good scientific work be distinguished from bad scientific work?) the year two internship group males scored more than the no internship group males. The year three internship group males scored less than the no internship group males. The internship group females scored more than the no internship group females in year three. The internship group females scored less than the no internship group females in year two. Table 4.2.2.6 shows average combined score of cogen students and sharing students per year for females and males, and female and male no internship students for question three. When question three was looked at from the perspective of its categories, the internship groups scored similar to the no internship control groups for all categories. Table 4.2.2.7 shows average change scores of females and males split into internship and no internship groups by category.

Table 4.2.2.6. Q by Q question three (How can good scientific work be distinguished from bad scientific work?) average change scores of females and males split into internship and no internship groups by year.

Year	Internship-Female	Internship-Male	No Internship-Female	No Internship-Male
Year 1	3.38	3.15		
Year 2	1.27	5		
Year 3	4.81	2.62		
Years 1-3	3.38	3.43	3.35	3.67

Table 4.2.2.7. Q by Q question three "How can good scientific work be distinguished from bad scientific work?" average change scores of females and males split into internship and no internship groups by category.

Category	Internship-Female	Internship-Male	No Internship-Female	No Internship-Male
Quality of the Work/Results	1.18	1.06	1.32	0.9
Utilitarian	1.25	1.37	1.65	1.67
Extending Knowledge	0.95	1	0.39	1.1

In question four, (Why do you think that some scientific work stands the test of time whereas other scientific work is forgotten?) the year one internship group females scored more than the no internship group females. The year three internship group females scored more than the no internship group females. The year two internship group males scored more than the no internship group males. Table 4.2.2.8 shows average combined score of cogen students and sharing students per year for females and males, and female and male no internship students for question four. When question four was looked at from the perspective of its categories, the internship groups scored similar to the no internship control groups for all categories. Table 4.2.2.9 shows average change scores of females and males split into internship and no internship groups by category for years one through three.

Table 4.2.2.8. Q by Q question four (Why do you think that some scientific work stands the test of time whereas other scientific work is forgotten?) average change scores of females and males split into internship and no internship groups by year.

Year	Internship-Female	Internship-Male	No Internship-Female	No Internship-Male
Year 1	4.69	3.69		
Year 2	2.27	5.56		
Year 3	5	4.69		
Years 1-3	4.15	4.54	3.16	4.43

Table 4.2.2.9. Q by Q question four (Why do you think that some scientific work stands the test of time whereas other scientific work is forgotten?) average change scores of females and males split into internship and no internship groups by category.

Category	Internship-Female	Internship-Male	No Internship-Female	No Internship-Male
Revolutionary	0.4	1.14	0.16	0.71
Coherent field	1.25	1.31	0.35	1.43
Inherent quality of work	1.43	0.57	0.84	0.9
Utilitarian	0.7	1.37	1.48	0.9
Untestable	0.38	0.14	0.32	0.48

In question five (how are conflicts of ideas resolved in the scientific community?) the year one-three internship group males scored more than the no internship group males. The year one

internship group males scored more than the no internship group males. The year three internship group males scored more than the no internship group males. The year three internship group females scored more than the no internship group females. Table 4.2.2.10 shows average combined score of cogen students and sharing students per year for females and males, and female and male no internship students for question five. When question five was looked at from the perspective of its categories, the internship group males scored more than the no internship group males for the empirical category. Table 4.2.2.11 shows average change scores of females and males split into internship and no internship groups by category for years one through three.

Table 4.2.2.10. Q by Q question five (How are conflicts of ideas resolved in the scientific community?) average change scores of females and males split into internship and no internship groups by year.

Year	Internship-Female	Internship-Male	No Internship-Female	No Internship-Male
Year 1	2.62	5.23		
Year 2	3.36	3.78		
Year 3	4.94	4.38		
Years 1-3	3.75	4.54	3.16	2.9

Table 4.2.2.11. Q by Q question five "How are conflicts of ideas resolved in the scientific community?" average change scores of females and males split into internship and no internship groups by category.

Category	Internship-Female	Internship-Male	No Internship-Female	No Internship-Male
Individualist	1.28	1.63	1.58	1.38
Empirical	1.49	2.03	0.81	0.76
Appeal to Authority	1.03	0.89	0.77	0.76

4.2.2.1 Question by Question Gender Analysis Summary

Criteria for observed change was a difference of more than one from the corresponding no internship group score for each question. A difference of more than five from the corresponding no internship group score was used for the overall combined score since there are five questions combined.

Q by Q Combined Changes

- The year three internship group females scored more than the no internship group females for the overall Q by Q score. The internship group scored 23.06 while the no internship group scored 17.06.

Question One Changes (How do scientists decide what questions to investigate?)

- The year three internship group males scored more than the no internship group males. The internship group scored 7.31 while the no internship group scored 4.29.
- The year one internship group females scored more than the no internship group females. The internship group scored 4.92 while the no internship group scored 3.84.
- The internship group males scored more than the no internship group males for the category of extending knowledge. The internship group scored 1.34 while the no internship group scored 0.24.

Question Two Changes (Why do scientists do experiments?)

- The year one internship group males scored less than the no internship group males. The internship group scored 1.92 while the no internship group scored 3.33.

Question Three Changes (How can good scientific work be distinguished from bad scientific work?)

- The year two internship group males scored more than the no internship group males. The internship group scored 5.0 while the no internship group scored 3.67.
- The year three internship group males scored less than the no internship group males. The internship group scored 2.62 while the no internship group scored 3.67.
- The year three internship group females scored more than the no internship group females. The internship group scored 4.81 while the no internship group scored 3.35.

- The year two internship group females scored less than the no internship group females. The internship group scored 1.27 while the no internship group scored 3.35.

Question Four Changes (Why do you think that some scientific work stands the test of time whereas other scientific work is forgotten?)

- The year two internship group males scored more than the no internship group males. The internship group scored 5.56 while the no internship group scored 4.43.
- The year one internship group females scored more than the no internship group females. The internship group scored 4.69 while the no internship group scored 3.16.
- The year three internship group females scored more than the no internship group females. The internship group scored 5.0 while the no internship group scored 3.16.

Question Five Changes (How are conflicts of ideas resolved in the scientific community?)

- The year one-three internship group males scored more than the no internship group males. The internship group scored 4.54 while the no internship group scored 2.9.
- The year one internship group males scored more than the no internship group males. The internship group scored 5.23 while the no internship group scored 2.9.
- The year three internship group males scored more than the no internship group males. The internship group scored 4.38 while the no internship group scored 2.9.
- The year three internship group females scored more than the no internship group females. The internship group scored 4.94 while the no internship group scored 3.16.
- The internship group males scored more than the no internship group males for the empirical category. The internship group scored 2.03 while the no internship group scored 0.76.

4.2.3 Framework Analysis

The internship versus no internship framework analysis showed how the two groups improved their NOS views over the course of a year. The average combined score of internship students was 7.03 for all three years, while the average combined score for no internship students was 6.42 for all three years. All groups scored similar for the overall framework scores. The scores of both groups by year is in Table 4.2.3.1 and Figure 4.2.3.1. When looked at based on each of the three dimensions, the internship group scored similar to the no internship group for all three dimensions. Table 4.2.3.2 shows average change scores of internship students, and no internship students by dimension for years one through three.

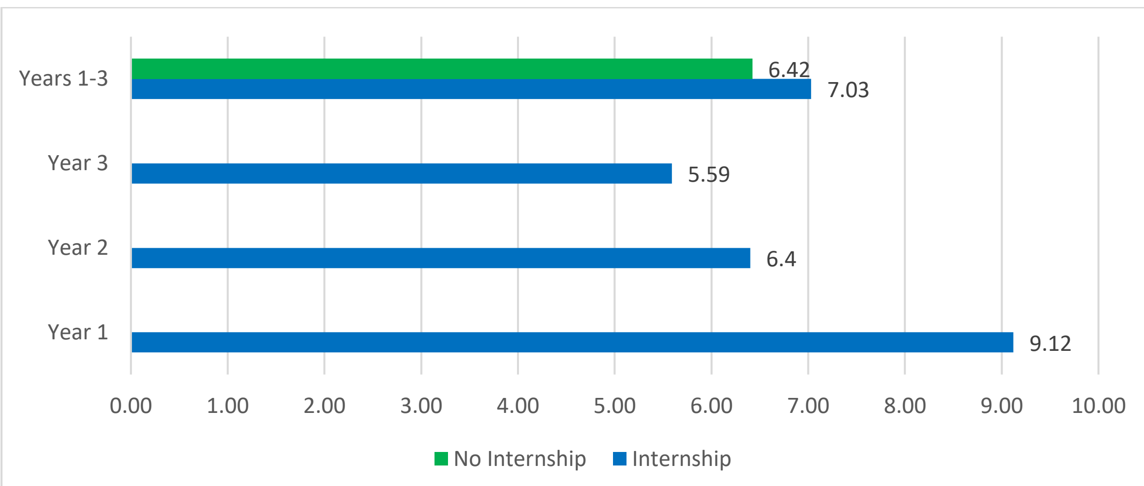

Figure 4.2.3.1. Internship students versus no internship student's average framework change scores by year. This figure illustrates the combined framework average change scores for internship students, and no internship students for all three program years.

Table 4.2.3.1. Internship students versus no internship student's average framework change scores by year.

Year	Internship	No Internship
Year 1	9.12	
Year 2	6.4	
Year 3	5.59	
Years 1-3	7.03	6.42

Table 4.2.3.2. Internship students versus no internship student's average framework change scores by dimension.

Dimension	Internship	No Internship
Relationship between Knowledge Claims and Data	2.10	1.58
Nature of Lines of Scientific Enquiry	2.87	3.44
Social Dimension of Science	2.07	1.4

Next, scores for each individual dimension were analyzed. First, dimension one (the relationship between knowledge claims and data) is analyzed in detail. The average combined score of cogen students and sharing students was 2.1 and no internship students was 1.58. The internship group scored similar to the no internship group all three years. Table 4.2.3.3 shows the yearly average change scores for dimension one. When dimension one was looked at from the perspective of its categories, the internship group scored similar to the no internship group for all categories. Table 4.2.3.4 shows average change scores of internship students, and no internship students by subdimension.

Table 4.2.3.3. Internship students versus no internship students dimension one average change scores by year: Relationship between knowledge claims and data.

Year	Internship	No Internship
Year 1	2.58	
Year 2	1.7	
Year 3	1.93	
Years 1-3	2.1	1.58

Table 4.2.3.4. Internshipstudents versus no internship students dimension one average change scores by subdimension: Relationship between knowledge claims and data.

