Perspectives on the Nature of Science from a Group of Students Attending Predominantly Hispanic West Texas High School

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PERSPECTIVES ON THE NATURE OF SCIENCE FROM A GROUP OF STUDENTS ATTENDING PREDOMINANTLY HISPANIC WEST TEXAS HIGH SCHOOL

CAMERON KING WILSON

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Dedication

Special thanks and love to Nicole Gergas and Austin Russell for giving me my inspiration in grandson Kayden Brendan Russell, as well as their love and support.

Special thanks to Michael and Dr. Josie Keffer for their lifetime friendship and support.

Special thanks to Dr. Donald and Sherry Collins for their enduring friendship and support.
PERSPECTIVES ON THE NATURE OF SCIENCE FROM A GROUP OF
STUDENTS ATTENDING PREDOMINANTLY HISPANIC WEST TEXAS
HIGH SCHOOL

by

CAMERON KING WILSON, Bachelor of Interdisciplinary Studies

THESIS

Presented to the Faculty of the Graduate School of
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for the Degree of

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Abstract

The United States is falling far behind the rest of the world in its ability to fulfill its needs for qualified workers in Science, Technology, Engineering, and Mathematics (STEM) fields. The Hispanic population is now the largest minority in the United States but is proportionally underrepresented in the STEM fields today. It is shown that students who have a good understanding of the Nature of Science (NOS) are far more likely to be interested in science which may lead to an interest in careers in STEM fields. There is very little if any research identifying Hispanic high school students’ view of the nature of science. Analyzing Hispanic high school students’ perception of the nature of science will increase the body of knowledge of Hispanic high school students.
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**Introduction**

In 1957, the Soviets union launched Sputnik. This event transformed the way the United States looked at education. In the decade to follow, the United States competing with the Soviet Union in the space race was able to supply the needed mathematicians, technicians, and scientists to the space program. This enabled the United States to land a man on the moon within 12 years. Recently there has been a steady down turn in the interest of students pursuing careers in Science, Technology, Engineering, and Mathematics (STEM) fields. The acronym STEM has been a buzzword in education for the last few decades. Among American youth interest in these fields is on the decline. This is causing United States to fall behind in relation to the rest of the developed world, “the World Economic Forum (2010) ranks the United States 48th in the quality of mathematics and science education” (Schmidt, Hardinge & Rokutani, 2012, p. 25). The science education system in the United States needs to change in order to produce the numbers of qualified individuals in STEM workforce. The United States is falling behind its ability to produce qualified workforce in order to meet the demand in Science, Technology, Engineering, and Mathematics, (STEM) fields. “…workforce projections indicate that the United States is not producing enough skilled workers to fulfill demand in STEM fields” (Wyss, 2013, p.54). The problem of young Americans not finding interest in these fields is not evenly divided among ethnicities.

Minority students are far behind majority students in acquiring degrees in STEM related fields. Blacks and Hispanics individuals remain underrepresented among college graduates in STEM fields as well as in the labor force (Riegle-Crumb, Moore & Ramos-Wada, 2011). In the 2009- 2010 school year only 8% of all certifications and degrees conferred in science, technology, engineering and mathematics were earned by Latinos (Hyman, 2012). This underrepresentation remains despite some of the recent research that has found that many educational disadvantaged minority students such as black and
Hispanic high school students do have similar or even greater interest in pursuing STEM majors in college in comparison to white students (Riegle-Crumb, 2011). There must be an underlying reason for the discrepancy between the numbers of Non-Hispanic White or majority students’ attainment of degrees in STEM fields and those for Hispanic students.

It is possible that Hispanic students have a different concept of the nature of science than majority students. Students’ understanding of the nature of science is an important dimension in science education. Not only is it important in developing scientifically literate citizenry but also has the potential to create an interest in science as a possible career field. Recently there has been an increasing interest in researching students’ understanding of the nature of science (Gobert, O’Dwyer, Horwitz, Buckley, Levy & Wilensky, 2011). By understanding students’ view of nature of science it is possible to develop curriculum and programs that enhances science education. When the students understand the culture of science it avails them the understanding of the nature of science, which can develop a positive image of science and an understanding of scientists (Guney & Seker, 2012). When students understand the nature of science they often find greater interest in science. Therefore, the nature of science has become an important aspect in science education. Hispanic students have a diverse racial, cultural, and linguistic background when compared to majority or other minority students.

Hispanics are the fastest-growing minority in the United States today. If educational trends remain the same Hispanics will remain disproportionately represented in STEM fields. This is not only a disservice to the Hispanic community but also has a negative effect on the country as a whole by missing out on the opportunity to tap into an abundant intellectual resource. Although there has been a large volume of research focusing on minorities in science, few of these studies specifically looked at Latina/o students (Peterson-Beeton, 2007). Currently there is little research on Hispanic high school students’ view of the nature of science. What is the Hispanic high school students’ unique perception of the nature of science? This paper intends to analyze a group Hispanic high school students’ response to a
specific set of questions in order to identify any unique viewpoint towards the nature of science held within the group of students. It’s extremely important to increase the body of knowledge concerning Hispanic high school students. Understanding students’ view of the nature of science is an important tool that can help in creating enhanced curriculum and can be used in developing programs help to further interest students in STEM education and pursuing STEM fields as a career.

1.1 STEM WORKFORCE IN THE UNITED STATES

The United States is falling behind in its ability to produce a workforce to fill the need in STEM careers. In 2012 Pres. Obama’s, President’s Council of Advisors on Science and Technology (PCAST) published a report, Engaged to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics, which stated that in the next decade our country will need over One million more STEM professionals in our workforce than what was previously estimated (Musante, 2012). Lest the current trend in the ability to produce STEM professionals is changed, the United States will have to import large quantities qualified workers from other countries in order to fill these positions. Colleges and universities all across the country are establishing, publishing, and announcing their goals and intentions for students learning goals both within and beyond STEM fields (Narum, 2008). Many college and universities have developed programs to promote interest in STEM careers. However, research producing an increasing body of evidence showing the importance of creating an interest at a much earlier age in students in regards with career choices. A reason for guiding young people’s interest at a younger age is the fact that too many today are straying off the path losing interest in science. Wyss (2013) states, “while research has shown that students are making decisions about their careers as early as middle school, students at this age may lack exposure to the career possibilities in STEM fields and therefore may not make decisions about career choices without accurate information” (Wyss, 2013, pp. 55-56). Although nine out of ten parents believe that their children will attend college, the fact is that only 41% of 18 to 24-year-olds enrolled in
college in 2009 (MetLife Foundation Afterschool Alert, 2011). Increasing teen students’ interest in future careers can have a major impact on their decision to seek a post-secondary education. Often physical science and technology are gateways that can lead to interest in engineering and mathematics. Many educators have seen the benefit of integrating the concepts of math and science as they help students experience real – world problems thus linking STEM fields and sparking interest early in students’ educational career (Brown, Brown, Reardon, Merrill, 2011). One of the changes currently being implemented through STEM education is the creation of a variety of activities that are designed to replace traditional lecture-based teaching strategies with more inquiry project-based approaches which more closely parallels the real-life work of scientists or engineers (Breiner, Harkness, Johnson & Koehler, 2012).

The United States is currently facing a tremendous problem by not being able to supply the country’s needs in STEM fields. It is up to the education system to find a way to direct students’ interests towards these careers. It is extremely important to find any way to help this essential task to be accomplished. Developing an understanding of how Hispanic students’ perceive the nature of science can help in developing programs and redesigning curriculum that can enhance these students’ interest which can lead to their success and may help funnel them towards STEM field careers.

1.2 SHORTAGE OF LATINOS IN STEM WORKFORCE AND EDUCATION

The consensus is that the nation is in a state of crisis concerning the economy and global competitiveness. This problem has a distinct effect on all segments of the population. In order to change this tide the United States needs to tap every resource available. One of the disproportionately underdeveloped intellectual resources is the Hispanic population. Why is this resource not being tapped? The number of Hispanics has grown in the United States four times faster than the total population rate between 2000 and 2010 (Hispanic Population Is Booming, 2011). Although the Hispanic population increases to grow at a rapid pace representation of Hispanics in the STEM workforce is
disproportionately low. With this increase in population an increase in the number of students entering STEM education and then seeking careers in STEM fields should have increased significantly. This increase is not taking place. In 2006, of all the students receiving bachelor’s degrees in science and engineering only 6% were Hispanic, which is nearly the same percentage as in 2000 (Cech, 2008). This shows that Hispanics are losing ground which translates directly into a disproportionate underrepresentation of Hispanics working in STEM career fields. Hispanic population has increased significantly while individuals entering into STEM education has remained static. Today the largest minority group in the nation are Hispanics comprising 14.8% of the total population or 44.3 million of the 300 million total population (Minority population tops 100 million: Nearly one in three U.S. residents is a minority, U.S. Census Bureau reports, 2007). The number of Hispanics entering STEM career fields should have increased by about four times the number as in 2000 instead of remaining the same. There may be a problem with Hispanic youths’ attitude towards science which may be reflected through their understanding of the nature of science.

The Hispanic community is a vital component in our country. There needs to be a way to tap this tremendous resource. Advancing the position of Hispanics is not only beneficial to the community but is also tremendously beneficial to the health of the entire country. It is important to increase the understanding about this segment of the population. By examining Hispanic high school students’ view of the nature of science it may be possible to develop an understanding of the reasons behind the apparent lack of interest in STEM fields.

1.3 The Importance of the Nature of Science in Education

An enduring goal in science education today is the development in students of some understanding of the nature of science (Rudolph, 2000). Understanding the nature of science (NOS) has become recently an important goal in science education. In the past, science has been taught as a rigid, static subject that is based on a fixed view of the scientific method. It has been found that scientific
knowledge is tentative (dynamic) yet reliable, it uses empirical evidence, inference and creativity to 
increase knowledge, also uses methods that often go beyond a formulaic “scientific method” as well as 
uses social interaction in the review process and support findings (Schussler, Bautista, Link-Perez, 
Solomon & Steinly, 2013). Scientific knowledge is ever changing as advances in technology and new 
ideas are always been developed.

The way scientists do their work often does not align with what has been traditionally taught in 
science education. Generally authentic science learning has been commonly thought of as students 
participating in activities that resemble those of scientists such as designing and conducting research, 
asking scientific questions, generating and testing hypothesis, and discussing results (Peker & Dolan, 
2012). When students identify science as being what they have learned in school they may lose interest 
in pursuing science any further. When students understand the culture of science it avails them the 
understanding of the nature of science which then can help develop a positive image of science as well 
as an understanding of scientists (Guney & Seker, 2012). As students develop a good understanding of 
the nature of science they have a far greater chance of sparking an interest in continuing in science 
education and possibly entering into science as a career field. Hispanic students often do not start on an 
even playing field.

A major issue facing Hispanic students is the issue of equality in science education (Bolshakova, 
Johnson & Czerniak, 2011). This may be a factor that pre-destines Hispanic students to lose interest in 
science due to their experience in school. Increasing the knowledge of Hispanic students’ view of the 
nature of science may help bring insight and assist educators in creating programs and curriculum to 
promote a positive attitude toward science as well as a better understanding of the nature of science.

1.4 LACK OF RESEARCH ON LATINO/A HIGH SCHOOL STUDENTS AND THE NATURE OF SCIENCE

Although there is a large body of research dealing with the nature of science, very little of it 
focuses on Hispanic high school students. In order to find the amount of research that exists in regards to 
Hispanic high school students and their view of the nature of science, the task of compiling the existing
research needed to be done. A very popular database that contains a great deal of research in the field of
education is the Educational Research Information Center or ERIC. Using ERIC in completing a
keyword search on the topic the Nature of Science starting with the key phrase, “nature of science”; this
term was entered within quotes in order to limit the search to the phrase instead of the individual words,
‘all databases’ was selected yielding a total of 9,677 hits. By adding a second word, “students” yielded a
total of 2,995 hits. Approximately 31% of the total 9,677 hits also contained the word students. Further
refined by adding a third word or topic, grade or school type as in “elementary school”, “middle school”,
“high school”, “college”, and “university” the total number of hits, 2,995 for students. All of the 2,995
articles that were found using the key phrase “nature of science” and keyword “students” were
accounted for using the third term of grade level. The breakdown of the division of articles according to
grade levels can be seen in Table 1.

Table 1 ERIC search results of the nature of science, students and grade

<table>
<thead>
<tr>
<th>Key words entered in category of “topic”</th>
<th>Hits</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Nature of science” and “students”</td>
<td>2,995</td>
<td>100%</td>
</tr>
<tr>
<td>“Nature of science” and “students” and “elementary school”</td>
<td>341</td>
<td>11.4%</td>
</tr>
<tr>
<td>“Nature of science” and “students” and “middle school”</td>
<td>197</td>
<td>6.6%</td>
</tr>
<tr>
<td>“Nature of science” and “students” and “high school”</td>
<td>533</td>
<td>17.8%</td>
</tr>
<tr>
<td>“Nature of science” and “students” and “college”</td>
<td>711</td>
<td>23.7%</td>
</tr>
<tr>
<td>“Nature of science” and “students” and “University”</td>
<td>1,213</td>
<td>40.5%</td>
</tr>
<tr>
<td>Total</td>
<td>2,995</td>
<td>100%</td>
</tr>
</tbody>
</table>

This process was repeated this time focusing on “nature of science”, “students” and “high school” then
adding a fourth term or topic that relates to ethnicity or nationality. Based on the 533 hits found for
“nature of science” and “high school”, as seen in Table 1, the culture, ethnicity or nationality was
examined through the fourth keyword. Starting with “majority” and “minority” as the fourth keyword
and then continuing with the most prominent ethnicities found in the United States. World regions were
examined followed by a cross-section of the nationalities accounting for 430 hits 80.7% of the 533 total.
The 103 or 19.7% remaining articles contained no known reference to ethnicity, culture, world region or
nationality. This process yielded a reasonable breakdown of the research along the cultural, ethnic and nationality lines. These results are shown in Table 2.

Table 2 ERIC search results of the nature of science, students, culture, ethnicity or nationality.

<table>
<thead>
<tr>
<th>Key words entered in the category of “Topic”</th>
<th>Hits</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Nature of science” and “students” and “high school”</td>
<td>533</td>
<td>100%</td>
</tr>
<tr>
<td>“Nature of science” and “students” and “high school” and “majority”</td>
<td>76</td>
<td>14.26%</td>
</tr>
<tr>
<td>“Nature of science” and “students” and “high school” and “minority”</td>
<td>9</td>
<td>1.69%</td>
</tr>
<tr>
<td>“Nature of science” and “students” and “high school” and “White Non-Hispanic”</td>
<td>20</td>
<td>3.75%</td>
</tr>
<tr>
<td>“Nature of science” and “students” and “high school” and “African-American”</td>
<td>18</td>
<td>3.38%</td>
</tr>
<tr>
<td>“Nature of science” and “students” and “high school” and “Asian American”</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>“Nature of science” and “students” and “high school” and “Latino American” or “Hispanic American” or “Mexican American”</td>
<td>2</td>
<td>0.38%</td>
</tr>
<tr>
<td>“Nature of science” and “students” and “high school” and “Asian”</td>
<td>2</td>
<td>0.38%</td>
</tr>
<tr>
<td>“Nature of science” and “students” and “high school” and “European”</td>
<td>3</td>
<td>0.56%</td>
</tr>
<tr>
<td>“Nature of science” and “students” and “high school” and “Eastern European”</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>“Nature of science” and “students” and “high school” and “American”</td>
<td>91</td>
<td>17.1%</td>
</tr>
<tr>
<td>“Nature of science” and “students” and “high school” and “Latin America”</td>
<td>1</td>
<td>0.19%</td>
</tr>
<tr>
<td>“Nature of science” and “students” and “high school” and “Australian”</td>
<td>4</td>
<td>0.75%</td>
</tr>
<tr>
<td>“Nature of science” and “students” and “high school” and “Africa” or “African”</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>“Nature of science” and “students” and “high school” and “Zimbabwe”</td>
<td>1</td>
<td>0.19%</td>
</tr>
<tr>
<td>“Nature of science” and “students” and “high school” and “British” or “English”</td>
<td>192</td>
<td>36%</td>
</tr>
<tr>
<td>“Nature of science” and “students” and “high school” and “Taiwanese”</td>
<td>2</td>
<td>0.38%</td>
</tr>
<tr>
<td>“Nature of science” and “students” and “high school” and “Chinese”</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>“Nature of science” and “students” and “high school” and “Polish”</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>“Nature of science” and “students” and “high school” and “Russian”</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>“Nature of science” and “students” and “high school” and “Israeli”</td>
<td>8</td>
<td>1.5%</td>
</tr>
<tr>
<td>“Nature of science” and “students” and “high school” and “Middle Eastern”</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>“Nature of science” and “students” and “high school” and “Turkish”</td>
<td>1</td>
<td>0.19%</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td><strong>430</strong></td>
<td><strong>80.7%</strong></td>
</tr>
<tr>
<td>“Nature of science” and “students” and “high school” and other</td>
<td>103</td>
<td>19.3%</td>
</tr>
<tr>
<td><em>(These articles contained no known reference to culture, ethnicity or nationality)</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>533</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

Performing this keyword search yielded only 2 articles or 0.38% of the total 533 articles that contained either “Latino American”, “Hispanic American” or “Mexican American” as the fourth topic. Therefore it can be concluded that research on Hispanic high school students’ view of the nature of science is very limited. This research could have great value to the science education community by increasing the knowledge of Hispanic high school students.


## Literature Review

### 2.1 “Nature of Science” in Science Education

In 1996, the National Science Education Standards (NSES) were introduced. This turned the focus of science education leaders’ attention towards ways to enable teachers to construct understanding of the science of nature (NOS) for both teachers and for their students (Spector, Burkett & Leard, 2012). Before teachers are able to adequately teach NOS they themselves must first develop their own understanding. Currently major reform efforts in science education are revealing a strong agreement in the importance of enhancing students’ conceptions of NOS. It has been stated, “in fact, ‘the longevity of this educational objective has been surpassed only by the longevity of the students' inability to articulate the meaning of the phrase ‘nature of science’ and to delineate the associated characteristics of science’” (Lederman, Lederman & Antink, 2013, p. 139). Students are not adequately able to grasp an understanding of the nature of science as science is currently taught. The National Research Council (NRC) states that inquiry-based instruction along with explicit teaching of nature of science are important components in the United States’ reform-based science teaching and by combining the two promote scientific literacy and can potentially improve both students’ engagement in science as well as their achievement (Capps & Crawford, 2013). These researchers continue to warn that current classroom teachers have little opportunity of participating in science inquiry and that even highly qualified teachers often have limited knowledge of NOS. Currently there are very few qualified teachers that have the ability and training to fully understand NOS, which renders them incapable of developing an understanding in their students (Capps & Crawford, 2013). It has been found that by combining instructional approaches has the potential for reaching diverse students in science as ‘multicultural inquiry’ used to create a culturally congruent practice involving students in inquiry in the context of authentic science activity to demystify NOS as well as the deeper set of cultural notions students have about science (Myers, Capps, Crawford & Ross, 2012). By developing ways to include students’
cultural background into science education a positive attitude towards NOS can be developed.

2.1.1 **Definition of “Nature of Science”**

In review of the literature in regards to the nature of science it is found that there is not one set definition. One group of researchers identified the nature of science as scientific data, scientific behavior, and probably the most important dimension, the way information is gathered along with the phases of the scientific method. In order to experience the process an individual must have some skills known as science process skills (SPS). These skills consist of the ability to observe, classify, measure, setting correlations of a number of spaces, predict, organizing data, formulate models, interpret, identify variables, formulate hypothesis and experiment (Feyzioğlu, Akyıldız, Demırdag & Altun, 2012). This understanding is quite similar to the traditional view of science in general. Yacoubian and BouJaoude state, “the nature of science (NOS) includes understanding and appreciating the nature of construction and validation of scientific knowledge, the work of scientists, processes of science, and sociology of science” (Yacoubian & BouJaoude, 2010, p. 1229). Though not a true definition this conveys some idea of what is the nature of science. Another group of researchers point out a unique aspect to the nature of science by stating, “Values and underlying assumptions that are intrinsic to scientific knowledge, including the influences and limitations that result from science as being a human endeavor” (Ozgelen, Yılmaz-Tuzun & Hanuscin, p. 1552). This view of the nature of science is a much more philosophical and points out that science is done by scientists who are human beings and are not immune to the quirks and shortfalls of this creature. It has even been stated that there are competing views of the nature of science within the education community. There is a hope that one view may be settled upon. This view would be more authentic or be reasonably abstracted from the various interpretations and be able to be incorporated into curriculum. But in light of increasing understanding of science it appears to be increasingly undoable (Rudolph, 2000). The varying definitions and wide range of understanding of the nature of science make it very difficult to create a one size fits all method of increasing students
understanding of NOS. Capps and Crawford (2013) state the nature of scientific knowledge as understanding of science as a way of knowing and describe a set of seven aspects of NOS, identified as (a-g), which are based in historic, philosophical, and sociological studies, “these aspects include the following: scientific knowledge (a) is tentative, (b) is partially subjective (i.e. theory laden), (c) relies on and empirical basis, (d) is creative, (e) is socially and culturally embedded, (f) is based upon observation and inferences, and (g) theories and laws are different forms of scientific knowledge” (Capps & Crawford 2013, p. 1950). As seen in this view of the nature of science is dynamic, not set in stone, which makes it extremely difficult to narrow down to one specific definition. Rudolph states that there is a real problem in sorting through the competing and sometimes conflicting views of NOS (Rudolph, 2000). With the differing views held today in the science education community agreeing on a specific definition is a definite problem. Donnelly and Argyle (2011) have created a set of six aspects, which are very similar to the previously presented aspects but have expanded the explanation of each:

- Scientific knowledge is tentative but durable. Such as, scientific explanations are likely to change with the addition of new evidence or the reinterpretation of prior evidence.
- Scientific knowledge is partially based on human imagination and creativity. Data do not interpret themselves: scientists use their creative metaphors and imagination to make sense of the empirical world and to develop future research questions.
- Scientific knowledge is empirically-based.
- Scientists make observation and inferences from those observations to generate scientific knowledge.
- Scientific knowledge is theory-laden and subjective. Scientists are always viewing the world through the lens of current scientific paradigms and personal conceptions of the world.
- Law describes patterns or irregularities in data while theories are explanatory (Donnelly
These expanded aspects give a clearer picture of what the nature of science is, while representing just how difficult it is for individuals to fully understand. As philosophers, historians, sociologists, and scientists discuss the nature of science no single view of science which can be used to understand the wide range of scientific activities (Ryder, Leach & Driver, 1999). All individuals have some concept of the nature of science even though it may be naïve, incorrect or underdeveloped.

There are multiple definitions of the nature of science. For this study certain aspects of the nature of science were examined. The definitions for these aspects are as follows. Empirical: scientific claims are made by observation of nature although it is through the lens of the human experience. Inferential: statements are made on the unseen by examining the effects. Creativity: generating scientific lot knowledge requires imagination. Theory/law: science incorporates hypothesis, theories and law but one does not lead to the other, each stands alone. Tentative: scientific knowledge is durable and reliable it is not absolute and it is subject to change. Social dimension of science: scientific knowledge can be socially negotiated through established venues of communication and criticism. An example is through the peer review process of scientific journal entries. These are the definitions used in evaluating the questions used in this study.

2.1.2 DEVELOPING A PROFILE OF THE NATURE OF SCIENCE

Everyone has a profile of images of science that has been developed without conscious attempt, which has been constructed informally through a wide range of experiences of science (Ryder, Leach & Driver, 1999). Every student has an understanding of NOS, though it may be naïve or inaccurate. Students’ image of the nature of science are developed through their experience of science through exposure in school, as being depicted in the media, through documentaries, scientific news stories, exposure to informal science education such as Museum exhibits and also cultural knowledge acquired
at home and in the community. Informal settings may include natural physical sites (e.g., forest and beaches) and can include human enhanced settings (e.g., nature center preservatives) human made locations can also be venues (e.g. fishing wharfs, industrial settings, or theme parks) also places that were specifically designed for the education of the public such as museums, aquariums, zoos, libraries, botanical gardens and other natural settings outside of classroom (Spector, 2012). These experiences have worked together to unconsciously create a unique image of science or nature of science profile. This unique image is the individual’s profile and will guide an individual and their interaction within and without a science community as they discuss specific scientific context. In order to identify this profile researchers have established or created analysis frameworks.

2.1.3 FRAMEWORKS OF ANALYSIS ON NATURE OF SCIENCE

This thesis focuses on approaches that analyze participants’ interviews. Research for the nature of science utilizes many different approaches. Three different studies will be examined in this chapter, first Ryder, Leach, and driver (1999), second Khishfe (2012), and third Donnelly & Argyle (2011). In each of the following studies the primary source of data was either through participant interview or questionnaires with open ended questions were participants responded in their own words. These studies provided a guideline for creating a framework for analysis used in this thesis.

First, Ryder, Leach, and Driver (1999) analysis framework: all students’ responses were analyzed on a question-by-question basis. The initial framework involved creating categories of responses, identified through the analysis and tabulated; results were incorporated into tables identifying the number of students which made statements that were in line with the category types. Through this analysis epistemological and sociological positions reoccurred within the categories of responses. One table contains categories of extending knowledge; another table contains categories of coherence in the field. The first contains categories of responses in regards to the question, “How do scientists decide which question to investigate” (Ryder, Leach & Driver 1999, p. 205)? These categories are curiosity led,
extending knowledge, utilitarian, and financial benefits. Categories of coherent field in regards to the question; “Why do you think that some scientific work stands the test of time whereas other scientific work is forgotten” (Ryder, Leach & Driver 1999, p. 205)? These categories are revolutionary, coherent field; inherit quality of work, utilitarian and untestable. The categories of responses are described by a short sentence following the description. An example: curiosity led followed by the statement; ‘Investigative questions scientists choose are based on those which they are personally curious about.’

The second aspect of the analysis was created in an attempt to develop a framework that categorizes the fundamental issues running through the conversation with the students. The final framework focuses on three aspects of the nature of science and divided into sections A, B, and C. Section A, deals with scientific knowledge and its relation to data. Section B addresses the way scientific inquiry is followed by scientists, the coherent lines either by individual or within a community. Section C focuses on the social dimension of science as students discuss science as collaboration and institutionally regulated activity. By using this system the authors were able create a profile of the students understanding of NOS. Other researchers have developed other methods in order to develop a similar profile.