Subdimension	Internship	No Internship
Knowledge Claims as Description	1.05	0.48
Knowledge Claims as Provable	0.91	0.88
Knowledge Claims go Beyond the Data	0.14	0.21

Second, dimension two (the nature of lines of scientific enquiry) is analyzed in detail. The average change scores for internship students was 2.87 and no internship students was 3.44. The

year three internship group scored less than the no internship control group. Table 4.2.3.5 shows the yearly average change scores for dimension two. When dimension two was looked at from the perspective of its categories, the internship group scored similar to the no internship group for all categories. Table 4.2.3.6 shows average change scores of internship students, and no internship students by subdimension.

Table 4.2.3.5. Internship students versus no internship students dimension two average change scores by year: Nature of lines of scientific enquiry.

Year	Internship	No Internship
Year 1	3.85	
Year 2	2.55	
Year 3	2.21	
Years 1-3	2.87	3.44

Table 4.2.3.6. Internship students versus no internship students dimension two average change scores by subdimension: Nature of lines of scientific enquiry.

Subdimension	Internship	No Internship
Location in individual interests of scientists	1.35	1.48
Internal location in epistemology of discipline	0.87	1
External location	0.65	0.96

Third, dimension three (the social dimension of science) is analyzed in detail. The average change scores for internship students was 2.07 and no internship students was 1.4. The year one internship group scored more than the no internship control group. Table 4.2.3.7 shows the yearly average change scores for dimension three. When dimension three was looked at from the perspective of its categories, the internship group scored similar to the no internship group for all categories. Table 4.2.3.8 shows average change scores of Internship students, and no internship students by subdimension.

Table 4.2.3.7. Internship students versus no internship students dimension three average change scores by year: Social dimension of science.

Year	Internship	No Internship

Year 1	2.69	
Year 2	2.15	
Year 3	1.45	
Years 1-3	2.07	1.4

Table 4.2.3.8. Internship students versus no internship students dimension three average change scores by subdimension: Social dimension of science.

Subdimension	Internship	No Internship
Individualist view	0.41	0.12
Recognition of a community of scientists	1.37	1.06
Recognition of institutions of science	0.28	0.23

4.2.3.1 Framework Analysis Summary

Criteria for observed change was a difference of more than one from the corresponding no internship group score for each dimension. A difference of more than three from the corresponding no internship group score was used for the framework combined score since there are three dimensions combined.

Framework Analysis Combined Changes

- No change was observed.

Dimension One Changes (Relationship between Knowledge Claims and Data)

- No change was observed.

Dimension Two Changes (Nature of Lines of Scientific Enquiry)

- No change was observed.

Dimension Three Changes (Social Dimension of Science)

- The year one internship group scored more than the no internship control group. The internship group scored 2.69 while the no internship group scored 1.4.

4.2.4 Framework Gender Analysis

The next observation for the framework analysis for the internship vs no internship paradigm is to take students' gender into account. The year one internship group females scored

more than the no internship group females. Figure 4.2.4.1 shows average combined score of cogen students and sharing students per year for females and males, and female and male no internship students. The internship group males scored less than the no internship group males for the nature of lines of scientific enquiry dimension. Table 4.2.4.1 shows the individual framework dimension scores of average combined scores of cogen students and sharing students for females and males, and female and male no internship student's groups for each dimension.

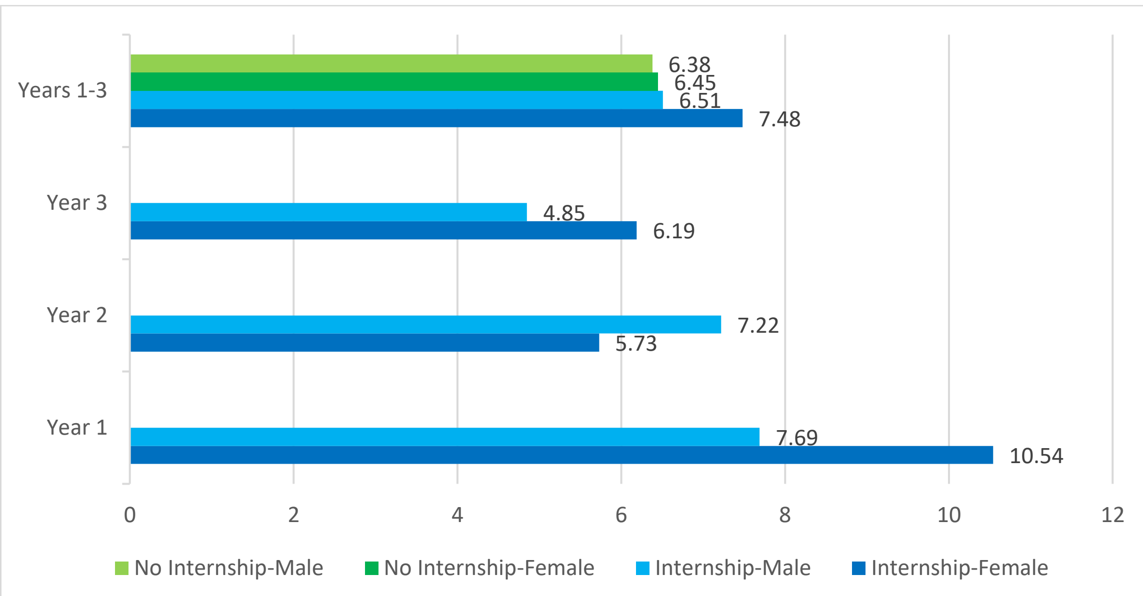

Figure 4.2.4.1. Male and female internship students versus no internship students combined average change scores for framework analysis. This figure illustrates the average change scores for male and female Internship students versus no internship students for all three program years.

Table 4.2.4.1. Individual framework dimension scores of average combined scores of cogen students and sharing students for females and males, and female and male no internship group students.

Dimension	Internship-Female	Internship-Male	No Internship-Female	No Internship-Male
Relationship between knowledge claims and data	2.35	1.8	1.77	1.29
Nature of lines of scientific enquiry	3.18	2.51	3.32	3.62
Social dimension of science	1.95	2.2	1.35	1.48

First, dimension one (relationship between knowledge claims and data) is analyzed. The year one internship group females scored more than the no internship group females. Table 4.2.4.2 shows average combined score of cogen students and sharing students per year for females and males, and female and male no internship students. When dimension one was looked at from the perspective of its categories, the internship groups scored similar to the no internship control groups for all subdimensions. Table 4.2.4.3 shows the dimension one subdimension scores of average combined scores of cogen students and sharing students for females and males, and female and male no internship student groups.

Table 4.2.4.2. Framework dimension one “Relationship between knowledge claims and data” average change scores of females and males split into internship and no internship groups by year.

Year	Internship-Female	Internship-Male	No Internship-Female	No Internship-Male
Year 1	3.69	1.46		
Year 2	1.36	2.11		
Year 3	1.94	1.92		
Years 1-3	2.35	1.8	1.77	1.29

Table 4.2.4.3. Framework dimension one average change scores of internship students for females and males, and female and male no internship group students by subdimension. (Relationship between knowledge claims and data).

Subdimension	Internship-Female	Internship-Male	No Internship-Female	No Internship-Male
Claims as Description	1.13	0.97	0.61	0.29
Claims as Provable	1.1	0.69	0.97	0.76
Claims Beyond the Data	0.13	0.14	0.19	0.24

Next, dimension two (nature of lines of scientific enquiry) was analyzed. The year one internship group females scored more than the no internship group females. The year one-three internship group males scored less than the no internship group males. The year two internship group males scored less than the no internship group males. The year three internship group males scored less than the no internship group males. Table 4.2.4.4 shows average combined score of

cogen students and sharing students per year for females and males, and female and male no internship students. When dimension two was looked at from the perspective of its categories, the internship groups scored similar to the no internship control groups for all subdimensions. Table 4.2.4.5 shows the dimension two subdimension scores of average combined scores of cogen students and sharing students for females and males, and female and male no internship group students.

Table 4.2.4.4. Framework dimension two average change scores of internship students for females and males, and female and male no internship group students by year. (Nature of lines of scientific enquiry).

Year	Internship-Female	Internship-Male	No Internship-Female	No Internship-Male
Year 1	4.38	3.31		
Year 2	2.73	2.33		
Year 3	2.5	1.85		
Years 1-3	3.18	2.51	3.32	3.62

Table 4.2.4.5. Framework dimension two average change scores of internship students for females and males, and female and male no internship group students by subdimension (Nature of lines of scientific enquiry).

Subdimension	Internship-Female	Internship-Male	No Internship-Female	No Internship-Male
Location in individual interests of scientists	1.65	1	1.39	1.62
Internal location in epistemology of discipline	0.85	0.89	0.97	1.05
External location	0.68	0.63	0.96	0.95

Finally, dimension three (social dimension of science) was analyzed. The year one internship group males scored more than the no internship group males. The year two internship group males scored more than the no internship group males. The year one internship group females scored more than the no internship group females. Table 4.2.4.6 shows average combined score of cogen students and sharing students per year for females and males, and female and male no internship students. When dimension three was looked at from the perspective of its categories,

the internship groups scored similar to the no internship control groups for all subdimensions. Table 4.2.4.7 shows the dimension three subdimension scores of average combined score of cogen students and sharing students for females and males, and female and male no internship student groups by subdimension.

Table 4.2.4.6. Framework dimension three average change scores of internship students for females and males, and female and male no internship student groups by year (Social dimension of science).

Year	Internship-Female	Internship-Male	No Internship-Female	No Internship-Male
Year 1	2.46	2.92		
Year 2	1.64	2.78		
Year 3	1.75	1.08		
Years 1-3	1.95	2.2	1.35	1.48

Table 4.2.4.7. Framework dimension three average change scores of internship students for females and males, and female and male no internship group students by subdimension (Social dimension of science).

Subdimension	Internship-Female	Internship-Male	No Internship-Female	No Internship-Male
Individualist view	0.23	0.63	0	0.29
Recognition of a community of scientists	1.6	1.11	1.16	0.9
Recognition of institutions of science	0.13	0.46	0.19	0.29

4.2.4.1 Framework Gender Analysis Summary

Criteria for observed change was a difference of more than one from the corresponding no internship group score for each dimension. A difference of more than three from the corresponding no internship group score was used for the framework combined score since there are three dimensions combined.

Framework Gender Analysis Combined Changes

- The year one internship group females scored more than the no internship group females. The internship group scored 10.54 while the no internship group scored 6.45.

Dimension One Changes (Relationship between Knowledge Claims and Data)

- The year one internship group females scored more than the no internship group females. The internship group scored 3.69 while the no internship group scored 1.77.

Dimension Two Changes (Nature of Lines of Scientific Enquiry)

- The year one internship group females scored more than the no internship group females. The internship group scored 4.38 while the no internship group scored 3.32.
- The year one-three internship group males scored less than the no internship group males. The internship group scored 2.51 while the no internship group scored 3.62.
- The year two internship group males scored less than the no internship group males. The internship group scored 2.33 while the no internship group scored 3.62.
- The year three internship group males scored less than the no internship group males. The internship group scored 1.85 while the no internship group scored 3.62.

Dimension Three Changes (Social Dimension of Science)

- The year one internship group males scored more than the no internship group males. The internship group scored 2.92 while the no internship group scored 1.48.
- The year two internship group males scored more than the no internship group males. The internship group scored 2.78 while the no internship group scored 1.48.
- The year one internship group females scored more than the no internship group females. The internship group scored 2.46 while the no internship group scored 1.35.

4.3 Cogen Versus Sharing Versus No Internship Responses

The second means of analyzing results is looking at the effect that participating in cogenerative dialogues had on cogen students versus sharing and no internship students who did not participate in cogenerative dialogues. These results are compiled to show how answers varied

based on program year, question or dimension, and category of question or dimension. Results are further analyzed to show trends based on participants' gender.

4.3.1 Question by Question Analysis

The cogen, sharing, and no internship question by question analysis resulted in some interesting data. The average combined score of cogen students was 20.32 for all three years, the average combined score of sharing students was 17.77, while the average combined score for no internship students was 17.76 for all three years. The year three cogen group scored more than the no internship control group. The scores of all three groups by year is in Figure 4.3.1.1. When looked at based on each of the five questions, the cogen group scored more than the no internship group on question five: How are conflicts of ideas resolved in the scientific community? The sharing group scored less than the no internship group on question two: Why do scientists do experiments. The sharing group scored more than the no internship group on question four: Why do you think that some scientific work stands the test of time whereas other scientific work is forgotten? All three groups scored similar on questions one and three. These scores are included in Table 4.3.1.1.

Table 4.3.1.1. Cogen, sharing, and no internship question by question average change scores by question.

Question	Cogen	Sharing	No Internship
How do scientists decide what questions to investigate?	4.95	3.54	4
Why do scientists do experiments?	3.76	1.23	3.51
How can good scientific work be distinguished from bad scientific work?	3.23	4.23	3.45
Why do you think that some scientific work stands the test of time whereas other scientific work is forgotten?	4.1	5.46	3.71
How are conflicts of ideas resolved in the scientific community?	4.29	3.31	3.1

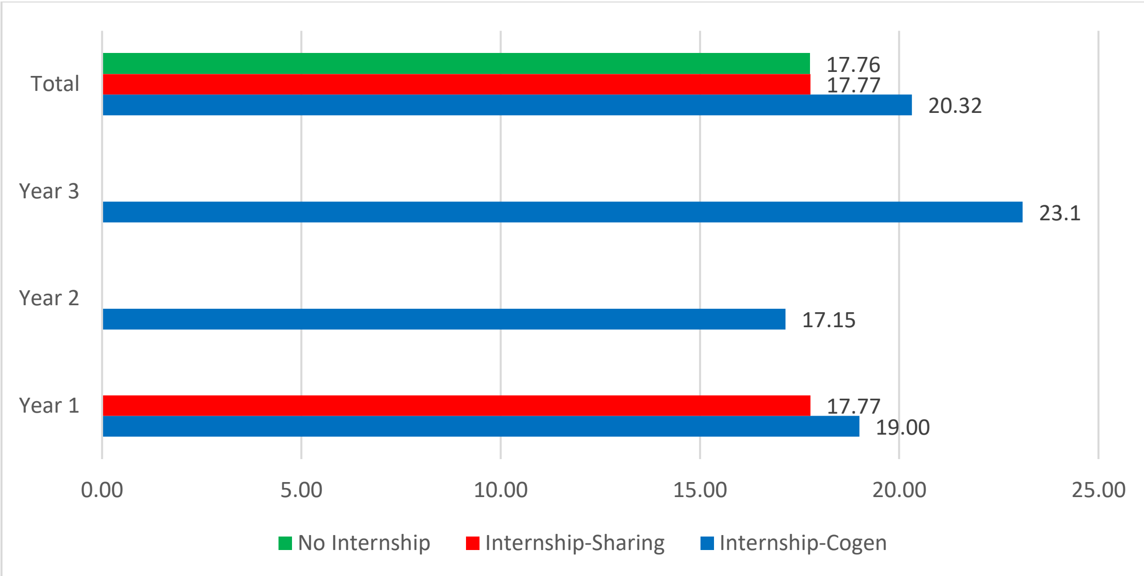

Figure 4.3.1.1. Cogen, sharing, and no internship question by question average change scores by year. This figure illustrates the combined average change scores for cogen, sharing, and no internship students for all three program years.

Next, scores for each individual question were analyzed. First, question one (how do scientists decide what questions to investigate?) is analyzed in detail. The average change scores for cogen students was 4.95, sharing students was 3.54 and no internship students was 4. The year one cogen group scored more than the no internship control group. The year three cogen group scored more than the no internship control group. Table 4.3.1.2 shows the yearly average change scores for question one. All three groups scored similar for all categories. Table 4.3.1.3 shows the average change scores for each category of question one.

Table 4.3.1.2. Cogen, sharing, and no internship question one average change scores by year: How do scientists decide what questions to investigate?

Year	Cogen	Sharing	No Internship
Year 1	5.62	3.54	
Year 2	3.75		
Year 3	5.48		
Year 1-3	4.95	3.54	4

Table 4.3.1.3. Cogen, sharing, and no internship question one average change scores by category: How do scientists decide what questions to investigate?

Category	Cogen	Sharing	No Internship
Curiosity Led	1.03	0.92	1.27
Extending Knowledge	1.47	0.69	0.63
Utilitarian	1.16	1	1.61
Financial Benefit	0.21	0.08	0.04
Personal Recognition	0.11	0.08	0.02
Feasibility	0.97	0.77	0.43

Second, question two (why do scientists do experiments?) is analyzed in detail. The average change scores for cogen students was 3.76, sharing students was 1.23 and no internship students was 3.51. The year one sharing group scored less than the no internship control group. Table 4.3.1.4 shows the yearly average change scores for question two. All three groups scored similar for all categories. Table 4.3.1.5 shows the average change scores for each category of question two.

Table 4.3.1.4. Cogen, sharing, and no internship question two average change scores by year: Why do scientists do experiments?

Year	Cogen	Sharing	No Internship
Year 1	3.62	1.23	
Year 2	3.15		
Year 3	4.24		
Year 1-3	3.76	1.23	3.51

Table 4.3.1.5. Cogen, sharing, and no internship question two average change scores by category: Why do scientists do experiments?

Category	Cogen	Sharing	No Internship
Knowledge	0.97	0.46	0.63
Empirical	0.84	0.62	1.41
Interest	0.98	0	0.37
Utilitarian	0.97	0.15	1.1

Third, question three (how can good scientific work be distinguished from bad scientific work?) is analyzed in detail. The average change scores for cogen students was 3.23, sharing

students was 4.23, and no internship students was 3.45. The year one cogen group scored less than the no internship control group. Table 4.3.1.6 shows the yearly average change scores for question three. The sharing group scored more than the no internship group in the category of quality of the work/results. Table 4.3.1.7 shows the average change scores for each category of question three.

Table 4.3.1.6. Cogen, sharing, and no internship question three average change scores by year: How can good scientific work be distinguished from bad scientific work?

Year	Cogen	Sharing	No Internship
Year 1	2.31	4.23	
Year 2	2.95		
Year 3	3.83		
Year 1-3	3.23	4.23	3.45

Table 4.3.1.7. Cogen, sharing, and no internship question three average change scores by category: How can good scientific work be distinguished from bad scientific work?

Category	Cogen	Sharing	No Internship
Quality of the Work/Results	0.87	2.31	1.08
Utilitarian	1.35	1.08	1.69
Extending Knowledge	1	0.85	0.69

Fourth, question four (why do you think that some scientific work stands the test of time whereas other scientific work is forgotten?) is analyzed in detail. The average change scores for cogen students was 4.1, sharing students was 5.46 and no internship students was 3.71. The year three cogen students scored more than the no internship control group. The year one sharing students scored more than the no internship control group. Table 4.3.1.8 shows the yearly average change scores for question four. All three groups scored similar for all categories. Table 4.3.1.9 shows the average change scores for each category of question four.

Table 4.3.1.8. Cogen, sharing, and no internship question four average change scores by year: Why do you think that some scientific work stands the test of time whereas other scientific work is forgotten?

Year	Cogen	Sharing	No Internship
Year 1	2.92	5.46	

Year 2	3.75		
Year 3	4.86		
Year 1-3	4.1	5.46	3.71

Table 4.3.1.9. Cogen, sharing, and no internship question four average change scores by category: Why do you think that some scientific work stands the test of time whereas other scientific work is forgotten?

Category	Cogen	Sharing	No Internship
Revolutionary	0.82	0.38	0.39
Coherent field	1.21	1.62	0.78
Inherent quality of work	0.95	1.38	0.86
Utilitarian	0.95	1.31	1.27
Untestable	0.16	0.77	0.39

Finally, question five (how are conflicts of ideas resolved in the scientific community?) is analyzed in detail. The average change scores for cogen students was 4.29, sharing students was 3.31 and no internship students was 3.1. The year one-three cogen students scored more than the no internship control group. The year one cogen students scored more than the no internship control group. The year three cogen students scored more than the no internship control group. Table 4.3.1.10 shows the yearly average change scores for question five. All three groups scored similar for all categories. Table 4.3.1.11 shows the average change scores for each category of question five.

Table 4.3.1.10. Cogen, sharing, and no internship question five average change scores by year: How are conflicts of ideas resolved in the scientific community?

Year	Cogen	Sharing	No Internship
Year 1	4.54	3.31	
Year 2	3.55		
Year 3	4.69		
Year 1-3	4.29	3.31	3.1

Table 4.3.1.11. Cogen, sharing, and no internship question five average change scores by category: How are conflicts of ideas resolved in the scientific community?

Category	Cogen	Sharing	No Internship
Individualist	1.55	0.92	1.53
Empirical	1.74	1.77	0.8

Appeal to Authority	1.03	0.62	0.76

4.3.1.1 Question by Question Analysis Summary

Criteria for observed change was a difference of more than one from the corresponding no internship group score for each question. A difference of more than five from the corresponding no internship group score was used for the overall combined score since there are five questions combined.

Q by Q Combined Changes

- The year three cogen group scored more than the no internship control group. The cogen group scored 23.1 while the no internship group scored 17.76.

Question One Changes (How do scientists decide what questions to investigate?)

- The year one cogen group scored more than the no internship control group. The cogen group scored 5.62 while the no internship group scored 4.0.
- The year three cogen group scored more than the no internship control group. The cogen group scored 5.48 while the no internship group scored 4.0.

Question Two Changes (Why do scientists do experiments?)

- The year one sharing group scored less than the no internship control group. The sharing group scored 1.23 while the no internship group scored 3.51.

Question Three Changes (How can good scientific work be distinguished from bad scientific work?)