Second, Khishfe’s (2012) research article investigates the relationship between nature of science and argumentation with no intervention involved. The paper is mixed methods research that incorporated surveys, which had two scenarios, which were designed to create a dialogue concerning controversial socio-scientific issues, genetically modified food and fluoridation of water. Also, interviews were used to examine students understanding of the nature of science in more detail. Eight questions were used in the questionnaire and in the follow-up interviews: “(a) as a scientist, would you vote for adding fluoride to drinking water in your city (Khishfe, 2012, p.497)? The purpose of this question is to have students make a decision. “(b) explain and justify your decision” (Khishfe, 2012, p.497). The purpose of this question is to find out about students’ skills in generating arguments. “(c) another scientist, Prof. Ponso, disagrees with your position. How could he explain his position to
illustrate the reason supporting it and convince you (Khishfe, 2012, p.497)? The purpose of this question is to find out about students’ skills in generating counterarguments. “(d) what would you reply to Prof. Ponso to explain that your position is right” (Khishfe, 2012, p.497)? This question was to find out about students’ skills in generating rebuttals. “(e) how can you explain that scientists reach different conclusions even though scientists were all looking at the same data about this effects of water fluoridation” (Khishfe, 2012 p.497)? This question was intended to assist students’ view about the subjective aspect of the nature of science. “(f) do you think the knowledge about water fluoridation might change in the future? Explain why or why not” (Khishfe, 2012, p.497). This question was designed to assess students’ view about the tentative and empirical aspect of the nature of science. “(g) as a scientist, do you think you might change your decision in the future? explain why or why not” (Khishfe, 2012, p.497). This question as well as the final question, is also related to assessing students view about the tentative and empirical aspect of the nature of science. “(h) is there anything else you would want to know about this issue that might help you decide or even change your decision” (Khishfe, 2012, p.497)? The student’s responses were categorized into three levels of understanding, naïve, intermediate, and informed. Points were assigned to each category one point for naïve: no justification or invalid justification, two points for intermediate: valid justification supported by one reason, and three points for informed: valid justification supported by more than one reason. Students’ responses were categorized as naïve when they did not exhibit any informed view of the target aspect of nature of science or their view misaligns with the contemporary view of the nature of science. An intermediate view may contain some co-existing fragmented views that sometimes is contradictory, an example that is given for the intermediate view was where a participant in response to question (e) stated that different scientists might come to different conclusions due to differences in opinions. An informed view is that which corresponds to the contemporary view of the nature of science. The nature of science was looked at with three aspects, subjective, tentative, and empirical. The score for the participants was
coded in regards to the aspects of nature of science (subjective, tentative, and empirical) as well as the responses of argumentation (argument, counterargument, and rebuttal) using tables and the quantitative aspect of this study was done through correlation and chi-square tests. Other researchers developed yet another approach.

Third, Donnelly & Argyle (2011) study focused on preservice teachers attending a professional development session and contained a pre-and post-survey. The View of Nature of Science (VNOS) questionnaires were open-ended written surveys. Though the surveys did not allow for open dialogue the analysis and coding could be used with interviews. The coding for the responses to the questions in the questionnaires are as follows: tentative, empirical, indirect evidence, theories/law, creativity, and subjectivity. The criteria for the coding as being adequate responses are as follows:

Tentative: Scientific knowledge changes with new data, new technology, or interpretation of old data. Scientific knowledge is not ‘proven’. Empirical: Scientific knowledge is testable, based on data, ‘facts,’ evidence, observations. Indirect evidence: Scientists make inferences, construct categories, and use indirect evidence. Theories/law: Theories are evidence-based explanations of data; laws are evidence-based patterns of regularities of data. Theories do not become laws. Creativity: Scientists use creativity before (developing questions, designing procedures) and after (interpreting data) data collection. Subjectivity: Scientists interpret data differently given their background knowledge, theoretical framework, and personal inclinations (Donnelly & Argyle, 2011, p. 483).

The responses to the questions were identified as either adequate or inadequate in regards to the categories listed above. This information was compared between the pre-and post-questionnaires identifying changes from inadequate to adequate in participants understanding. This framework could be easily adapted to a one-time interview format identifying participants’ adequate or inadequate understanding of the nature of science.
2.2 **Social Representation and the Nature of Science**

Thornburg (2010) states in regards to social representation, “Any interaction, between individuals as well as a group, presupposed social representations (i.e., shared meanings), which enables the individual to understand the various aspects of their social reality, to make sense of the world and communicate that sense to each other” (Thornburg, 2010). Social representations can be thought of as common sense knowledge of language, values, images, ideals as well as a script for action, which are shared, to an extent, by members of a particular social group (Orr, Assor & Cairns, 1996). These social representations can be thought of the way an individual creates an understanding of a particular object or concept within a particular social environment through observation and interaction. Social representations are the midpoint of social, affective, and cognitive aspects of an interpretive framework. Social representations are made up of beliefs and opinions organized that give core meaning to an object (Simonneaux & Simonneau, 2009). There are two dimensions to social representation. The first is where individuals establish an order and orient themselves in their material and social world. The second is the communication which takes place within the community among the members which provides codes for social exchange and codes for naming and classifying the world as well as other individuals along with group history (Ivinson & Duveen, 2005). Individuals develop social representation through questioning and interpreting information themselves as well as through discussing with other members of the community (Ryder, Leach & Driver 1999). Social representations are a means for developing an individual profile of understanding the nature of science. Students create an image of science through their interaction and discourse within their particular science community and this understanding grows regularly and spontaneously (Ryder, Leach & Driver 1999). A key aspect to the concept of representation is the understanding of the difference between the specialized area of knowledge itself and people’s representation of that knowledge. Representations can be looked at as those concepts, values, ideas and commitments which give people the ability to think about issues that are unfamiliar.
and allow the individual to communicate these thoughts within a community. Representations are what control individual and group attitudes and activities. There are two social aspects to representations. First they are shared, developed and unified within the community. Second they are either held unchanged or they change together within the community. An aspect of representation on an individual basis is the fact that there are two distinct dialogues to take place within an individual, internal dialogue where an individual questions and interprets information themselves and external dialogue where individuals discuss within the community. The main purpose of this dialogue is to connect unfamiliar area of knowledge with that which is familiar to either individual or within the community. It has been stated that the theory of social representation’s main function should be in explaining and describing the ways cognition of individuals, which is encapsulated within their brains, enables them to function as socially interacting human beings (Orr, Assor & Cairns, 1996). Social representation is a way of explaining how an individual subconsciously makes connections between previous experiences or previously discussed subjects with new and unfamiliar subjects in order for them to make sense. Social representation within an individual may have two completely different identities. First is the socio-professional identity which is created within the community such as science education. Second is that national or cultural identity which is created within the community where individuals live (Lopez-Facal & Jimenez-Aleixandre, 2009). These two identities can either enhance each other or they can conflict with each other. For example: a Hispanic student may have a dominant Catholic background where the concept of evolution contradicts their cultural beliefs. The conflict lies between what empirical evidence shows with the belief system held within their culture. It is possible that through interaction lower-status social economic individuals can become motivated to take on the ideas of the high-status majority in order to enable upward mobility (Orr, Assor & Cairns, 1996). Individuals may be forced to go against their ingrained beliefs in order to climb the rungs of the ladder out of the pit of poverty in order to achieve individual success. Social ideas are not a single discrete unit but are actually more of a
collection of interconnected ideas whose meaning has been developed through interrelationships (Orr, Assor & Cairns, 1996). This is especially true within the Hispanic community due to the strong almost unbreakable family bonds. Social representation can be an important tool in analyzing responses to specific questions. This study intends to use aspects of social representation as a tool in analyzing interviews and questionnaires of the participants.

The nature of science is a very important aspect of science education. Students’ ability to fully understand the nature of science can not only help in their success in science education but also has the potential to inspire students and science careers. It is difficult to find a single definition for the nature of science. It is too complex and fluid in nature as understanding is ever changing. Social representation is an important tool that can aid in developing an understanding of a particular individual or groups science profile. By examining individuals through in-person interviews and questionnaires and analyzing using a framework it is possible to create profile of their understanding of the nature of science. This thesis intends to use an analysis framework similar to the afore mentioned methods to analyze a predominantly Hispanic American group of students attending an El Paso area high school to create a profile of this unique group of students understanding of NOS.

2.3 LATINOS/AS AND SCIENCE

Understanding Latinos/as students experience in science is critical. As Meyer and Crawford (2011) point out, “Without directing greater attention to students’ actual experience in school science and how science may or may not align with students’ diverse racial, cultural, and linguistic backgrounds and understandings, these student groups will remain underrepresented in the sciences” (Meyer & Crawford, 2011, p.530). There needs to be a closer look to see how science education can address the differences in Latino students’ backgrounds in order to increase these students representation in science fields. A disturbing fact is; “Latino students, on the average, begin school far behind their non-Hispanic peers, and these gaps and skill have not been closed by any of the existing programs interventions or
reforms reported in the literature to date” (Gandara, 2006, p.234). According to Irizarry and Raible, “the educational status of Latinos remains dire, as measured by traditional indicators of its easement such as high school completion, grade point average, and college attendance, suggesting that schools have grossly underserved this group of students” (Irizarry & Raible, 2011, p. 187). The current school system is not addressing the needs of Latino students. Aguirre, citing her own experience, “although the attrition rate of Latino/as in math and science at the college level is cause for concern, even more students are lost before college starts” (Aguirre, 2009, p.701). In order to address the low representation of students in STEM fields, intervention needs to happen before college. Hispanic students often do not begin school had an equal level compared to non-Hispanic students.

Large percentage of the population on the border is either immigrants or first-generation Americans and often struggle with low socioeconomic situations. Hispanic students not entering school on an equal level is a serious issue that may come from the fact that many of these students come from low income households with parents that may have low levels of education (Bolshakova, Johnson & Czerniak, 2011). There are number of reasons that the Latino community experience under achievement in school which can include poverty, language barrier, cultural discontinuities between school and home, racism and classism (Irizarry & Raible, 2011).

An overwhelming amount of evidence shows that a positive attitude towards science is a prerequisite for students considering science careers this is particularly important in regards to Hispanics who may be discouraged from science careers by societal pressures such as racism (Sorge, Newsom & Hagerty 2000). Evidence shows that it is important for students to have a positive attitude toward science if they are to be interested in pursuing a science field, this is especially important for Hispanic students who may suffer the effect of racism and/or classism. Many Hispanic students are not aware of the wide diversity of fields that can be pursued through STEM. Aguirre states, “before coming to college, I didn’t realize that a clever of careers in math and science exist beyond medicine and basic
science research, and so the range of career opportunities never occurred to me” (Aguirre, 2009, p.701). All these factors combine to give Hispanic high school students in El Paso Texas a unique perspective of the nature of science.

2.4 LATINOS/AS AND CULTURE

Every individual has cultural values and scripts. These are developed through interaction with immediate family and community as the individual grows up. These cultural values and scripts have a major impact on how individuals think and behave. In this section nine particular cultural values and scripts which have been identified as relating to the Hispanic community will be presented, defined and discussed in regards to how these may manifest in certain situations. The ten cultural values and scripts that will be discussed in this section are Collectivism, Simpatía, Personalismo, Respeto, Familismo, Religiosidad, or Religiosity, Marianismo, Hembrismo and Machismo. The first six cultural values and scripts are not gender sensitive. These can be held equally by either male or female. The last three cultural values and scripts are distinctly gender sensitive and are held specifically by either male or female.

Collectivism is the idea that all work together as one. It is defined as holding accomplishments as being dependent on others. Individuals look at it achievement as being interdependent within the group as opposed to looking at individual achievement. Collaboration is for the benefit of the entire group (Ruiz, 2009). Working in cooperation holds more value than individual competition. Hispanics in the United States tend to be group oriented as well as collectivistic (Rinderle & Montoya, 2008). A possible manifestation of this value would be where an individual would sacrifice their goals for the goals of the entire group.

Simpatía can be described as an individual holding a permanent personal quality where an individual is thought of as being likable, attractive, as well as easy going and fun to be with. Individuals would value holding the ability to maintain positive and harmonious relationships. An individual with
this value would have respect for others, empathy for their feelings and would treat them with respect and dignity (Ruiz, 2009). Behaviors such as criticizing, confronting, or bossing others around, along with using a demeaning manner in speaking to others would be contradictory to this value. This is a key Hispanic cultural value where a great deal of value is placed on respect, politeness towards others, harmonious, smooth and pleasant relationships as opposed to interpersonal conflict and confrontation (Jeong, Lucero-Liu, Gamble, Taylor, Christensen & Modry-mandell, 2008). This value may manifest in the heightened loyalty, dignity towards others, along with admiration for others accomplishments as well is making an extra effort and avoiding any kind of conflict or confrontation.

Personalismo is the appreciation of others individual uniqueness and sense of worth. This focuses on individuals inner qualities giving them value and a sense of self-worth regardless of material wealth (Ruiz, 2009). Individuals put greater value in the others uniqueness and inner qualities over and individuals economic success. This gives importance to having smooth interpersonal relationships through warm and friendly personal interactions (Torres, 2009). An individual having this value appreciates warm and honest interaction with others regardless of their station. It is the importance that Hispanics place on personal goodness and getting along with others putting in great value on personal character and inner qualities but may incorporate a preference for people within the same ethnic group (Ayón & Aisenberg, 2010). It is putting a greater importance of who a person is over what a person does or their position. An example of how this may manifest would be for an individual to derive far greater importance from a conversation during a meal than by having the other individual pick up the tab for that meal.

Respeto is the value held by being respected by others especially those of authority (Ruiz, 2009). Those with this value would give respect to those of authority especially but not limited to within the family. This value is taught at a young age where the emphasis of obedience which dictates the children should be highly inconsiderate of adults and as adults this gives Hispanics the understanding of what
level of courtesy and decorum which is required in any given situation with relation to others of particular age, sex and social status. This value can ultimately serve as a way of maintaining harmony within community (Calzeda, Fernandez & Cortez, 2010). It is respect and admiration awarded to an individual for their position including family members. Individual would suppress and discourage negative feelings towards parents and extended family members, especially those of authority (Morgan, Consoli & Llamas, 2013). Individuals with this value would be always mindful of their responsibilities to their families as well as to those in authority within society. The manifestation of this value could be that an individual may also hold a great deal of respect for someone that is highly educated or has a very respectful position.