- The year one cogen group scored less than the no internship control group. The cogen group scored 2.31 while the no internship group scored 3.45.
- The sharing group scored more than the no internship group in the category of quality of the work/results. The sharing group scored 2.31 while the no internship group scored 1.08.

Question Four Changes (Why do you think that some scientific work stands the test of time whereas other scientific work is forgotten?)

- The year three cogen students scored more than the no internship control group. The cogen group scored 4.86 while the no internship group scored 3.71.
- The year one sharing students scored more than the no internship control group. The sharing group scored 5.46 while the no internship group scored 3.71.

Question Five Changes (How are conflicts of ideas resolved in the scientific community?)

- The year one-three cogen students scored more than the no internship control group. The cogen group scored 4.29 while the no internship group scored 3.1.
- The year one cogen students scored more than the no internship control group. The cogen group scored 4.54 while the no internship group scored 3.1.
- The year three cogen students scored more than the no internship control group. The cogen group scored 4.69 while the no internship group scored 3.1.

4.3.2 Question by Question Gender Analysis

The next data observation for the question by question analysis for the cogen, sharing, and no internship paradigm is to take students' gender into account. The year three cogen females scored more than the no internship group females. Figure 4.3.2.1 shows combined average change scores per year for female and male cogen students, female and male sharing students, and female and male no internship students. Cogen group males scored more than no internship group males in question one and question five. Sharing group males scored more than the no internship group males in question four and question five, and scored less in question two. Cogen group females scored more than no internship group females in question five. Sharing group females scored more than the no internship group females in question four and question five, and scored less in question

two. Questions three and five did not have a clear distinction of males or females scoring higher. Table 4.3.2.1 shows the individual Q by Q question scores of females and males split into cogen, sharing, and no internship groups.

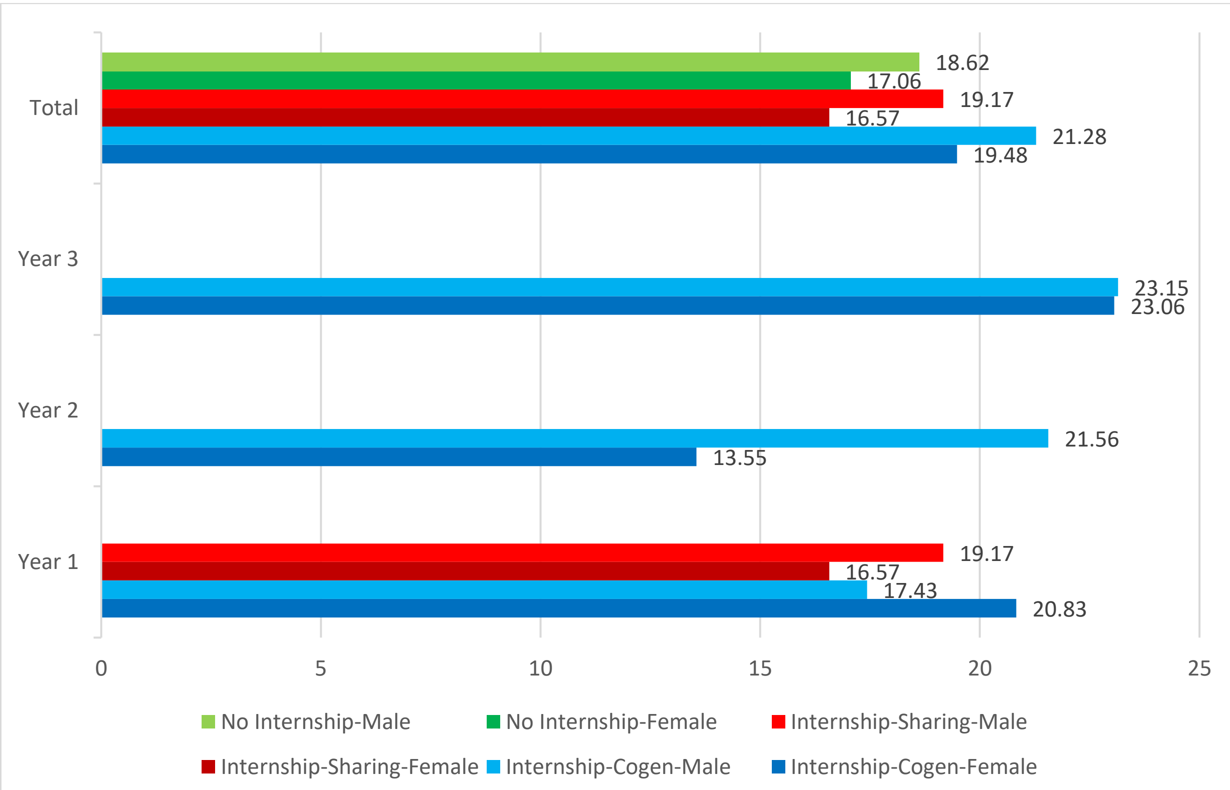

Figure 4.3.2.1. Male and female cogen, sharing, and no internship students combined average change scores for question by question analysis. This figure illustrates the average change scores for male and female cogen, sharing, and no internship students for all three program years.

Table 4.3.2.1. Individual Q by Q question average change scores of females and males split into cogen, sharing, and no internship groups.

Question	Cogen-Female	Cogen-Male	Sharing-Female	Sharing-Male	No Internship-Female	No Internship-Male
How do scientists decide what questions to investigate?	4.33	5.66	3.71	3.33	3.84	4.29
Why do scientists do experiments?	3.88	3.62	1.57	0.83	3.55	3.33
How can good scientific work be distinguished from bad scientific work?	3.24	3.21	4	4.5	3.35	3.67

Why do you think that some scientific work stands the test of time whereas other scientific work is forgotten?	4.03	4.17	4.71	6.33	3.16	4.43
How are conflicts of ideas resolved in the scientific community?	4	4.62	2.57	4.17	3.16	2.9

In question one, (How do scientists decide what questions to investigate?), the year one cogen group females scored more than the no internship group females. The year one-three cogen males scored more than the no internship group males. The year three cogen males scored more than the no internship group males. Table 4.3.2.2 shows male and female average change scores for question one by year and cogen, sharing, and no internship participation. When question one was looked at from the perspective of its categories, the cogen group males scored more than the no internship group males on extending knowledge. The sharing group males scored more than the no internship group males on extending knowledge. The sharing group males scored less than the no internship group males on curiosity led. The sharing group males scored less than the no internship group males on utilitarian. The sharing group females scored less than the no internship group females on extending knowledge. Table 4.3.2.3 shows average change scores of females and males split into cogen, sharing, and no internship groups by category.

Table 4.3.2.2. Q by Q question one "How do scientists decide what questions to investigate?" average change scores of females and males split into cogen, sharing, and no internship groups by year.

Year	Cogen-Female	Cogen-Male	Sharing-Female	Sharing-Male	No Internship-Female	No Internship-Male
Year 1	6.33	5	3.71	3.33		
Year 2	3.73	3.78				
Year 3	4	7.31				
Year 1-3	4.33	5.66	3.71	3.33	3.84	4.29

Table 4.3.2.3. Q by Q question one "How do scientists decide what questions to investigate?" average change scores of females and males split into cogen, sharing, and no internship groups by category.

Category	Cogen - Female	Cogen - Male	Sharing-Female	Sharing-Male	No Internship-Female	No Internship-Male
Curiosity Led	0.58	1.55	1.57	0.17	1.1	1.48
Extending Knowledge	1.61	1.31	0	1.5	1.03	0.24
Utilitarian	1.15	1.17	1.43	0.5	1.45	1.76
Financial Benefit	0.18	0.24	0	0.17	0.03	0.05
Personal Recognition	0.06	0.17	0	0.17	0.03	0
Feasibility	0.76	1.21	0.71	0.83	0.19	0.76

In question two, (Why do scientists do experiments?), the year one sharing group females scored less than the no internship group females. The year one sharing group males scored less than the no internship group males. Table 4.3.2.4 shows male and female average change scores for question two by year and cogen, sharing, and no internship participation. When question two was looked at from the perspective of its categories, the sharing group males scored less than the no internship group males for utilitarianism. The cogen group females scored more than the no internship group females for interest. Table 4.3.2.5 shows average change scores for question two of females and males split into cogen, sharing, and no internship groups by category.

Table 4.3.2.4. Q by Q question two "Why do scientists do experiments?" average change scores of females and males split into cogen, sharing, and no internship groups by year.

Year	Cogen - Female	Cogen - Male	Sharing-Female	Sharing-Male	No Internship-Female	No Internship-Male
Year 1	4.5	2.86	1.57	0.83		
Year 2	2.91	3.44				
Year 3	4.31	4.15				
Year 1-3	3.88	3.62	1.57	0.83	3.55	3.33

Table 4.3.2.5. Q by Q question two "Why do scientists do experiments?" average change scores of females and males split into cogen, sharing, and no internship groups by category.

Category	Cogen - Female	Cogen - Male	Sharing-Female	Sharing-Male	No Internship-Female	No Internship-Male
Knowledge	0.82	1.14	0.71	0.17	0.74	0.48
Empirical	0.82	0.86	0.71	0.5	1.61	1.05
Interest	1.39	0.52	0	0	0.19	0.62
Utilitarian	0.85	1.1	0.14	0.17	1	1.19

In question three, (How can good scientific work be distinguished from bad scientific work?), the year three cogen group females scored more than the no internship group females. The year two cogen group females scored less than the no internship group females. The year two cogen group males scored more than the no internship group males. The year one cogen group males scored less than the no internship group males. The year three cogen group males scored less than the no internship group males. Table 4.3.2.6 shows male and female average change scores for question three by year and cogen, sharing, and no internship participation. When question three was looked at from the perspective of its categories, the sharing group males scored more than the no internship group males for quality of the work/results. All females scored similar for all categories. Table 4.3.2.7 shows average change scores for question three of females and males split into cogen, sharing, and no internship groups by category.

Table 4.3.2.6. Q by Q question three "How can good scientific work be distinguished from bad scientific work?" average change scores of females and males split into cogen, sharing, and no internship groups by year.

Year	Cogen - Female	Cogen - Male	Sharing-Female	Sharing-Male	No Internship-Female	No Internship-Male
Year 1	2.67	2	4	4.5		
Year 2	1.27	5				
Year 3	4.81	2.62				
Year 1-3	3.24	3.21	4	4.5	3.35	3.67

Table 4.3.2.7. Q by Q question three "How can good scientific work be distinguished from bad scientific work?" average change scores of females and males split into cogen, sharing, and no internship groups by category.