Familismo is a value that holds the family as fundamental and that it takes precedence over the needs of the individual (Morgan, Consoli & Llamas, 2013). The family is held as being the supreme focus of responsibility for individuals the needs of the family come before the needs of the individual. There is a strong sense of loyalty, solidarity and mutuality that can be seen in three ways. “(1) feeling obligated to perform for the material and emotional support of family members; (2) relying on family for help and support; and (3) viewing family members as role models of behavior and attitudes” (Ruiz, 2009, p.39). Familismo and collectivism are not the same concept both tend to be manifested together in Hispanics (Rinderle & Montoya, 2008). This value may manifest as individuals sacrificing personal dreams and goals for the dreams and goals of the family. This may also manifest in individuals putting prominence to family short-term needs over individual long-term goals.

Religiosidad or religiosity is a value associated with being religious or having religious devotion. It is the belief in a greater power and to the benefit of prayer (Morgan, Consoli & Llamas, 2013). It often takes the form of, but not is exclusive to, Catholicism in the Hispanic culture. Religiosidad in the Hispanic culture can affect an individual’s acceptance of concepts that may be contradictory to their religious beliefs. This value can be associated with implicit distrust and dislike of atheists (Shen,
Haggard, Strassburger & Rowatt, 2013). This distrust and dislike may lead an individual who holds this value to not accept any concepts they perceive as atheistic. This may take the form of an individual believing in creationism and not accepting the theory of evolution.

Marianismo, this is an exclusively female script based on the admiration for a mother’s self-sacrifice for her children. This is derived from a strong Catholic belief of the Virgin Mary and gives women the perception of having the capacity of enduring and suffering more than men due to their superior morality and spirituality (Ruiz, 2009). Individuals holding this value may consider marriage and raising children as being far more important than any desires for a career.

Hembrismo is a less known female script which gives Hispanic women the belief that they have the strength, perseverance, courage, and ability to survive and has been seen in their ability to overcome seemingly insurmountable odds and hardships (Ruiz, 2009). In contrast to Marianismo this script may give an individual the motivation to succeed in new and untested waters such as being the first member of the family to pursue a college education or succeed outside of the home. This script for a Hispanic female may be difficult to balance with the more traditional Marianismo script.

Machismo is a distinctly male script where the male is considered the head of the household and responsible for ensuring that the family is cared for and protected. Contradictory to the Western perception that machismo has a negative sexist characteristic the Hispanic view emphasizes the male’s use of strength and power in order to care for and protect others (Ruiz, 2009). This script gives an individual the idea of the importance of the male being strong, responsible and supportive of others within the family. A young Hispanic male may feel that it is their responsibility to set themselves up as the sole provider of their family.

These nine cultural values or scripts give Hispanic individuals a unique perspective on life. This can not only affect their interaction within their community but can have a distinct effect on their education and career choices. Education and a career choice that are found to be in conflict with these
scripts may be not considered as a life choice. Individuals may have a varying degree of these values and scripts. Some Hispanic individuals may align very closely with all of these cultural values while others may be aligned with few or none. Many of these cultural values can have a distinct effect on Hispanic individuals’ education.

Subjects such as science may turn off students if they are forced to give up what they understand through their beliefs or as cultural identities (Marcum-Dietrich, 2008). Students being taught concepts that are contradictory to the way that they have been raised may struggle to learn the new concepts. McCollough, and Ramirez (2012) state, “for many Hispanic students who understand, at least implicitly, that school affirms that Anglo, middle-class culture; these Eurocentric curricula tend to disqualify their own view of the world, as well as their cultural identity” (McCollough & Ramirez, 2012, p. 443). These students may feel that what they are being taught is not really for them. Hispanic students often face challenges due to their language and diverse cultures which may cause a disconnect between their own cultural knowledge and science discipline; where home and community are the primary discourse and school is the secondary discourse (McCollough, Ramirez, 2012). The Hispanic culture is deeply centered in the family, which is the individual’s main focus; everything outside of the family is viewed as secondary. The majority population, white non-Hispanic as well as other minorities ascribe to the concept of individualism. A child is viewed as an individual, independent, individual achievement is valued and science information disengaged from social contexts. The Hispanic population predominantly ascribes to the concept of collectivism and Familismo. A child is viewed as part of the family, helpfulness and interdependent is required in the family. The primary focused is on the group’s success and scientific information is embedded in social experiences (Rothstein-Fisch, Greenfield & Trumbull, 1999). This often makes it difficult for young Hispanic students to give the full attention to their education as they are pulled in two directions; to be supportive of the family or to focus on their independent achievement.
Method

3.1 PARTICIPANTS REGIONAL BACKGROUND AND RECRUITMENT

Latinos/as or Hispanic Americans as previously mentioned are the largest minority group in the United States (Minority, 2007). There are regions in the southwest United States that have a predominantly Hispanic population, though the majority Hispanic Americans, still struggle with poverty. This study takes place in the Southwest region of the United States in far West Texas the city of El Paso. High school campus demographics in El Paso are fairly uniform and consistent of 92% economically disadvantaged, 99% Hispanic, 83% at risk, and 41% limited English proficient (LEP) (Canon, 2011). El Paso is one of the nation’s poorest congressional districts (Palmaffy, 1998). One of the poorest Metropolitan regions in the United States, in an annual ranking of per capita income El Paso was found to be the fifth poorest of the 317 largest urban communities in the nation (Daresh & Parra, 1999). Another important aspect of the El Paso area is its proximity to Ciudad Juárez, literally large areas of the cities are within 100 yards or less of each other. In 2003 Ciudad Juárez was the fourth largest city in Mexico with a population nearly 1.5 million (Hamilton & Rippberger, 2003). Events on one side of the border can have an effect on the other side. Ciudad Juárez has recently been the epicenter of a horrific drug war which has seen more than 6,500 deaths since 2008 and in 2010 recorded over 3,000 murders in the city which gave the city the reputation as ‘the most violent city in the world’ (Munter, McKinley & Sarabia, 2012). This has created an influx of refugees seeking the safety of the other side of the border in El Paso. This also had a major impact on the psyche of the entire population of El Paso. Despite its proximity to Ciudad Juárez, El Paso was found the safest city of its size in the United States in 2012 (City Crime Ranking 2013, 2013). The drug war across the border had a distinct effect on all the students on this the side of the border. The Hispanic population in El Paso is quite unique but still shares a great deal of aspects with the Hispanic population of the rest of the country in regards to culture, poverty and language barriers. The participants of this study have been recruited from Irving high school
located in the North East part of El Paso Texas. The northeast side of El Paso has a high percent of active military and retired military due to its proximity to Fort Bliss. The students will be in the 11th grade and will be invited to volunteer to participate in videotaped interviews.

3.2 **DATA COLLECTION AND ANALYSIS**

Based on the concept of social representation (Ryder, Leach & Driver, 1999) as being a means to provide insight into how people develop an understanding of the nature of science. This study will investigate the image of the nature of science held by the group of 11th grade Irvin high school students, a predominantly Hispanic high school in El Paso Texas. The student interviews were done as part of The National Science Foundation (NSF) funded, Transforming Students’ Partnership with Scientists through Cogenerative Dialogues project. Secondary data will be analyzed in order to answer the following research question:

- What range of images of science do Hispanic urban high school students hold?

The data has been developed through interviews with 42 11th grade students from Irvine high school in a predominantly Hispanic urban community in order for them to develop an understanding of their perception of the NOS. The current study is compared with the Ryder, Leach & Driver (1999) study for three reasons. The first reason is that both studies share in the use interviews in order to collect the data. This enables the development of follow-up questions which can enhance the quality of the data. The second reason for the comparison between the two studies is the age of the students. The Hispanic high school students are eleventh graders with an average age of seventeen. In the Ryder 1999 study the students are preservice undergraduates in their early 20s. The third reason to compare the studies is that each are from a unique culture the current study focuses on Hispanic students while the Ryder 1999 study involves British students. This allowed for a multidimensional comparison. This study will share in the use of the use of the stimulus questions identified in previous study by Ryder, Leach & Driver
(1999) although the focus of the previous study was to identify changes and participants views or understandings, this study will focus on participants view or understanding of the nature of science.

Five stimulus questions were used for the interview:

1. How do scientists decide which question 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?

The purpose of the stimulus questions is to create dialogues in order to, not only answer the specific stimulus question but to identify how and why the individual responds in the specific way. A copy of the stimulus questions and possible follow-up questions is found in the appendix. The stimulus questions are designed with no reference to any particular scientific context. Answer to the initial stimulus questions invoked representations that have been created within the individuals’ mind through experiences in science and life in general. Follow up questions were used to help the participants respond to the fullest and aid them in making connections to previous knowledge and experience. The participants will be asked not only to respond to the questions but also to think about why they responded to the questions in the way that they did. Therefore, the response to further questions will invoke from the interviewee images based on their unique image of the nature of science. The questions were analyzed and categorized using two methods of categorization.

The first method was a question by question analysis for a particular type of response. Question one: “How do scientists decide which question to investigate?” participants responses will be categorized into the same categories used in the Ryder, Leach and Driver (1999) study. These categories are "(a) Curiosity led: Scientist used to investigate questions which they are personally curious about.
(b) Extending knowledge: scientists seek to increase and improve the knowledge of the discipline. (c) Utilitarian: scientists work to help solve medical or environmental problems for the benefit of humanity. (d) Financial benefit: scientists working area for which they know they can get funding, or which may lead to financial reward” (Ryder, Leach & Driver, 1999, p.206). Participant responses will be evaluated and assigned to the category which most aligns with their statement.

The second question “Why do scientists do experiments?” will be analyzed using a method which aligns with the Donnelly and Argyle (2011) study. The Donnelly 2011 study was chosen for its category coding alignment with NOS. The responses will be examined and aligned with “(a) Tentative: Scientific knowledge changes with new data, new technology, or reinterpretation of old data. Scientific knowledge is not 'proven' (b) Empirical: Scientific knowledge is testable, based on data, 'facts,' evidence, observations (c) Indirect evidence: Scientists make inferences, construct categories, and use indirect evidence (d) Theory/law: Theories are evidence-based explanations of data; laws are evidence-based patterns or regularities of data. Theories do not become laws (e) Scientists use creativity before (developing questions, designing procedures) and after (interpreting data) data collection (f) Subjectivity: Scientists interpret data differently given their background knowledge, theoretical frameworks, and personal inclinations (Donnelly & Argyle, 2011, p.483). The responses will also be analyzed and assigned to the most fitting category.

Question three “How can good scientific work be distinguished from bad scientific work?” will be analyzed in regard to the participants ability to elaborate on their initial statement providing understanding of why they responded the way they did and ranked either adequate or inadequate in understanding. Students will be asked to give examples if they are unable to think of a clear and precise distinction between good and bad scientific work. This will be done to help the student make images in their mind and give them the best opportunity to come up with a response that would be considered adequate.
Question four “why do you think that some scientific work stands the test of time where as other scientific work is forgotten?” Will be analyzed using categories of response also from the Ryder, Leach & Driver (1999) study. These categories are “Revolutionary: If scientific work solves a long lasting problem in a revolutionary way, then it will last. Coherent field: If scientific work builds on previous work and is consistent with it, then it will last. Inherent quality of work: If scientific ideas rest on highly reproducible data, then it will last. Utilitarian: If the work has many particular benefits to humanity, then it will last. Untestable: If predictions from the scientific area are difficult to test, then the idea may last a long time (Ryder, Leach & Driver, 1999 p. 207).

Question five “how is conflicts of ideas resolved in the scientific community?” will use categories from the Ryder, Leach & Driver (1999) study where participants responses will be identified as either an individualists view, or institutional view. The individualists’ view participants will recognizes a community of scientists. The institutional view the participants will recognizes the institution of science (Ryder, Leach & Driver, 1999). The five questions will be individually categorized as described above and all responses will be categorized using a second technique.

The second method analyzed the questions in a more general method. The Khishfe (2012) study was chosen for its use of eleventh grade students and its analysis of complexity in regards to NOS. As with the Khishfe (2012) study the students’ responses will also be categorized into three levels of understanding of the nature of science. These levels are naïve when they can give a justification for their response, intermediate if they give a response with a justification but is not made totally clear or not fully valid, and finally informed if the justification is clear and fully valid. The students’ responses to each question will be analyzed individually. The responses will be scored; naïve will score one point, intermediate will score two points, informed will score three points. Individual’s scores will be totaled as well as the overall score for all participants. Lowest possible score for individuals would be five points and the highest possible score would be fifteen points. Once the total number of participants is
finalized the overall group score will be calculated. The Lebanese students in the Khishfe 2012 study were given two different scenarios as well as three different occasions to respond. The first response was the argument followed by the counter argument and final response was rebuttal. The data presented for the first scenario argument was compared to the data from the Hispanic students. The data from the interviews will be examined and compared in order to identify any unique patterns that may connect the participants. As well as the individual and group score in understanding. These patterns may help to create an overall profile of the entire group of participants that can develop new understanding of 11th grade high school students in a predominant Hispanic urban environment who have been successful in their science education. This study will be limited in its focus to the why and how the participants developed the responses to the stimulus questions in an attempt to find similar or shared experiences which enabled these students to establish their understanding of the nature of science as well as enabling these students to be successful in their science education.