Category	Cogen - Female	Cogen - Male	Sharing-Female	Sharing-Male	No Internship-Female	No Internship-Male
Quality of the Work/Results	1.03	0.69	1.86	2.83	1.32	0.9
Utilitarian	1.24	1.48	1.29	0.83	1.65	1.67
Extending Knowledge	0.97	1.03	0.86	0.83	0.39	1.1

In question four, (Why do you think that some scientific work stands the test of time whereas other scientific work is forgotten?), the year two cogen group males scored more than the no internship group males. The year one cogen group males scored less than the no internship group males. The year one sharing group males scored more than the no internship group males. Table 4.3.2.8 shows male and female average change scores for question four by year and cogen, sharing, and no internship participation. When question four was looked at from the perspective of its categories, the sharing group males scored more than the no internship group males for coherent field. The cogen group females scored more than no internship group females for coherent field. Table 4.3.2.9 shows average change scores for question four of females and males split into cogen, sharing, and no internship groups by category.

Table 4.3.2.8. Q by Q question four "Why do you think that some scientific work stands the test of time whereas other scientific work is forgotten?" average change scores of females and males split into cogen, sharing, and no internship groups by year.

Year	Cogen - Female	Cogen - Male	Sharing-Female	Sharing-Male	No Internship-Female	No Internship-Male
Year 1	4.67	1.43	4.71	6.33		
Year 2	2.27	5.56				
Year 3	5	4.69				
Year 1-3	4.03	4.17	4.71	6.33	3.16	4.43

Table 4.3.2.9. Q by Q question four "Why do you think that some scientific work stands the test of time whereas other scientific work is forgotten?" average change scores of females and males split into cogen, sharing, and no internship groups by category.

Category	Cogen - Female	Cogen - Male	Sharing-Female	Sharing-Male	No Internship-Female	No Internship-Male
Revolutionary	0.48	1.21	0	0.83	0.16	0.71
Coherent field	1.36	1.03	0.71	2.67	0.35	1.43
Inherent quality of work	1.3	0.55	2	0.67	0.84	0.9
Utilitarian	0.58	1.38	1.29	1.33	1.48	0.9
Untestable	0.3	0	0.71	0.83	0.32	0.48

In question five, (How are conflicts of ideas resolved in the scientific community?), the year one-three cogen group males scored more than the no internship group males. the year one cogen group males scored more than the no internship group males. the year three cogen group males scored more than the no internship group males. The year one sharing group males scored more than no internship group males. The year three cogen group females scored more than the no internship group females. Table 4.3.2.10 shows male and female average change scores for question five by year and cogen, sharing, and no internship participation. When question five was looked at from the perspective of its categories, the cogen group males scored more than the no internship group males for empirical. The sharing group males scored more than the no internship group males for empirical. The three groups of females scored similar for all categories. Table 4.3.2.11 shows average change scores for question five of females and males split into cogen, sharing, and no internship groups by category.

Table 4.3.2.10. Q by Q question five "How are conflicts of ideas resolved in the scientific community?" average change scores of females and males split into cogen, sharing, and no internship groups by year.

Year	Cogen - Female	Cogen - Male	Sharing- Female	Sharing- Male	No Internship- Female	No Internship- Male
Year 1	2.67	6.14	2.57	4.17		
Year 2	3.36	3.78				
Year 3	4.94	4.38				
Year 1-3	4	4.62	2.57	4.17	3.16	2.9

Table 4.3.2.11. Q by Q question five "How are conflicts of ideas resolved in the scientific community?" average change scores of females and males split into cogen, sharing, and no internship groups by category.

Category	Cogen - Female	Cogen - Male	Sharing- Female	Sharing- Male	No Internship- Female	No Internship- Male
Individualist	1.3	1.83	1.14	0.67	1.58	1.38
Empirical	1.69	1.79	0.57	3.17	0.81	0.76
Appeal to Authority	1.06	1	0.86	0.33	0.77	0.76

4.3.2.1 Question by Question Gender Analysis

Criteria for observed change was a difference of more than one from the corresponding no internship group score for each question. A difference of more than five from the corresponding no internship group score was used for the overall combined score since there are five questions combined.

Q by Q Combined Gender Changes

- The year three cogen females scored more than the no internship group females. The cogen group scored 23.06 while the no internship group scored 17.06.

Question One Changes (How do scientists decide what questions to investigate?)

- The year one cogen group females scored more than the no internship group females. The cogen group scored 6.33 while the no internship group scored 3.84.
- The year one-three cogen males scored more than the no internship group males. The cogen group scored 5.66 while the no internship group scored 4.29.
- The year three cogen males scored more than the no internship group males. The cogen group scored 7.31 while the no internship group scored 4.29.
- The cogen group males scored more than the no internship group males on extending knowledge. The cogen group scored 1.31 while the no internship group scored 0.24.
- The sharing group males scored more than the no internship group males on extending knowledge. The sharing group scored 1.5 while the no internship group scored 0.24.
- The sharing group males scored less than the no internship group males on curiosity led. The sharing group scored 0.17 while the no internship group scored 1.48.
- The sharing group males scored less than the no internship group males on utilitarian. The sharing group scored 0.5 while the no internship group scored 1.76.

- The sharing group females scored less than the no internship group females on extending knowledge. The sharing group scored 0 while the no internship group scored 1.03.

Question Two Changes (Why do scientists do experiments?)

- The year one sharing group females scored less than the no internship group females. The sharing group scored 1.57 while the no internship group scored 3.55.
- The year one sharing group males scored less than the no internship group males. The sharing group scored 0.83 while the no internship group scored 3.33.
- The sharing group males scored less than the no internship group males for utilitarianism. The sharing group scored 0.17 while the no internship group scored 1.19.
- The cogen group females scored more than the no internship group females for interest. The cogen group scored 1.39 while the no internship group scored 0.19.

Question Three Changes (How can good scientific work be distinguished from bad scientific work?)

- The year three cogen group females scored more than the no internship group females. The cogen group scored 4.81 while the no internship group scored 3.35.
- The year two cogen group females scored less than the no internship group females. The cogen group scored 1.27 while the no internship group scored 3.35.
- The year two cogen group males scored more than the no internship group males. The cogen group scored 5 while the no internship group scored 3.67.
- The year one cogen group males scored less than the no internship group males. The cogen group scored 2 while the no internship group scored 3.67.
- The year three cogen group males scored less than the no internship group males. The cogen group scored 2.62 while the no internship group scored 3.67.

- The sharing group males scored more than the no internship group males for quality of the work/results. The sharing group scored 2.83 while the no internship group scored 0.9.

Question Four Changes (Why do you think that some scientific work stands the test of time whereas other scientific work is forgotten?)

- The year two cogen group males scored more than the no internship group males. The cogen group scored 5.56 while the no internship group scored 4.43.
- The year one cogen group males scored less than the no internship group males. The cogen group scored 1.43 while the no internship group scored 4.43.
- The year one sharing group males scored more than the no internship group males. The sharing group scored 6.33 while the no internship group scored 4.43.
- The sharing group males scored more than the no internship group males for coherent field. The sharing group scored 2.67 while the no internship group scored 1.43.
- The cogen group females scored more than no internship group females for coherent field. The cogen group scored 1.36 while the no internship group scored 0.35.

Question Five Changes (How are conflicts of ideas resolved in the scientific community?)

- The year one-three cogen group males scored more than the no internship group males. The cogen group scored 4.62 while the no internship group scored 2.9.
- The year one cogen group males scored more than the no internship group males. The cogen group scored 6.14 while the no internship group scored 2.9.
- The year three cogen group males scored more than the no internship group males. The cogen group scored 4.38 while the no internship group scored 2.9.
- The year one sharing group males scored more than no internship group males. The sharing group scored 4.17 while the no internship group scored 2.9.

- The year three cogen group females scored more than the no internship group females. The cogen group scored 4.94 while the no internship group scored 3.16.
- The cogen group males scored more than the no internship group males for empirical. The cogen group scored 1.79 while the no internship group scored 0.76.
- The sharing group males scored more than the no internship group males for empirical. The sharing group scored 3.17 while the no internship group scored 0.76.

4.3.3 Framework Analysis

The cogen, sharing, and no internship framework analysis showed how the three groups improved their NOS views over the course of a year. The average combined score of cogen students was 6.65 for all three years, average combined score of sharing students was 8.85, and the average combined score for no internship students was 6.42 for all three years. All groups scored similar for all three dimensions and combined. The scores of all three groups by year is in Figure 4.3.3.1. When looked at based on each of the three dimensions, the sharing group scored more than the no internship group for dimension two: Nature of lines of scientific enquiry. These scores are included in Table 4.3.3.1.

Table 4.3.3.1. Cogen, sharing, and no internship average framework change scores by dimension.

Dimension	Cogen	Sharing	No Internship
Relationship between Knowledge Claims and Data	1.77	3.62	1.58
Nature of Lines of Scientific Enquiry	2.71	3.62	3.44
Social Dimension of Science	2.16	1.62	1.4

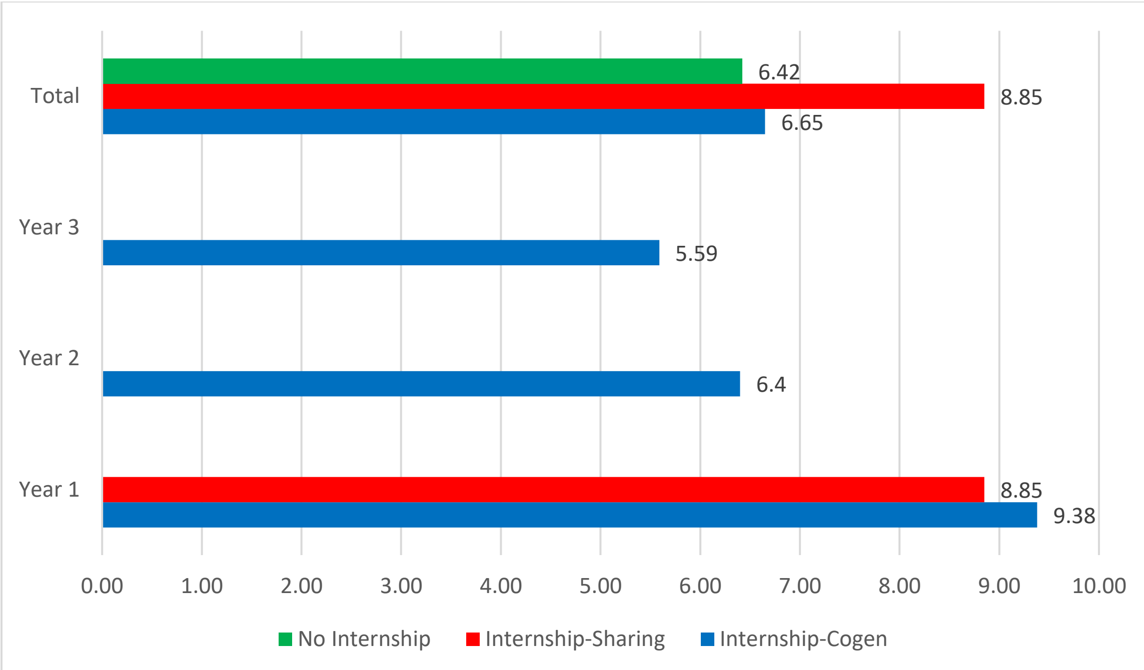

Figure 4.3.3.1. Cogen, sharing, and no internship framework average change scores by year. This figure illustrates the combined framework average change scores for cogen, sharing, and no internship students for all three program years.