**Findings**

4.1 **QUESTION BY QUESTION EXPLANATION**

The purpose of the study was to identify perceptions, in regards to the nature of science, held by a group of Hispanic high school students. In this chapter the five individual questions were analyzed individually. Each section was broken down into subcategories which outline. These subcategories will show how the results of this analysis will be described, broken down into the categories as well as give examples of student responses which align with individual categories. Each question will be analyzed, an explanation of the findings followed by graphic representations depicting the findings for each individual question. There will be a comparison between the either another study or when no comparison can be made between the two genders in this study. The last section will contain an analysis of the complexity of response by the students for each question.
4.2 **Question One**

Question one, “how do scientists decide which question to investigate?” is divided into four categories, Curiosity Led, Extending knowledge, Utilitarian and financial benefit. By identifying key words or phrases each response aligns with a particular category. This question compares the responses between the Hispanic students by gender as well as comparing the overall responses of the Hispanic students to the British students. There will be given a discussion of the breakdown by students overall as well as gender including a graphic representation of the findings. There is a comparison between the findings in the Ryder 1999 study and this study. One figure presented giving a numerical and percentage representation of the studies and reflects the difference between genders. Another figure compares the percentage of responses between the two studies. Next a table is illustrated to demonstrate examples of the student responses in alignment with the category. This section will conclude with a review of the information presented.

4.2.1 **Meaning of Category**

The students’ responses are broken down in the following ways. The first category is “Curiosity Led.” This indicates that the students feel that scientists are motivated by curiosity and do research on what they are personally curious about. The second category is “Extending Knowledge.” Students’ responses aligned with this category if they indicate scientists’ motive for deciding what question to investigate is to either improve or extend the knowledge of their discipline. The third category is “Utilitarian.” Students’ responses aligned category if they indicate scientist choose their research for the betterment of the environment or of mankind. The fourth category is “Financial Benefit.” Students’ responses aligned category if students indicate the reason for scientists working in a particular area is due to available funding or financial gain.
4.2.2 **Key Words in Response**

Key words or phrases were found which allowed alignment to the appropriate category. For example for Curiosity Led, a response may include phrases such as “want to find out” or “would like to know”. If in a response in a mention of “other scientists” or “other research” it would be considered to align with Extending Knowledge. Responses that included phrases such as “helps people” or “environment” it would align with Utilitarian. If the response included “money” or “funding” it would align with Financial Benefits. This is the method that is used to decide how the responses align with the categories.

4.2.3 **What Students Say**

This section contains a breakdown of the number of students’ responses aligned with the four categories for the current study only. There are a total of forty-two students’ responses used in this study. Curiosity led has a total of twenty two students whose responses were in alignment. Extending knowledge has thirteen students’ responses aligning. Financial benefit has only one response aligning in this category. Also included is one example of each response which aligns with that category. All of this is represented in table 3.

<table>
<thead>
<tr>
<th>Categories</th>
<th>Number of students</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curiosity Led: scientist used to investigate questions which they are personally curious about.</td>
<td>22</td>
<td>L3LI: When they don’t know when it’s unanswered for them, their more curious about one thing than the other.</td>
</tr>
<tr>
<td>Extending Knowledge: scientists seek to increase and improve the knowledge of the discipline.</td>
<td>13</td>
<td>L4BQ: Umm….. It would probably be the one which they think other scientists have been working on or trying to figure out rather than something that’s simple and I can’t… Maybe like other scientist didn’t get the answer that you wanted maybe you can like research more and maybe find out.</td>
</tr>
<tr>
<td>Utilitarian: scientists work to help solve medical or environmental problems for the benefit of humanity.</td>
<td>6</td>
<td>L4CF: It could be how strongly they feel on that. Like, say oil spill, they might want to find a different way to, like, clean it up. Maybe it is like personal environmental thought on that subject or maybe it’s just pure money.</td>
</tr>
<tr>
<td>Financial Benefit: scientists working areas for which they know they can get funding, or which may lead to financial reward.</td>
<td>1</td>
<td>L4CF: It could be how strongly they feel on that. Like, say oil spill, they might want to find a different way to, like, clean it up. Maybe it is like personal environmental thought on that subject or maybe it’s just pure money.</td>
</tr>
</tbody>
</table>
This section gives the breakdown of response both numerical and in percentage. In Figure 1, the gender percentages are based on the individual gender, for females it is the percent of females responding to that category and for males it is the percentage of males responded to that category. In this study there were a total of forty-two students and only one response was counted for each student. The comparison was by gender and not across gender. For example, responses in this study to question one “how do scientists decide which question to investigate?” yields a 61.5% of the total female responses for Curiosity led while the percent for males was 37.5% of male total responses. This demonstrated a 24% difference in favor of the females in this category. This was done due to the fact that the number of females was nearly twice the number of males. By presenting the percentages in this manner a clearer understanding of how the students respond by gender was accomplished. The breakdown by category was as follows. Curiosity Led: Twenty-two student responses or 52.4% of the total student responses aligned with this category. Sixteen or 61.5% of the total female responses aligned in this category. Six or 37.5% of the total male student responses aligned with this category. Extending Knowledge: thirteen or 31% of the total student responses aligned with this category. Six or 21.7% of the total female responses aligned with this category. Seven or 43.8% of the total male responses aligned with this category. Utilitarian: six or 14.3% of the total student responses aligned with this category. Four or 15.4% of the total female responses aligned with this category. Two or 12.5% of the total male responses aligned with this category. Financial Benefits: one or 2.4% of the total student responses aligned with this category. The majority of the students responses aligned with one category if their dialogue reflected two categories only the first response was counted with the one exception of Financial Benefit, which was an afterthought, Utilitarian stated first but Financial Benefit was counted instead due to its importance. Zero
female responses aligned to this category. One or 6.3% of the total male responses aligned with this category.

Figure 1 Question one: Responses by Hispanic students.

4.2.5 **Comparison by Gender: Hispanic Students**

The findings for question one “how do scientists decide which question to investigate?” show a difference between the genders in their responses. One major phenomenon is apparent in regards to gender for this question. *Females are more likely to have a response that aligns with Curiosity Led than any other category.* The percentage of responses is 61.5% of the female responses for Curiosity Led while only 21.7% for Extending Knowledge, 15.4% for Utilitarian and no responses for Financial Benefit (see figure 1). For the male students the category that had the most responses was Extending Knowledge with 43.8% followed by Curiosity Led with 37.5%, 12.5% for Utilitarian and 6.3% for Financial Benefit.
4.2.6 FREQUENCY OF RESPONSES BY CATEGORY: BRITISH STUDENTS

The Ryder 1999 study interviewed eleven students, four male students and seven female students. They were undergraduate students at the University of Leeds in England. Some of the students in the Ryder studies responses aligned with more than one category therefore there are a total of nineteen responses. This study does not delineate between genders so there is no comparison between male and female. Curiosity led had five or 26% of the total responses align with this category. Aligning with Extending Knowledge were three or 15% of the total responses. Utilitarian; five or 26% of the total responses aligned with category. Financial benefit the category that had the highest amount of responses, six or 32% of the total. Figure 2 compares the total responses from both studies. The representation is based on percentages due to the difference in the number of students in each of the studies.

Figure 2 Question one: Comparison between Hispanic and British students.

4.2.7 COMPARISON BETWEEN HISPANIC AND BRITISH STUDENTS

The findings for question one “how do scientists decide which question to investigate?” show a distinct difference between the groups in the two studies. In comparing the two studies the first
category, Curiosity led had 26% of the responses in the Ryder 1999 study aligning with this category while the current study had 52.4%. Extending knowledge had 15% British students and 31% for the Hispanic students. The British students had 26% aligning with utilitarian whereas Hispanic students hold 14.3% responses. Financial benefit holds the greatest difference between the two groups studied. A phenomenon which occurred during this comparison relates to financial benefit. British students see the financial benefit in scientific research whereas it may not be a factor considered by Hispanic students. The Ryder study had 32% responses aligning with this category where the current study had 2.4% responses. Financial benefit had the greatest difference of 29.6%.

4.2.8 SUMMARY OF RESULTS FOR “HOW DO SCIENTISTS DECIDE WHICH QUESTION TO INVESTIGATE?”

For question one, distinct differences were seen in both the comparison between the two genders of the Hispanic students as well as between the Hispanic and British students. First, Hispanic females are far more likely to have a response that aligns with Curiosity Led than any other category. In comparison between the two genders of the Hispanic students the female students are nearly 3 times more likely to respond to Curiosity Led than any other category. It appears that Hispanic females consider scientists going into research primarily out of curiosity. Second, British students see the financial benefits in scientific research whereas it may not be a factor considered by Hispanic students. In comparing the British students and Hispanic students the British students are nearly 16 times more likely to align with Financial Benefit. Hispanic students may not consider financial benefit has a factor that scientists consider when going into research.

4.3 QUESTION TWO

Question two “why do scientists do experiments?” is broken down into six categories; Tentative, Empirical, Indirect evidence, Theory/law, Creativity, and Subjectivity. This question will help develop an understanding of the perception of these students of the reasons why scientists do experiments. This will help to develop a fuller picture of these students perception of the nature of science. The Ryder
1999 study did not present data for this question. There was no comparison between these studies. The criteria for the coding on this question are based on the Donnelly and Argyle (2011) study. The Donnelly (2011) study developed the categories as they studied K-12 teachers’ perception of NOS through professional development. The analysis for this study was based on a comparison between pre- and post-interviews of practicing teachers looking for changes due to an intervention. The data presented was not directly comparable to the responses given by the students in this study. The data will be presented based on the interviews of the Hispanic high school students only. The meanings of the categories will be identified in this section as well as examples of keywords including students’ responses. There will be a figure which will depict a breakdown of climate to each category as well as depicting the differences in response by gender. A table will follow showing the number of students responding to the particular category as well as an example of the students’ response which aligns. The section will end with an overview.

4.3.1 MEANING OF CATEGORY

A description of the characteristics of each category will be listed in this section. The first is “Tentative.” If students’ responses indicate they believe that scientific knowledge is changing as new data, new technologies or as old data is reinterpreted, they will align with the category. The second category is “Empirical” if the students response shows that they believe that scientific knowledge is testable based on facts, data evidence and observations it aligns with this category. “Indirect evidence” is the next category if students believe that scientists make inferences, create categories, and use indirect evidence their response will be in this category. Followed by “Theories/Law,” where theories are evidence-based explanations of data and laws are evidence-based patterns or regularities of data; if students’ responses reflect this concept they will fall within this category. “Creativity” if students reflect the understanding that scientists use creativity in the development of questions and designing procedures as well as using creativity interpreting data or even in data collection by their response it falls under this
category. The final category is “Subjective” if students’ responses indicate they believed that scientists interpret data differently depending on their background knowledge, theoretical framework, and personal inclination they will align with this category.

4.3.2 **Key Words in Response**

In order to align each response with its category keywords were developed and identified in the response dialogue. For tentative students’ responses may include terms such as to learn new, to learn more, future, innovative or cutting-edge. An example, L2AM: “I think, well to me, I think they do experiments to get research out of it, to learn more things, as they learn and do experiments with medicine and everything they come up with something that will help in the future”. To align with empirical the students’ would include terms such as, based on data, based on observations, seeing with their own eyes, evidence or show it correct. This categories example, CEV: "To learn more about, about it besides getting facts to see how like to see with their own eyes, cause like when they tell you facts sometimes you can imagine them but when you do them like, it’s like you could say like no that’s true it’s going on. You see things like…..". For indirect evidence students would respond using terms such as make inferences, create category or use indirect evidence. There is no example for this category. Response to fall under the theory/law category the students answer must include either law or theory. An example line with this category, 1L4JJJC: “to prove their theories or like to research like things happen and how they can help”. For students’ response to fall under creativity they would terms such as, figure something out, think in their mind, or work something out indicating their belief that the scientists came up with the idea on their own. Creativity’s example, 1L3LA: “what does it mean? what is it going to go on and many more that they think in their mind”. And finally for subjectivity the student would indicate that scientists would use understanding about their own fields in order to complete their experiment as a chemist may use theirs background to create new medication or materials. Key words for this category would be, using knowledge in their own subject, simplify for others or use their knowledge to connect to others. Subjectivity’s example, L4CNY "They do experiments so… So any of the people that are not involved with science and don’t know the information, they could understand it they… They simplify as
to us, other people who are not scientists, we could see that”. Each one of the interview dialogues response to this question was analyzed and aligned with the applicable category.

### 4.3.3 What Students Say

This section gives examples of students’ responses showing their alignment with the specific category. Each category except indirect evidence has an example of the students’ responses; no student responses aligned with indirect evidence. Tentative had fourteen students’ responses which align with this category. Empirical yielded nineteen alignments. Indirect evidence had no students’ responses which aligned with this category. The remaining three categories, Theory/Law, Creativity and Suggestively, each yielded two alignments. Table 4 gives a numerical breakdown of the number of students that responded in each category. Also included in this section is an example of students’ responses for each of these categories.

Table 4 Question two categories and examples. Why do scientists do experiments?

<table>
<thead>
<tr>
<th>Categories</th>
<th>Number of students</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tentative: Scientific knowledge changes with new data, new technology, or</td>
<td>14</td>
<td>L2AM: I think, well to me, I think they do experiments to get research</td>
</tr>
<tr>
<td>reinterpretation of old data. Scientific knowledge is not ‘proven’.</td>
<td></td>
<td>out of it, to learn more things, as they learn and do experiments with</td>
</tr>
<tr>
<td></td>
<td></td>
<td>medicine and everything they come up with something that will help in</td>
</tr>
<tr>
<td></td>
<td></td>
<td>the future.</td>
</tr>
<tr>
<td>Empirical: Scientific knowledge is testable, based on data, ‘facts,’</td>
<td>19</td>
<td>CEV: ”To learn more about, about it besides getting facts to see how</td>
</tr>
<tr>
<td>evidence, observations.</td>
<td></td>
<td>like to see with their own eyes, cause like when they tell you facts</td>
</tr>
<tr>
<td></td>
<td></td>
<td>sometimes you can imagine them but when you do them like, it’s like</td>
</tr>
<tr>
<td></td>
<td></td>
<td>you could say like no that’s true it’s going on. You see things like</td>
</tr>
<tr>
<td></td>
<td></td>
<td>……”</td>
</tr>
<tr>
<td>Indirect Evidence: Scientists make inferences, construct categories, and</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>use indirect evidence.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Theory/Law: Theories are evidence-based explanations of data; laws are</td>
<td>2</td>
<td>L4JJC: To prove their theories or like to research like things happen</td>
</tr>
<tr>
<td>evidence-based patterns or regularities of data. Theories do not become</td>
<td></td>
<td>and how they can help.</td>
</tr>
<tr>
<td>laws.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Creativity: Scientists use creativity before (developing questions,</td>
<td>2</td>
<td>L3LA: To find out the results of the experiment, amm…the experiments,</td>
</tr>
<tr>
<td>designing procedures) and after (interpreting data) data collection.</td>
<td></td>
<td>like to see if it comes out true, if it's false and what it is about,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>some people have question that they tell what it is about of what it</td>
</tr>
<tr>
<td></td>
<td></td>
<td>is about. What does it mean? What is it going to go on and many more</td>
</tr>
<tr>
<td></td>
<td></td>
<td>that they think in their mind.</td>
</tr>
<tr>
<td>Suggestively: Scientists interpret data differently given their</td>
<td>2</td>
<td>L4CNY: They do experiments so… So any of the people that are not</td>
</tr>
<tr>
<td>background knowledge.</td>
<td></td>
<td>involved with science and don’t know the information, they could</td>
</tr>
<tr>
<td></td>
<td></td>
<td>understand it they… They simplify as to us, other people who are not</td>
</tr>
</tbody>
</table>
4.3.4 **Frequency of Responses by Category**

The majority of the female responses aligned with Empirical, 54%. This is followed by 34.6% aligning with Tentative. Theory/law, Creativity, Suggestively all received 3.8%. The majority of the male responses aligned with Tentative at 43.8%, followed by Empirical at 37.5%. Theory/law, Creativity, Suggestively all received 6.25%. Figure 2 gives a graphical representation of the students’ responses to this question.

![Graph showing frequency of responses by category](image)

Figure 3 Question two: Responses by Hispanic students.

4.3.5 **Comparison by Gender**

The responses to question two are compared within the group of Hispanic high school students by gender. Two categories held the overwhelming majority of the students’ responses. Tentative had the highest percentage of the male responses with 43.8%. The female’s response is 34.6%. This yields a 9.2% difference favoring the male students. Empirical yielded 54% for female and 37.5% for male which is a 16.5% difference in favor of the female students. The remaining categories, Theory/Law,
Creativity, Suggestively each had one response by a male and a female student. With the analysis of these responses one distinct anomaly was found. *The Hispanic students did not consider indirect evidence as being a factor for scientists to do experiments.* None of the student responses aligned with the category Indirect Evidence.

4.3.6 **Response by Teachers**

The Ryder 1999 study did not present data for this question. The coding criteria for this question were based on the Donnelly and Argyle (2011) study. This study used an intervention of a professional development workshop. There was no presentation of individual teachers’ responses presented as data.

4.3.7 **Comparison between Hispanic Students and Teachers**

The data developed in the Donnelly and Argyle (2011) study was produced by comparing pre- and post-interviews given by the teachers. The analysis was designed to highlight changes made in participants’ perception of the nature of science due to the intervention of the professional development workshop. Individual teachers’ responses were presented in the form of change or increase due to the intervention. There were no individual teachers responses presented in the study therefore no comparison could be made between the teachers in the Donnelly (2011) study and this one.

4.3.8 **Summary of Results for “Why do scientists do experiments?”**

In examining the responses for question two it was shown that over half of the female responses, 54% aligned with Empirical. 34.6% of the female responses aligned with Tentative followed equally by Theory/Law, Creativity, and Suggestively all with 3.8%. Male responses aligned first with Tentative at 43.8% followed by empirical at 37.5% with Theory/Law, Creativity, and Suggestively with 6.25%. Over half of the female’s responses aligned with Empirical whereas just over one third of the males aligned with that category. Just under one half of the males responses aligned with Tentative while just over one third of the females. The main finding for this question; *The Hispanic students did not consider indirect evidence as being a factor for scientists to do experiments.* Apparently, this is an aspect missing in these Hispanic students perception of the nature of science.
4.4 **Question Three**

Originally question three “how can good scientific work be distinguished from bad scientific work?” ranked students’ responses either adequate or inadequate. This question could not be analyzed using the criteria in the Ryder study because this was an initial interview and the Ryder study compared three interviews at different times with a treatment. Initially for this study a new analysis was developed based on the quality of the students’ responses. A student’s response is ranked adequate if they come up with a reasonable example of either good or bad scientific work and were able to explain why they believe this work is either good or bad. If the student is not able to come up with the reasonable example or if there example is invalid the ranking for this question will be inadequate. After examining the responses it was found there was a distinct delineation between students responses which made a more natural and usable set of categories. All of the students responded in one of two ways; they looked at scientific work being considered either good or bad due to either the quality of the work or the use of the work. By analyzing in this manner new information is created for the Hispanic high school students’ perception of the nature of science in regards to the difference between good or bad scientific work. The claim made for this question: three out of four of the male student responses aligned with Quality of Work whereas the female student responses were nearly split equally between Quality of Work and Use of the Work. This section will identify the meanings of the categories. There will be key words and examples of responses aligning with keywords. There will be at an illustration depicting the breakdown of the total number of students as well as a breakdown between genders. There will be a table containing example of students’ responses aligning with the categories. This will be followed by an overview of the findings for this question.

4.4.1 **Meaning of Category**

The two categories in this section are quality of work and use of the work. Some students considered the quality of the work as being the factor deciding whether the work was good or bad. These students would consider how well the research was documented and the quality of the overall work. Other students considered the use or outcome of the work being the deciding factor whether the work
was good or bad. In this case if the students thought that the scientific work was for something that would be bad for humanity such as chemical or nuclear weapons.

### 4.4.2 Key Words in Responses

Although there was a wide range of responses they all aligned with one of the two categories. Students’ responses that aligned with quality of work included terms such as organized, good results, or answers questions as well as other positive or negative references to the quality of the work. An example of a student’s response which aligns with this category giving an example of bad scientific work, L4BA: “sighs! Well you not organized and stuff is everywhere”. Students’ responses that aligned with use of the work would include terms such as experiments that destroy the world, having a good impact on the population, or address environmental issues. An example for this category, L2MR: “by… in other words, if it is good it helps certain people or the world like, how they discovered global warming, the effects of it, it effects the people in the future health wise and all that will”.

### 4.4.3 What Students Say

This section contains two examples of the students responses representing how they feel good scientific work can be distinguished from bad scientific work. For the question “how can good scientific work be distinguished from bad scientific work?” twenty-six students aligned with quality of work and sixteen students aligned with use of work. Table 5 lists both the categories with explanation, the number of students whose response aligned with the category and examples of students’ responses aligning with the category.

Table 5 Question three categories and examples. How can good scientific work be distinguished from bad scientific work?

<table>
<thead>
<tr>
<th>Categories</th>
<th>Number of students</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality of the Work</td>
<td>26</td>
<td>L4BA: Well, mm… if you do like a run through and have problems with your first experiment, I would say, you go to redo that second time so that what we did the first time that causes problems and fix it the second time… I would say having a good report down, good information, have notes. Interviewer: Okay, that okay, and how about example of bad scientific work? L4BA: Sighs! Well you not organized and stuff is everywhere.</td>
</tr>
<tr>
<td>Use of the Work</td>
<td>16</td>
<td>L2MR: By… in other words, if it is good it helps certain people or the world like, how they discovered global warming, the effects of it, it effects the people in the future health wise and all that will”</td>
</tr>
</tbody>
</table>
4.4.4 Frequency of Responses by Category: British Students

This section contains a graphical representation of how the students’ responses aligned in these categories. The table shows that there is a distinct majority of the students who considered the quality of the work as being the deciding factor whether the work is good or bad. A little more than one third of the respondents viewed the use of the work as being the deciding factor whether the work was good or bad. In comparing the female responses the two categories fell fairly equal with 54% aligning with quality of work and 46% aligning with use of work. In regards to the male students, 75% of the males aligned with quality of work where as 25% aligned with use of the work. The outcome of this analysis is represented in table 7.

![Graph showing the frequency of responses by category for British students.](image)

Figure 4 Question three: Comparison by gender between Hispanic Students.

4.4.5 Comparison by Gender: Hispanic Students

The responses to “how can good scientific work be distinguished from bad scientific work?” are divided into two categories quality of work and use of work. One distinct phenomenon was apparent by
this analysis. Male students are more likely to consider the quality of the work as a reason the work is good or bad over the use of the work. The male students responded 75% for quality of work and 25% for use of work. Female responses are 54% for quality of work and 46% for use of work. The difference in percentage between male and female for quality of work is 21% in favor of the male students. The difference in percentage between male and female for use of work is also 21%.

4.4.6 Frequency of Responses by Category: British Students

The Ryder (1999) study when analyzing the question “how can good scientific work be distinguished from bad scientific work?” compared three different interviews after a treatment of a professional development workshop. There were no individual participant responses for this question. It was not possible to track responses to any category.

4.4.7 Comparison between Hispanic and British Students

The Ryder (1999) study did not present data on individual responses to the question “how can good scientific work be distinguished from bad scientific work?”. It was not possible to make a comparison between the responses in the Ryder (1999) study with this current study. The data presented in this section compares only the Hispanic students by gender.

4.4.8 Summary of Results for “How can good scientific work be distinguished from bad scientific work?”

As responses for question three were examined two distinct categories arose and were used for the analysis; student responses indicated they believed the difference between good and bad scientific work was based on either the quality of the work or the use of the work. Three quarters of the male responses aligned with Quality of the Work, whereas female responses divided nearly evenly between the two categories. Therefore males are 25% more likely to respond to the quality of work than females.
There was discovered, *Male students are more likely to consider the quality of the work as a reason the work is good or bad over the use of the work.*

### 4.5 Question Four

Question four “why do you think that some scientific work stands the test of time whereas other scientific work is forgotten?” is divided into five categories. These categories are revolutionary, coherent infield, inherent quality of work, utilitarian, and untestable. This question will be compared to the responses given during the first interview in the Ryder study. In this section the meaning of the categories will be explained and then keywords will be identified. This will be followed by an illustration of how the responses are broken down by total number and gender for the current study. The Ryder study is not broken down by gender. A claim for this question: the majority of the Hispanic students’ responses aligned with Inherent Quality of Work while the British students favored equally Revolutionary and Coherent Field. This will be followed by a table which contains examples of student responses aligning with the categories followed by a comparison. This question was designed to invoke the students’ feelings on what they believe gives scientific work longevity.

#### 4.5.1 Meaning of Category

The first category “Revolutionary” will be indicated if students’ responses indicate that they believe that scientific work is able to solve long-term problems in a revolutionary way that is lasting. The next category is “Coherent field” which would be selected of the students responses indicated they felt good scientific work stand the test of time if it was built on previous or existing bodies of work. The third category is “Inherent quality of work” students responses fell in this category if they indicated that they felt scientific work would last if its basis would produce highly reproducible data. The next category is “Utilitarian” the students responses indicated that they believed scientific work lasted due to its benefit to the environment or to mankind. The final category for this question “Untestable” if students’ responses indicated they believed scientific work would stand the test of time if predictions from the scientists are difficult to test (Ryder, Leach & Driver, 1999). The students’ responses varied and the approach that they would take to answer the question. Some students responded citing scientific
work that did stand the test of time while others referred to work that is no longer considered valid. Students were prompted to try to think of examples of both work that didn’t stand the test of time as well is word that as long since forgotten.

4.5.2 **Key Words in Response**

For the first category Revolutionary terms such as new findings, never seen before, cutting-edge or any other term that may notate new innovation. The second category, Coherent Infield, if the responses contained terms such as prove other research, do a better job, improve on. The third category, Inherent Quality of Work, may have responses that contained terms such as clear or precise, concrete, more knowledgeable are examples that would align. The fourth category, Unitarian, responses could contain items such as effects people, cure diseases, environment, or affects the world. For the final category, Untestable, responses which contained terms such as could not repeat, not able to duplicate, or untestable would align with this category. An example for this category, L3LG: "It would be too much of a hassle to prove it wrong".

4.5.3 **What Students Say**

The students’ responses were quite diverse. This section contains a numerical breakdown of the alignment of the students’ responses. Revolutionary aligned with ten students. Coherent infield aligned with six students. Inherent quality of work aligned with seventeen students. Utilitarian aligned with for students. Untestable aligned with only one student. Also there are examples of each category’s responses. This information is found in table 6.

<table>
<thead>
<tr>
<th>Categories</th>
<th>Number of students</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revolutionary: if scientific work solves long lasting problems in a revolutionary way.</td>
<td>10</td>
<td>CEV: I think because they think that now that we are little bit more modern, they think that the old stuff is not useful anymore. So now that we have new technologies and could find stuff easily they think that the old way is just a waste of time.</td>
</tr>
</tbody>
</table>

Table 6 Question Four Categories and Examples. *Why do you think that some scientific work stands the test of time whereas other scientific work is forgotten?*
Coherent field: if scientific work builds on previous work and is consistent with it, then it will last 6

L2BD: Because they do a better job than the other ones when it's forgotten it didn't make like, a world impact.