Next, scores for each individual dimension were analyzed. First, the relationship between knowledge claims and data is analyzed in detail. The average change scores for cogen students was 1.77, sharing students was 3.62, and no internship students was 1.58. The year one sharing group scored more than the no internship control group. Table 4.3.3.2 shows the yearly average change scores for dimension one. When dimension one was looked at from the perspective of its subdimensions, the sharing group scored more than the no internship group for knowledge claims as description. Table 4.3.3.3 shows the average change scores for each subdimension of dimension one.

Table 4.3.3.2. Cogen, sharing, and no internship dimension one average change scores by year: Relationship between knowledge claims and data.

Year	Cogen	Sharing	No Internship
Year 1	1.54	3.62	
Year 2	1.7		

Year 3	1.93		
Year 1-3	1.77	3.62	1.58

Table 4.3.3.3. Cogen, sharing, and no internship dimension one average change scores by subdimension: Relationship between knowledge claims and data.

Subdimension	Cogen	Sharing	No Internship
Knowledge Claims as Description	0.9	1.77	0.48
Knowledge Claims as Provable	0.71	1.85	0.88
Knowledge Claims go Beyond the Data	0.16	0	0.21

Second, the nature of lines of scientific enquiry is analyzed in detail. The average change scores for cogen students was 2.71, sharing students was 3.62, and no internship students was 3.44. The year three cogen group scored less than the no internship control group. Table 4.3.3.4 shows the yearly average change scores for dimension two. When dimension two was looked at from the perspective of its subdimensions, all three groups scored similar for all subdimensions. Table 4.3.3.5 shows the average change scores for each subdimension of dimension two.

Table 4.3.3.4. Cogen, sharing, and no internship dimension two average change scores by year: Nature of lines of scientific enquiry.

Year	Cogen	Sharing	No Internship
Year 1	4.08	3.62	
Year 2	2.55		
Year 3	2.21		
Year 1-3	2.71	3.62	3.44

Table 4.3.3.5. Cogen, sharing, and no internship dimension two average change scores by subdimension: Nature of lines of scientific enquiry.

Subdimension	Cogen	Sharing	No Internship
Location in Individual Interests of Scientists	1.29	1.62	1.48
Internal Location in Epistemology of Discipline	0.76	1.38	1
External Location	0.66	0.62	0.96

Third, the social dimension of science is analyzed in detail. The average change scores for cogen students was 2.16, sharing students was 1.62, and no internship students was 1.4. The year

one cogen group scored more than the no internship control group. The year two cogen group scored more than the no internship control group. Table 4.3.3.6 shows the yearly average change scores for dimension three. When dimension three was looked at from the perspective of its subdimensions, all three groups of students scored similar for all subdimensions. Table 4.3.3.7 shows the average change scores for each subdimension of dimension three.

Table 4.3.3.6. Cogen, sharing, and no internship dimension three average change scores by year: Social dimension of science.

Year	Cogen	Sharing	No Internship
Year 1	3.77	1.62	
Year 2	4		
Year 3	1.45		
Year 1-3	2.16	1.62	1.4

Table 4.3.3.7. Cogen, sharing, and no internship dimension three average change scores by subdimension: Social dimension of science.

Subdimension	Cogen	Sharing	No Internship
Individualist View	0.42	0.38	0.12
Recognition of a Community of Scientists	1.4	1.23	1.06
Recognition of Institutions of Science	0.34	0	0.23

4.3.3.1 Framework Analysis Summary

Criteria for observed change was a difference of more than one from the corresponding no internship group score for each dimension. A difference of more than three from the corresponding no internship group score was used for the framework combined score since there are three dimensions combined.

Framework Analysis Combined Changes

- No change was observed.

Dimension One Changes (Relationship between Knowledge Claims and Data)

- The year one sharing group scored more than the no internship control group. The sharing group scored 3.62 while the no internship group scored 1.58.
- The sharing group scored more than the no internship group for knowledge claims as description. The sharing group scored 1.77 while the no internship group scored 0.48.

Dimension Two Changes (Nature of Lines of Scientific Enquiry)

- The year three cogen group scored less than the no internship control group. The cogen group scored 2.21 while the no internship group scored 3.44.

Dimension Three Changes (Social Dimension of Science)

- The year one cogen group scored more than the no internship control group. The cogen group scored 3.77 while the no internship group scored 1.4.
- The year two cogen group scored more than the no internship control group. The cogen group scored 4 while the no internship group scored 1.4.

4.3.4 Framework Gender Analysis

The next observation for the framework analysis for the cogen, sharing, and no internship paradigm is to take students' gender into account. The year one cogen group females scored more than the no internship group females. The sharing group females scored more than the no internship group females in year one. Figure 4.3.4.1 shows combined average change scores per year for female and male cogen, female and male sharing, and female and male no internship students. The cogen group males scored less than the no internship group males for nature of lines of scientific enquiry. The sharing group females scored more than the no internship group females for relationship between knowledge claims and data. Table 4.3.4.1 shows the individual framework dimension scores of females and males split into cogen, sharing, and no internship groups.

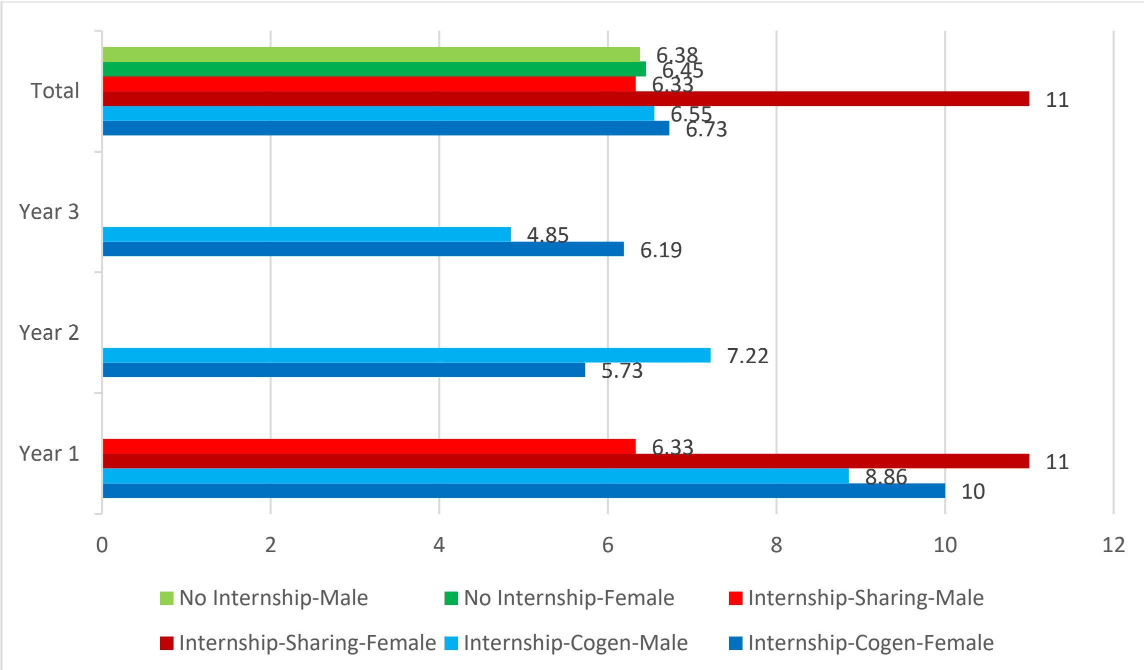

Figure 4.3.4.1 Male and female cogen, sharing, and no internship combined average change scores for framework analysis. This figure illustrates the average change scores for male and female cogen, sharing and no internship students for all three program years.

Table 4.3.4.1. Individual framework dimension average change scores of females and males split into cogen, sharing, and no internship groups.

Dimension	Cogen-Female	Cogen-Male	Sharing-Female	Sharing-Male	No Internship-Female	No Internship-Male
Relationship between knowledge claims and data	1.73	1.83	5.29	1.67	1.77	1.29
Nature of lines of scientific enquiry	2.97	2.41	4.14	3	3.32	3.62
Social dimension of science	2.03	2.31	1.57	1.67	1.35	1.48

In dimension one, relationship between knowledge claims and data, all three male and all three female groups scored similar for all three years. Table 4.3.4.2 shows male and female average change scores for dimension one by year and cogen, sharing, and no internship participation. When dimension one was looked at from the perspective of its subdimensions, the sharing group females scored more than the no internship group females for claims as description. The sharing group females scored more than the no internship group females for claims as provable. Table 4.3.4.3

shows average change scores of females and males split into cogen, sharing, and no internship groups by subdimension.

Table 4.3.4.2. Framework dimension one "Relationship between knowledge claims and data" average change scores of females and males split into cogen, sharing, and no internship groups by year.

Year	Cogen-Female	Cogen-Male	Sharing-Female	Sharing-Male	No Internship-Female	No Internship-Male
Year 1	1.83	1.29	2.71	0.83		
Year 2	1.36	2.11				
Year 3	1.94	1.92				
Year 1-3	1.73	1.83	2.71	0.83	1.77	1.29

Table 4.3.4.3. Framework dimension one "Relationship between knowledge claims and data" average change scores of females and males split into cogen, sharing, and no internship groups by subdimension.

Subdimension	Cogen-Female	Cogen-Male	Sharing-Female	Sharing-Male	No Internship-Female	No Internship-Male
Claims as Description	0.82	1	2.57	0.83	0.61	0.29
Claims as Provable	0.76	0.66	2.71	0.83	0.97	0.76
Claims Beyond the Data	0.15	0.17	0	0	0.19	0.24

In dimension two, nature of lines of scientific enquiry, the year one cogen group females scored more than the no internship group females. The year one-three cogen group males scored less than the no internship group males. The year two cogen group males scored less than the no internship group males. The year three cogen group males scored less than the no internship group males. Table 4.3.4.4 shows male and female average change scores for dimension two by year and cogen, sharing, and no internship participation. When dimension two was looked at from the perspective of its subdimensions, sharing group females scored more than the no internship group females on location in individual interests of scientists. Sharing group males scored more than the no internship group males for internal location in epistemology of discipline. Sharing group males scored less than the no internship group males for location in individual interests of scientists.

Table 4.3.4.5 shows average change scores of females and males split into cogen, sharing, and no internship groups by subdimension.