Inherent quality of work: if scientific ideas rest on highly reproducible data, then it will last. 17

L4QB: 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.

Utilitarian: if the work has many particular benefits to humanity, then it will last 4

CRS: Because some affect people in a better way than other, well, they affect people in a bigger way, than others. Interviewer: OK, so the ones that stay are the ones that have the biggest effect on people? Student: Yes.

Untestable: if predictions from the scientists are difficult to test then the idea may last a long time. 1

L3LG: It would be too much of a hassle to prove it wrong.

4.5.4 FREQUENCY OF RESPONSES BY CATEGORY: BRITISH STUDENTS

The Hispanic students responses to “why do you think that some scientific work stands the test of time where as other scientific work is forgotten?” showed variance. The category the received the highest percentage is Inherent Quality of Work. This accounted for 39% of the overall responses. Revolutionary came in second with 29% of the responses followed by Coherent field with 14.6%, utilitarian 12% and finally untestable which had 2.4%. Hispanic students are more likely to respond to Inherent Quality of Work in response to “why do you think that some scientific work stands the test of time where as other work is forgotten?”.

4.5.5 COMPARISON BY GENDER: HISPANIC STUDENTS

The comparison by gender found that 38% of the total number of females’ responses fell in the category of Inherent Quality of Work. This category also had the highest amount of male responses with 40% of total male responses. Revolutionary aligned with female responses at 34.6% total female responses whereas male responses were 20% of total male responses. Coherent field aligned 7.7% total female responses and 33.3% total male responses. Utilitarian aligned with 15.4% total female responses
and 6.7% total male responses. Untestable aligned with 2.4% total female responses and no male responses aligned with this category.

### 4.5.6 Frequency of Responses by Category: British Students

The responses for the first interview in the Ryder 1999 study are as follows. Revolutionary has three or 27% student responses. Coherent field has three or 27% student responses. Inherent quality of work has two or 18% student responses. Utilitarian has two or 18% student responses. Untestable has one or 9% student response. The Ryder study has eleven participants. How the students responded to this question is found in figure 5.

![Bar chart showing responses for British and Hispanic students.](image)

Figure 5 Question four: Comparison between Hispanic and British Students.

### 4.5.7 Comparison between Hispanic and British Students

The responses in this study for the question “why do you think that some scientific work stands the test of time whereas other scientific work is forgotten?” Two distinct differences were found when comparing the two groups. First, Hispanic students are more likely to consider the inherent quality of
the work as being the major factor in deciding longevity of scientific work than British students. The Hispanic students’ favored Inherent quality of work with a total of 39% compares with 18% total responses by the British students. Second, British students are more likely to consider Untestable as being a factor in scientific works ability to last than Hispanic students. Untestable had 2.4% of the Hispanic students compared to 9% by the British students. Revolutionary is the second most popular category to the Hispanic students with 29% the British students and 27% total responses. Coherent infield, the Hispanic students had 14.6% compares with 27% by the British students. Utilitarian had 12% by the Hispanic students and the British students had 18%.

4.5.8 SUMMARY OF RESULTS FOR “WHY DO YOU THINK SOME SCIENTIFIC WORK STANDS THE TEST OF TIME WHEREAS OTHER SCIENTIFIC WORK IS FORGOTTEN?”

In comparing the results from question three between the Hispanic students and the British students, major differences appear. Almost 40% of the Hispanic responses aligned with Inherent Quality of Work while less than 20% of the British students responded in that category. First, Hispanic students are more likely to consider the inherent quality of the work as being the major factor in deciding longevity of scientific work than British students. British students consider revolutionary and coherent field as being equally the two most important factors followed by inherent quality of work and utilitarian also tied for second with untastable coming in last. Less than 3% of the Hispanic female’s responses and no male responses aligned with Untestable whereas British students aligned with this category nearly 10% of the time. Second, British students are more likely to consider Untestable as being a factor in scientific works ability to last than Hispanic students. Even though untastable had the lowest number of responses by the British students it still far surpassed the Hispanic students’ responses. Hispanic students consider untastable as being far less important of a factor than the British students in deciding the longevity of scientific work.
4.6 Question Five

Question five “how is conflicts of ideas resolved in the scientific community?” responses were categorized either individualist views, which students show an understanding of the community of scientists or institutional view where students view science as an institution. As the questions were examined if the response is indicated the student believed that the conflict was resolved by the scientists themselves coming to a consensus they would be categorized individualist view. If however, the students’ response indicated they believed that further testing or experimentation was required in order to resolve the conflict that response would be categorized as institutional. This question is not compared directly to the Ryder 1999 study. This question compares the responses between the two genders given by the Hispanic students. The claim that can be made for this question is: three out of four of the male student responses aligned with institutional view while nearly half-and-half of the female responses aligned with both Individualist view and institutional view. The following section will contain the meaning of the category, key words in response, what the students say, frequency of responses by category and finally a comparison.

4.6.1 Meaning of Category

Understanding how conflicts of ideas are resolved is an important concept in understanding how any institution or organization runs. In the scientific community conflicts of ideas can be resolved in one of two ways. Individualist view is the idea that scientists work with each other to resolve conflicts of ideas. Institutional view is the point of view that conflicts are resolved through the institution of science by scientists.

4.6.2 Key Words in Response

In examining the dialogues for this question certain key terms or words were chosen to help align the responses into one of the two categories. Responses that aligned with individualist view may contain terms such as work together, exchange ideas, or compare. These responses show the concept of cooperative work to come to a consensus. For institutional view responses may contain terms such as turn to other scientists, testing out, or do more experiments. These responses show the idea that the conflicts are resolved through the Institute of science itself.
4.6.3 What Students Say

This section contains the categories with full description of each category. It also contains a numerical breakdown of the student responses and an example of the students’ responses for each category.

Table 7 Question five categories and examples. *How is conflicts of ideas resolved in the scientific community?*

<table>
<thead>
<tr>
<th>Categories</th>
<th>Number of Students</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individualists view: Participants will recognize a community of scientists.</td>
<td>15</td>
<td>L4BQ: I think they would have to collaborate and give each of their points maybe there work together and improve whether their opinions better to go with, than yours because I think it would have more, more stuff to find out I think that’s how they would decide on which idea is better.</td>
</tr>
<tr>
<td>Institutional view: The participants will recognize the institution of science.</td>
<td>24</td>
<td>L2AG: They would test it and test it many times to make sure which one is accurate and to know which one is, which one has the most, which one is more right.</td>
</tr>
</tbody>
</table>

4.6.4 Frequency of Responses by Category

54.8% of the responses aligned with institutional view while 45.2% of the responses aligned with individualist view. The breakdown by gender shows females responded with a higher percent, 57.7% for individual view and 42.3% for institutional view. The males were 25% for individualist view and 75% for institutional view.
Figure 6 Question Five: Comparison by gender between Hispanic Students.

4.6.5 COMPARISON BY GENDER: HISPANIC STUDENTS

Twenty-three of the forty-two or 54.8% student responses aligned with Institutional view. Nineteen of the forty-two or 45.2% student responses aligned with individualist view. In regards to the breakdown by gender twelve of the sixteen male students or 75% aligned with Institutional view. Four or 25% male responses aligned with Individualist view. For the female students fifteen or 57.7% aligned with Individualist view while eleven or 42.3% aligned with Institutional view.

4.6.6 COMPARISON BETWEEN HISPANIC AND BRITISH STUDENTS

According to table 6 of the Ryder (1999) study titled “students’ view about social dimensions of science” found on page 209 only seven out of the eleven students responded. The section of the table that reflected the responses from the first interview before the intervention were comparable to the Hispanic students’ responses. Only one student responded in the category of individualists view. Six
students responded in the category “recognition of community of scientists” which corresponds to institutional view in this study. Therefore, *Hispanic students have a wider range of responses in regards to the question “how are conflicts of ideas resolved in the scientific community?”* than *British students.* The Hispanics student responses were close to evenly divided between the two categories whereas the British student responses were in favor of institutional view in regards to the nature of science.

### 4.6.7 Summary of Results for “How Are Conflicts of Ideas Resolved in the Scientific Community?”

This question had no way of directly comparing to the Ryder 1999 study therefore the two genders was compared. One anomaly arose in this comparison. Females were divided approximately 60% individual view and just over 40% institutional view. The males on the other hand were 75% institutional view an oldie 25% individualist view. Frist, *Male Hispanic students were far more likely to consider institutional view as being a means of resolving conflicts within a scientific community.* 75% of the male responses aligned with institutional view while only 25% aligned with individualist view. A little more than half of the female responses aligned with individualist view while a little less than half of the responses aligned with institutional view. With only seven British responses recorded only one response aligned with individual view. Second, *Hispanic students have a wider range of responses in regards to the question “how are conflicts of ideas resolved in the scientific community?” than British students.* The British students’ responses reflected a predominant perception of institutional view in response to this question.

### 4.7 Complexity of Responses

The second method of analysis gauges the complexity of the students’ responses. This is based on Khishfe’s 2012 study in Beirut Lebanon. Khishfe’s also focused on eleventh grade students. Students’ responses are analyzed in accordance with their complexity. This is done in order to reference
the students’ levels of understanding of the nature of science as indicated by the students responses to the five questions used in the interview. Also this analysis gives an idea of how well each question was able to invoke responses from the students. Three levels of understanding of the nature of science are used to gauge this understanding. The first level is naïve when they cannot give a justification for their response. This level is worth one point. The second level is intermediate if they give a response with justification but is not made clear or not fully valid. This level is worth two points. The final level is informed if the justification is clear and fully valid. This level is worth three points. Each question was analyzed individually. The findings from this analysis show that eighty-six or 41% of the total responses were found to be intermediate. Eighty-two or 39% were found to be naïve. Forty-two or 20% of the responses aligned with informed. This information is graphically represented in figure 6.

4.7.1 **Example of Responses**

This section contains five tables, each table will breakdown each question showing the number of students’ responses. Also there is included and examples of responses which align with the three different levels.

Table 8 Complexity of response question one. *How do scientists decide which question to investigate?*

<table>
<thead>
<tr>
<th>Level</th>
<th>Number of students</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naïve</td>
<td>6</td>
<td>L2MR: Well, they want to learn more of that thing. May be they want to find details and details of that certain subject.</td>
</tr>
<tr>
<td>Intermediate</td>
<td>9</td>
<td>L4BA: I would say depending on the situation. Like what you’re looking at, I would go with the one that is most important for like the main thing that goes with the situation. Like when we do chemistry, we do stuff with the chemical and stuff. I would look at like the reactants and the products to see what would go into hypothesis and all.</td>
</tr>
<tr>
<td>Informed</td>
<td>4</td>
<td>L4CF: Well depending on the topic. I mean like it also depends on what they want to find and why they want to find. It could be how strongly they feel on that. Like, say oil spill, they might want to find a different way to, like, clean it up. Maybe it is like personal environmental thought on that subject or may be its just pure money.</td>
</tr>
</tbody>
</table>
Table 9 Complexity of response for question two. *Why do scientists do experiments?*

<table>
<thead>
<tr>
<th>Level</th>
<th>Number of students</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naïve</td>
<td>8</td>
<td>CBM: To find out things</td>
</tr>
<tr>
<td>Intermediate</td>
<td>9</td>
<td>CEV: To learn more about, about it besides getting facts to see how like to see with their own eyes, cause like when they tell you facts sometimes you can imagine them but when you do them like, it’s like you could say like no that’s true it’s going on. You see things like……</td>
</tr>
<tr>
<td>Informed</td>
<td>2</td>
<td>CYF: To learn why one thing can affect another and how it can impact something in your life, like an overall view like, um like, to see where like, why something happens and to see like the details of like fiction and all that.</td>
</tr>
</tbody>
</table>

Table 10 Complexity of response for question three. *How can good scientific work be distinguished from bad scientific work?*

<table>
<thead>
<tr>
<th>Level</th>
<th>Number of students</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naïve</td>
<td>2</td>
<td>L2AG: They do anything wrong then they, like the data is wrong and maybe that is bad scientists.</td>
</tr>
<tr>
<td>Intermediate</td>
<td>11</td>
<td>L1JG: The right data and the process that they do it, how they do it. Thing that makes you think like, oh yeah this so right, I could test this out and it will come out the way I did it.</td>
</tr>
<tr>
<td>Informed</td>
<td>5</td>
<td>CRS: The way it affects our society. Like, all the medication we get for, like to prevent like diseases? Interviewer: And then what would you can be considered as, as bad? Student: I think abortions would be bad.</td>
</tr>
</tbody>
</table>

Table 11 Complexity of response for question four. *Why do you think that some scientific work stands the test of time where as other scientific work is forgotten?*

<table>
<thead>
<tr>
<th>Level</th>
<th>Number of students</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naïve</td>
<td>8</td>
<td>L2AM: I don’t know Umm…Maybe….. Can’t think of anything.</td>
</tr>
<tr>
<td>Intermediate</td>
<td>7</td>
<td>L1JG: The scientists prove them to be right, the stuff they did, and the experiments they did. Because scientists proved them. Interviewer: And then the stuff that is forgotten is why? Student: It doesn’t matter anymore?</td>
</tr>
</tbody>
</table>
| Informed  | 4                  | L4BA: I would say yeah, I would say the findings, the big findings they do to help, like, to help the future. Like, for me I want to be a marine biologist so if I find something that is going to be really helpful to the animals then they are going to keep going on that because it helps them. Interviewer: Perfect! Ok and then, on the other end of flip, what makes a scientific work not last? L4BA: umm… If you do a poor job at it and you know you are not paying
attention to it, the people are not really going to remember it...it is not really big to them.