Table 4.3.4.4. Framework dimension two "Nature of lines of scientific enquiry" average change scores of females and males split into cogen, sharing, and no internship groups by year.

Year	Cogen-Female	Cogen-Male	Sharing-Female	Sharing-Male	No Internship-Female	No Internship-Male
Year 1	4.67	3.57	4.14	3		
Year 2	2.73	2.33				
Year 3	2.5	1.85				
Year 1-3	2.97	2.41	4.14	3	3.32	3.62

Table 4.3.4.5. Framework dimension two "Nature of lines of scientific enquiry" average change scores of females and males split into cogen, sharing, and no internship groups by subdimension.

Subdimension	Cogen-Female	Cogen-Male	Sharing-Female	Sharing-Male	No Internship-Female	No Internship-Male
Location in individual interests of scientists	1.39	1.17	2.86	0.17	1.39	1.62
Internal location in epistemology of discipline	0.88	0.62	0.71	2.17	0.97	1.05
External location	0.7	0.62	0.57	0.67	0.96	0.95

In dimension three, social dimension of science, the year one cogen group males scored more than the no internship group males. The year two cogen group males scored more than the no internship group males. The year one cogen group females scored more than the no internship group females. Table 4.3.4.6 shows male and female average change scores for dimension three by year and cogen, sharing, and no internship participation. When dimension three was looked at from the perspective of its subdimensions, all three groups scored similar for all three subdimensions. Table 4.3.4.7 shows average change scores of females and males split into cogen, sharing, and no internship groups by subdimension.

Table 4.3.4.6. Framework dimension three “Social dimension of science” average change scores of females and males split into cogen, sharing, and no internship groups by year.

Year	Cogen-Female	Cogen-Male	Sharing-Female	Sharing-Male	No Internship-Female	No Internship-Male
Year 1	3.5	4	1.57	1.67		
Year 2	1.64	2.78				
Year 3	1.75	1.08				
Year 1-3	2.03	2.31	1.57	1.67	1.35	1.48

Table 4.3.4.7. Framework dimension three “Social dimension of science” average change scores of females and males split into cogen, sharing, and no internship groups by subdimension.

Subdimension	Cogen-Female	Cogen-Male	Sharing-Female	Sharing-Male	No Internship-Female	No Internship-Male
Individualist view	0.27	0.59	0.0	0.83	0.00	0.29
Recognition of a community of scientists	1.61	1.17	1.57	0.83	1.16	0.9
Recognition of institutions of science	0.15	0.55	0.0	0.0	0.19	0.29

4.3.4.1 Framework Gender Analysis Summary

Criteria for observed change was a difference of more than one from the corresponding no internship group score for each dimension. A difference of more than three from the corresponding no internship group score was used for the framework combined score since there are three dimensions combined.

Framework Gender Analysis Combined Changes

- The year one cogen group females scored more than the no internship group females. The cogen group scored 10 while the no internship group scored 6.45.
- The sharing group females scored more than the no internship group females in year one. The sharing group scored 11.0 while the no internship group scored 6.45.

Dimension One Changes (Relationship between Knowledge Claims and Data)

- The sharing group females scored more than the no internship group females for claims as description. The sharing group scored 2.57 while the no internship group scored 0.61.
- The sharing group females scored more than the no internship group females for claims as provable. The sharing group scored 2.71 while the no internship group scored 0.97.

Dimension Two Changes (Nature of Lines of Scientific Enquiry)

- The year one cogen group females scored more than the no internship group females. The cogen group scored 4.67 while the no internship group scored 3.32.
- The year one-three cogen group males scored less than the no internship group males. The cogen group scored 2.41 while the no internship group scored 3.62.
- The year two cogen group males scored less than the no internship group males. The cogen group scored 2.33 while the no internship group scored 3.62.
- The year three cogen group males scored less than the no internship group males. The cogen group scored 1.85 while the no internship group scored 3.62.
- The sharing group females scored more than the no internship group females on location in individual interests of scientists. The sharing group scored 2.86 while the no internship group scored 1.39.
- The sharing group males scored more than the no internship group males for internal location in epistemology of discipline. The sharing group scored 2.17 while the no internship group scored 1.05.
- The sharing group males scored less than the no internship group males for location in individual interests of scientists. The sharing group scored 0.17 while the no internship group scored 1.62.

Dimension Three Changes (Social Dimension of Science)

- The year one cogen group males scored more than the no internship group males. The cogen group scored 4 while the no internship group scored 1.48.
- The year two cogen group males scored more than the no internship group males. The cogen group scored 2.78 while the no internship group scored 1.48.
- The year one cogen group females scored more than the no internship group females. The cogen group scored 3.5 while the no internship group scored 1.35.

Chapter 5: Discussion

5.1 Introduction

This analysis demonstrates some interesting trends. Understanding that this analysis is based on using numbers in qualitative research is important. The quasi-statistical nature of the results provides a means of quantitizing the data to demonstrate possible trends in student conceptual change resulting from the different interventions, without trying to ascribe significance to any finding. These findings help answer the broad questions about how internships and cogenerative dialogues impact students' NOS conceptual change. They also provide clues for future research on how to improve the use of cogen and conduct more in-depth research, resulting in a better understanding of how different variables impact NOS conceptualization.

Data analysis has shown that there are many examples of changes in NOS understanding within students in the program when compared to the no internship group students. There are several important trends that can be identified from these changes that can improve knowledge of the impact that science immersion internships have on NOS conceptual change. Across the analysis of the Q by Q and Framework analyses, there were numerous identified indications of change in NOS understanding between the internship groups and the control groups. When these indicators are aggregated by question or dimension, they can inform on how distinct factors within the study impact NOS change. As such, each question and dimension are examined to demonstrate its association with change, with the associated scores following in parentheses, ordered as such: internship score/control score, (example (XX/XX)). One point of clarification is that the sharing group sample only occurred in year one, so year two cogen group and year three cogen group are synonymous with year two internship group and year three internship group respectively.

5.2 Q by Q Discussion

For the combined Q by Q average, the year three internship group (23.1/17.76) and year three internship group females (23.06/17.06) scored more than the control groups. The key finding was that cogen groups scored more compared to the no internship group than the sharing students, who also participated in the internship. A possible explanation of these findings is that cogenerative dialogues were beneficial in improving participant's NOS understanding. According to Ryder et al. (1999), student's images of science are built on their experiences. Furthermore, "working among other scientists and students of science gives the student experiences which prompt discussions about science with others (external dialogue) and encourages the student to make sense of these experiences (internal dialogue)" (Ryder et al., 1999, p. 216). The difference between cogen and sharing, is that the participation in cogenerative dialogues provides additional focus on external dialogues with others in the scientific community. This additional support may have helped to increase cogen student's NOS views more than the sharing and no internship students.

5.2.1 Question One: How do scientists decide what questions to investigate?

Analysis of student understanding of the NOS concepts surrounding the question (How do scientists decide what questions to investigate?) resulted in some interesting data. Students who participated in cogen demonstrated more change as a group when compared to the control group. The year one cogen group (5.62/4.0), year three internship group (5.48/4.0), year one cogen group females (6.33/3.84), and year one-three cogen group males (5.66/4.29) scored more than the control group. Additionally, all the sharing groups demonstrated similar change to the control groups. One possible explanation for why the cogen students demonstrated more change for the question, is that they had to approach the decision of what investigation to pursue as a group. "Cogenerative dialogues make students roles as constitutive subjects of the activity systems

explicit, and with it their inevitable responsibilities toward the collective" (Stith & Roth, 2010, p. 369). It was from this communal understanding that the cogen students showed more change in their views of how scientists choose which questions to investigate.

When the question was examined based on its categories, there was an interesting finding. Both cogen group males (1.31/0.24) and sharing group males (1.5/0.24) demonstrated more change for the category of extending knowledge, while sharing group females (0.0/1.03) demonstrated less change. Ryder et al. (1999) found that participants in their study had increased their understanding of the need to gain more knowledge about the discipline due to working with scientists throughout the study. Meanwhile, de la Rubia et al. (2014) found that "Taiwanese male students were more inclined toward possessing constructivist-oriented VNOS…than the Taiwanese female students were" (p. 1704-1705). This presents some conflicting information, since extending knowledge with respect to deciding what questions to investigate is a positivist focused aspect, where the process leads the scientist to ask questions. Additional research on the interaction between NOS change and gender may be needed to clarify this finding.

5.2.2 Question Two: Why do scientists do experiments?

Analysis of student understanding of the NOS concepts surrounding the question (Why do scientists do experiments?) yielded several important findings. The cogen group females (1.39/0.19) scored more than the no internship group for the category of interest, the only incidence of any internship group scoring more than the no internship group on this question. The year one internship group (2.42/3.51), year one internship group males (1.92/3.33), year one sharing group (1.23/3.51), year one sharing group females (1.57/3.55), and year one sharing group males (0.83/3.33) all scored less than the control groups. These findings indicate that the sharing participant's NOS conceptualization did not stay similar to the cogen and control groups.

Additionally, the internship group scored less than the no internship group for the category of empirical, and the internship group and sharing group males scored less than the control groups for the category of utilitarian. According to Yacoubian and BouJaoude (2010), explicit and reflective methods of covering NOS concepts in research apprenticeships have led to higher levels of NOS understandings. This helps explain how the sharing group students scored less than the control and cogen groups. There was no explicit discussion as a group about why scientists do experiments for the sharing groups, while the cogen groups conducted reflective sessions and the control groups were in a traditional classroom environment. This is further supported by the cogen group females scoring more than the no internship group for the category of interest, demonstrating that explicit coverage of the NOS concepts did help improve NOS conceptualization.

5.2.3 Question Three: How can good scientific work be distinguished from bad scientific work?

Analysis of student understanding of the NOS concepts surrounding the question (How can good scientific work be distinguished from bad scientific work?) resulted in some conflicting results. The year two internship group males (5/3.67) and year three internship group females (4.81/3.35) scored more than the control groups. The year one cogen group (2.31/3.45), year one cogen group males (2/3.67), year two internship group females (1.27/3.35), and year three internship group males (2.62/3.67) scored less than the control groups. This variation in NOS conceptual change across the three years for the cogen groups results in an inability to draw a meaningful conclusion of whether cogenerative dialogues in a research internship setting are beneficial for improving student's abilities to distinguish between good and bad scientific work.

When the categories were examined, the sharing group (2.31/1.08) and sharing group males (2.83/0.9) scored more than the control groups for the category of quality of the work/results. An explanation for this emphasis on quality of work comes from Ryder et al. (1999). They found that

students discussed the importance of good experiments and results following immersion in scientific work where they focused on getting consistent data from their experiments. The sharing group answers demonstrate that they were involved in ongoing experiments where they worked to obtain reliable data and as a result they increased their understanding more than the other groups.

5.2.4 Question Four: Why do you think that some scientific work stands the test of time whereas other scientific work is forgotten?

Analysis of student understanding of the NOS concepts surrounding the question (Why do you think that some scientific work stands the test of time whereas other scientific work is forgotten?) demonstrated a trend. The year one internship group females (4.69/3.16), year one sharing group (5.46/3.71), year two internship group males (5.56/4.43), and year three internship group (4.86/3.71) all scored more than the control groups. The year one cogen group males (2/3.67) scored less than the control group. Next, the sharing group males (2.67/1.43) and cogen group females (1.36/0.35) scored more than the control groups for the category of coherent field. These findings are fairly evenly dispersed across cogen, sharing, and gender. An explanation for these findings is found in Ryder et al.'s (1999) study. Responses to the same question identified discussions with scientists and reviewing research literature about their projects as important factors in students gaining understandings about coherent development of a scientific field (Ryder et al., 1999). Internship participants reflected these findings which helps confirm that the science research internship helped them improve their understanding of the question (Why do you think that some scientific work stands the test of time whereas other scientific work is forgotten?) more than the control group.

5.2.5 Question Five: How are conflicts of ideas resolved in the scientific community?

Analysis of student understanding of the NOS concepts surrounding the question (How are conflicts of ideas resolved in the scientific community?) yielded several important findings. The

year one-three internship group (4.12/3.1), year one-three cogen group (4.29/3.1), and year one-three cogen group males (4.62/2.9) all scored more than the control groups. A possible explanation for these findings is that cogen played a role in participants gaining more understanding of the social construct of conflict resolution. In Ryder et al.'s (1999) study, they found little elaboration about social aspects of science, where the study focused on science research internships, without cogenerative dialogue. This points towards cogenerative dialogues being a key factor in participant's gaining more knowledge of social dynamics of conflict resolution in science.

5.3 Framework Discussion

For the combined framework average, year one internship group females (10.54/6.45), including both year one cogen group females (10/6.45) and year one sharing group females (11/6.45) scored more than the control group. These findings indicate that the year one female participants exhibited more improvement in the NOS conceptions than the second and third year participants. This lop-sided data makes it difficult to say there is a correlation between internship participation and improving NOS conceptualization. It does indicate that further research into science research internships is needed to provide clarity into their effects on NOS conceptual change.

5.3.1 Dimension One: Relationship between knowledge claims and data

Analysis of student understanding of the NOS concepts surrounding the dimension (Relationship between knowledge claims and data) showed a finding that correlated with previous studies. The year one sharing group (3.62/1.58) and year one internship group females (3.69/1.77) both scored more than the control groups. Additionally, the sharing group (1.77/0.48) and the sharing group females (2.57/0.61) scored more than the no internship group for the subdimension of knowledge claims as description, and the sharing group females (2.71/0.97) scored more than

the no internship group for the subdimension of knowledge claims as provable. A possible explanation for these findings is that there is a correlation between being in the sharing group and improving NOS concepts of knowledge claims as describable and provable. Ryder et al.'s (1999) study found that most of the participants in their study focused heavily on empirical evidence as the basis for proof. This shows that internship participation plays a role in participants gaining more understanding of the role of knowledge claims.

5.3.2 Dimension Two: Nature of lines of scientific enquiry

Analysis of student understanding of the NOS concepts surrounding the dimension (Nature of lines of scientific enquiry) resulted in some interesting data. The year one internship group females (4.38/3.32) and year one cogen group females (4.67/3.32) scored more than the control group, while the year one-three internship group males (2.51/3.62), year two internship group males (2.33/3.62), and year three internship group males (1.85/3.62) all scored less than the control groups. A possible explanation for why the male participants showed less change than the female participants can be found in the synthesis of Ryder et al.'s (1999) finding that students often placed a large emphasis on reliable data collection while conducting laboratory procedures, and de la Rubia et al.'s (2014) finding that male students were likely to have more improved views of constructivist based NOS. As such, the male students may have focused largely on improving their data collection during their hands-on lab work, and thus neglected discourse about the various factors that drive enquiry. This would explain why they did not demonstrate more change in understanding of nature of scientific enquiry.

Meanwhile, sharing group females (2.86/1.39) scored more than the no internship group on the subdimension of location in the individual interest of scientists, and sharing group males (2.17/1.05) scored more than the no internship group on internal location in the epistemology of

discipline. According to Ryder et al. (1999), "During interviews, it was clear that those students whose projects had involved working closely with professional scientists and research students had learned a great deal about the world of science, even though such issues were rarely discussed explicitly" (p. 216). They point out that explicit messaging does have drawbacks, including that the explicit messages can conflict with the implicit NOS messages that are learned through interactions (Ryder et al., 1999). When the performance of the sharing groups are compared to this information, it is clear that the sharing groups received clear implicit messages that improved their understanding of the nature of scientific enquiry, while the explicit messages from cogenerative dialogues may have conflicted with the implicit messages from the internship, that limited the knowledge gain for cogen students.

5.3.3 Dimension Three: Social dimension of science

Analysis of student understanding of the NOS concepts surrounding the dimension (Social dimension of science) resulted in some data that supported the role of cogen. The year one internship group (2.69/1.4), year one cogen group (3.77/1.4), and year two internship group (4/1.4) all scored more than the control groups. Tobin (2006), stated that a critical component of cogen, is finding resolutions for conflicts through collective discussion. When this is paired with Ryder et al.'s (1999) finding that "few [participants] elaborated on the ways in which scientists might interact" (p. 214), it shows that cogen plays an important role in helping improve participant's understanding of the social dimensions of science.

5.4 Implications for future research

On question one, (How do scientists decide what questions to investigate?), sharing group females (0/1.03) scored less than the no internship group for extending knowledge, and sharing group males (0.17/1.48), (0.5/1.76) scored less than the no internship group in the categories of

curiosity led and utilitarian. More research is needed to clarify if gender plays a role in determining what factors students focus that drive scientific investigations, such as extending knowledge, curiosity or utility, when in an internship without an external knowledge construct. Additional controls could be placed on the interview process to identify if gender stereotype confirmation is occurring during the interview process. Half of the participant sample could be interviewed by an interviewer of the same gender, while the other half are interviewed by an interviewer of the opposite gender, and interview responses could be compared to find if there are trends proving or disproving gender stereotype confirmation.

Cogen was not shown to affect students' NOS conceptual change more than the control for two dimensions of NOS (Relationship between knowledge claims and data; Nature of lines of scientific enquiry). This finding indicates that the cogen process could be improved for future studies. Sharing groups showed more change than the control groups in subdimensions of the lines of scientific enquiry dimension while the cogen groups scored similar to the control groups. This can possibly be attributed to communications conflicts between the implicit messaging from the internship, and explicit and reflective messaging from the cogen. Future research should provide additional scaffolds within the cogen process to ensure that the implicit messaging from the internship is acknowledged and expanded on during the process to better understand these NOS dimensions. Future research could also place emphasis on the institutional aspects of science in the cogen process. Providing explicit discussion and guiding questions for participants and instructors, of the roles institutions play in the research process (e.g., IRB, IACUC), can help instill a better understanding of the institutional aspects of science. It may also improve student's concepts of the differences between good and bad science.

5.4.1 Findings conflicting with other scholarly work

On question one, (How do scientists decide what questions to investigate?) it was shown that male students (cogen group males – 1.31/0.24; sharing group males – 1.5/0.24) demonstrated more change than the control groups while female students did not, for extending knowledge, which is based on positivist principles. This conflicts with findings from de la Rubia et al. (2014) where males demonstrated improved views of NOS when related to constructivist principles. On question five, (How are conflicts of ideas resolved in the scientific community?) the empirical category, which is based on positivist principles, stood out as both cogen group males (1.79/0.76) and sharing group males (3.17/0.76) scored more than the control groups, with all female groups scoring similar to the control groups. These findings identify an area for future research into how gender affects change in NOS views of positivist versus constructivist aspects.

5.5 Conclusion

The key takeaways from the two forms of analyses is in what they can reveal about student conceptions of NOS. The two overarching forms are: internship versus no internship, and cogen, sharing, and no internship provided some unique results. The internship versus no internship analysis provided insight into the effects of science inquiry internships on students' conceptions of NOS. The cogen, sharing, and no internship analysis provided insight into the differences that cogenerative dialogues and their explicit and reflective messaging had on participants' NOS conceptual change. The sample for sharing was small, so this analysis is limited in what can be inferred, while the cogen sample is larger and can provide more developed findings. The internship analysis provides some insight into trends, but the primary findings from this study are focused on the findings about the cogen group versus the no internship group.

The Work With A Scientist Program has shown that science research internships can be a successful means of improving particular aspects of NOS conceptualization in high school

students. An explicit and reflective approach based on communities of practice and cogenerative dialogues was a successful method for increasing participant's NOS conceptions of the social aspects of science and the relationship between knowledge claims and data. The social dimension of science was the NOS concept area from the framework analysis in which cogen participants showed the most improvement, due to internal and external discourse that leads them to improved understandings of how social interactions occur in science. Q by Q question five: (how are conflicts of ideas resolved in the scientific community?) was the question that showed the most change for cogen participants. Cogen participants demonstrated more change across the board, while Ryder et al. (1999) provided clear evidence to show that participation in the internship itself was not the cause for improving NOS views of scientific conflict resolution. The framework dimension of relationship between knowledge claims and data showed the most change for internship students. This was due to participation in the internship helping participants create a strong link between evidence and claims. Q by Q question four (why do you think that some scientific work stands the test of time whereas other scientific work is forgotten?) was the question that internship participants showed the most improvement of their NOS views due to the internship. The findings correlated with Ryder et al.'s (1999) findings that discussions with scientists and reviewing research literature about their projects was the main reason for why internship students improved their understanding of the reasons that scientific work stands the test of time.

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Vita

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I am an aspiring high school science teacher. I attended North Dakota State University in Fargo, ND where I received my B.S. in Emergency management in 2008. I was commissioned in the United States Army as a second lieutenant and held positions including tank platoon leader, operations planner, assistant operations officer, and detachment commander. While in the Army I attended several schools, including the Armor Officer Basic Officer Leaders Course and the Maneuver Captains Career Course, and relocated to El Paso, TX. I left the army at the rank of captain in 2015 to pursue my goal of becoming a high school science teacher. I enrolled in the Master of Arts in Education and the Alternative Teaching Certificate Program at the University of Texas at El Paso in 2015. During my master coursework, I co-wrote a conference paper with my thesis supervisor, Dr. Pei-Ling Hsu, that was peer reviewed and accepted for presentation at the 2017 Annual Meeting of the American Educational Research Association, AERA, San Antonio, TX. I am currently finishing my thesis and have passed both the Texas Science 7-12 content exam and the Professional Practice and Responsibilities exam and plan to begin teaching high school science this fall.

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This thesis was typed by Gabriel Hayes.