Table 12 Complexity of response for question five. *How is conflicts of ideas resolved in the scientific community?*

<table>
<thead>
<tr>
<th>Level</th>
<th>Number of students</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naïve</td>
<td>3</td>
<td>CBM: I'm not sure. By experimenting?</td>
</tr>
<tr>
<td>Intermediate</td>
<td>11</td>
<td>L4BA: umm……how are conflicts resolved……….I would say through the research, like depending on if the two people have the same research, one is more accurate than the other and then they will see which one is more put together and more accurate than compared to the other. I would see, I for I would go back and do it just to see if get the same answer, just to make sure and if I did, I would probably try and check to see like compare the two to see which ones were the same or different between the two to see which one is better than the other.</td>
</tr>
<tr>
<td>Informed</td>
<td>5</td>
<td>CYF: Mm, by looking at the problem and weighing it out from, from positive things to negative things looking at all the data and seeing how to solve the conflict. The one that's over ruled, the one that has the more, like, if you get a group together and they all decide on one over the other.</td>
</tr>
</tbody>
</table>

4.7.2 **Numerical Breakdown of Responses**

The following section has a graphical depiction of the breakdown of the responses. Each question is listed in order below and divided into three categories, naïve, intermediate, and informed. The information contained in this section is not broken down by gender but is by overall student responses.
The complexities of responses were tremendously varied depending on the individual. Very few students’ responses all fell within one category. Many of the students who had responses that would be considered naïve for one question would give a response for another question that would fall within the informed category. With the exception of question four which had a majority of naïve responses, the majority of the responses fell in the intermediate category. A total of 210 responses were categorized, eighty-two or 39% were found naïve, eighty-six or 41% intermediate and forty-two or 20% informed. Question to have the highest number of naïve responses with twenty-two over half of the responses. Question one followed with the highest number of naïve responses with twenty. Question three had the least amount of naïve responses and the highest number of informed responses. Therefore this question was able to develop the highest amount of dialogue.
4.7.3 **Comparison Between Lebanese and Hispanic Students**

The Lebanese students were all eleventh grade students around the same age as the Hispanic students. The Lebanese students were given two different scenarios to discuss and three different opportunities to discuss the scenarios, the argument, counterargument, and rebuttal. The data that was compared to the Hispanic students was based on Scenario one argument analysis concerning NOS. *Hispanic students were able to give informed responses more often than the Lebanese students.* Lebanese students had 11% informed while Hispanic students had 20% informed responses. The Lebanese students were 34% naïve, 55% intermediate and 11% informed. The Hispanic students were 39% naïve, 41% intermediate and 20% informed (Khishfe 2012). Although the Hispanic students had a slightly higher percentage of students responses considered naïve they had a considerably higher percentage of informed responses. Although each group used different questions, the same method for evaluating the complexity of responses was the same the two studies were comparable.

**Discussion**

5.1 **Discussion of Study**

The questions used in the interview were initially used for undergraduate students but are simple enough to be understood by the high school students that were interviewed. Any problems with English language learners or ELLs were addressed by the interview format which gave the students the ability to ask for explanations or to reword any question they may not understand. The individual format was superior in this situation to a focus group due to the desire for individual responses and not a consensus from a group. All the students in this group are maintaining an above average GPA in their studies and many of them are involved in extracurricular activities such as sports, performing arts. All of the students consider themselves Hispanic in heritage and according to one study may be at an advantage by
having a solid and positive validation of home culture which can help counter the homogenizing into mainstream (Eatela Zarate & Bhimji, 2005).

In this section the responses will be examined through the lens of the nine cultural values and scripts. There was inference based on the literature making the best possible connection. Looking at the analysis the alignments are one way of rationalizing the findings. This is not the only possible reason for the students responding as they did.

Upon analyzing question one, “how do scientists decide which question to investigate?” it can be seen that the students were not considering financial gain as being an important factor for scientists to do research. This was a sharp contrast to the British students in the Ryder 1999 study. The British students reflected that scientists go into scientific research for financial benefit more than any other factor. It may be possible that stemming from Familismo may lead to the idea of sacrificing one’s own needs for the good of the family. These students may look at the science community as being a family where the scientist is more concern for the good of the community. This may have been due to collectivism which extends this idea outside of the family to other groups. Considering collectivism these students may not consider individuals going into science for their own financial benefit. They may think that individuals going to scientific research for the good of the science community or for the good of mankind. Addressing this perception may help to increase Hispanic students interest in STEM fields as a life career. If these students are made aware of the financial benefits their interest in these type of careers may increase. There are many ways of correcting this misconception. One could be creating a spreadsheet that lists STEM fields as well as their average annual income. Another possible way to intercede may be by inviting actual scientists to speak at a school assembly where the scientist may discuss financial benefits of entering in the field.

Question two, “why do scientists do experiments?” found none of the Hispanic students considered Indirect Evidence as being a factor that scientist may consider when doing experiments.
According to Donnelly and Argyle’s 2011 study scientists making observation and inferences from those observations to generate scientific knowledge is an important aspect of NOS (Donnelly & Argyle’s 2011). Addressing this deficiency in understanding would help Hispanic students in their understanding of NOS. Students who understand that scientists are not limited to basing their findings on direct evidence but are allowed the ability to think outside of the box in order to further their research may find science more interesting. This could be accomplished by incorporating research that used indirect evidence and lesson plans. This issue could also be addressed by having actual scientists speak to students.

In examining the responses for question three, “how can good scientific work be distinguished from bad scientific work?” It was found that the students’ responses naturally fell into two distinct categories. The first category was that the students felt that the difference between good and bad scientific work was based on the quality of the work. The second was that scientific work was either good or bad based on the use of the work; whether the work was beneficial are detrimental to society, the environment or mankind. It was found that male students were far more likely to consider the quality of the work over the use of the work than the female students. One of the possible factors that may account for this difference could be the influence of Machismo. Although machismo is a cultural value shared by both male and female it manifests itself differently in the different genders. In Ruiz’s 2009 article gave the example of how females look more at how machismo affects them in their family relationships. Male students may believe that males are being the head of the household giving them responsibility to provide care and protection for the family. This value may extend beyond the family to the Institute of science. The male students could look at scientists as being the counterpart to head of the household. This would make the scientists responsible for producing quality work.

Some individuals had responses that reflected cultural influences due to religious beliefs or religiosity as deciding scientific work is bad as it conflicted with their beliefs. Two examples of what students felt was bad scientific work due to their beliefs are as follows. The first example, CAR: “I guess that whole evolution thing; because I don’t believe in it.” Responding to the same question to students
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These students demonstrated a strong delineation between science and their belief which in these examples are opposing.

Question four, “why do you think some scientific work stands the test of time whereas other scientific work is forgotten?” found that the Hispanic students were two times more likely to consider the inherent quality of work as being the factor that best influenced scientific works longevity than the British students. In examining the nine cultural values and scripts no correlation could be made to explain this phenomenon. Further investigation is needed in order to identify any cultural influences that could account for this difference.

For question five, “how is conflicts of ideas resolved in the scientific community?” may have yielded signs of influence from to Hispanic cultural values based on differences in perceptions by the genders. 57.7% of the total female responses aligned with individualist view while 75% of the male responses aligned with institutional view. The value which may have a greater influence upon the female students in higher alignment individualist view may have been more influenced by Simpatía. According to the Jeong Jin, Lucero-Liu, Gamble, Taylor, Christensen & Modry-mandell (2008) article, which explores cultural values as they affect women, indicate this value refers to respect and politeness.
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will look at other relationships through the lens of their core cultural value which is Familismo.

The last section of analysis which measures the complexity of the responses shows that some
questions invoked greater dialogue than others. Using this information further research may use better
developed questions to create greater amounts of dialogue which will allow better understanding of any
cultural influences which may affect the students’ understandings of the nature of science. When
compared with Lebanese students in the same grade the Hispanic students were able to give more
informed responses. The Hispanic students in this section still showed low numbers in informed
responses for all of the questions. This also indicates these students could benefit by having a higher
understanding of the nature of science.

The first question showed a deficit in understanding of the financial benefits in scientific
research. This is an important factor when considering career fields and may direct these students in
other vocations that they may feel has better earning potential. A Hispanic value or script that may have
effect on this outcome may be collectivism. These students may have the perception of scientific work
being beneficial to the whole group and not see individual benefits for themselves. Holding the value of
collectivism individuals may sacrifice their own needs for the benefits and good of the whole group.
These students may consider science as the group and scientists as individual members. According to a study in 2011 one of the most important factors high school students consider in choosing a career field is earning potential (Hall, Batts, Kaufmann & Bosse, 2011). Hispanic students’ perception of financial reward gained through involvement in science and STEM fields is misunderstood they may be led into other career choices that they may feel are more financially rewarding. By revealing to the students of the financial opportunities that can be found in pursuing STEM employment may increase the interest of the students in pursuing these fields. This may shed light and help in the understanding of Hispanic students experience in science. Addressing other cultural values which may impede student’s full understanding of the nature of science is of major significance. It is extremely important to develop ways to address any cultural influence which may predestined a student to have a low understanding of the nature of science. When students understand the culture of science it helps them to develop a positive understanding of science (Guney & Seker, 2012). All the students in this study were high school juniors who maintained an above average GPA. The high school they intended is focusing on STEM education. All the students are Hispanic. Therefore the findings of this research are culturally relevant even though none of the questions were designed to invoke responses based on cultural background the responses are the students’ responses and by definition are responses of Hispanic high school students. There is evidence of underdeveloped understanding of the nature of science in this study.

The questions used in the interview were initially used for undergraduate students but are simple enough to be understood by the high school students that were interviewed. Any problems with English language learners or ELLs were addressed by the interview format which gave the students the ability to ask for explanations or to reword any question they may not understand. The individual format was superior in this situation to a focus group due to the desire for individual responses and not a consensus from a group. All the students in this group are maintaining an above average GPA in their studies and
many of them are involved in extracurricular activities such as sports, performing arts. All of the students consider themselves Hispanic in heritage and according to one study may be at an advantage by having a solid and positive validation of home culture which can help counter the homogenizing into mainstream (Eatela Zarate & Bhimji, 2005).

Upon analyzing question one, “how do scientists decide which question to investigate?” it can be seen that the students were not considering financial gain as being an important factor for scientists to do research. This was a sharp contrast to the British students in the Ryder 1999 study. The British students reflected that scientists go into scientific research for financial benefit more than any other factor. It may be possible that stemming from Familismo may lead to the idea of sacrificing one’s own needs for the good of the family. These students may look at the science community as being a family where the scientist is more concern for the good of the community. This may have been due to collectivism which extends this idea outside of the family to other groups. Considering collectivism these students may not consider individuals going into science for their own financial benefit. They may think that individuals going to scientific research for the good of the science community or for the good of mankind. Addressing this perception may help to increase Hispanic students interest in STEM fields as a life career. If these students are made aware of the financial benefits their interest in these type of careers may increase. There are many ways of correcting this misconception. One could be creating a spreadsheet that lists STEM fields as well as their average annual income. Another possible way to intercede may be by inviting actual scientists to speak at a school assembly where the scientist may discuss financial benefits of entering in the field.

Question two, “why do scientists do experiments?” found none of the Hispanic students considered Indirect Evidence as being a factor that scientist may consider when doing experiments. According to Donnelly and Argyle’s 2011 study scientists making observation and inferences from those observations to generate scientific knowledge is an important aspect of NOS (Donnelly &
Argyle’s 2011). Addressing this deficiency in understanding would help Hispanic students in their understanding of NOS. Students who understand that scientists are not limited to basing their findings on direct evidence but are allowed the ability to think outside of the box in order to further their research may find science more interesting. This could be accomplished by incorporating research that used indirect evidence and lesson plans. This issue could also be addressed by having actual scientists speak to students.

In examining the responses for question three, “how can good scientific work be distinguished from bad scientific work?” It was found that the students’ responses naturally fell into two distinct categories. The first category was that the students felt that the difference between good and bad scientific work was based on the quality of the work. The second was that scientific work was either good or bad based on the use of the work; whether the work was beneficial are detrimental to society, the environment or mankind. It was found that male students were far more likely to consider the quality of the work over the use of the work than the female students. One of the possible factors that may account for this difference could be the influence of Machismo. Although machismo is a cultural value shared by both male and female it manifests itself differently in the different genders. In Ruiz’s 2009 article gave the example of how females look more at how machismo affects them in their family relationships. Male students may believe that males are being the head of the household giving them responsibility to provide care and protection for the family. This value may extend beyond the family to the Institute of science. The male students could look at scientists as being the counterpart to head of the household. This would make the scientists responsible for producing quality work.

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Question four, “why do you think some scientific work stands the test of time whereas other scientific work is forgotten?” found that the Hispanic students were two times more likely to consider the inherent quality of work as being the factor that best influenced scientific works longevity than the British students. In examining the nine cultural values and scripts no correlation could be made to explain this phenomenon. Further investigation is needed in order to identify any cultural influences that could account for this difference.

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5.2 Future Research

It appears that Hispanic students’ perception of NOS may differ by gender. In this study and effort was made to break down the analysis by gender. Further research needs to be done in order to identify both further differences between genders and why there are differences between genders and does not necessarily need to be done in regards to a particular culture. As seen in the responses to the
question “how can good scientific work be distinguished from bad scientific work?”
The students in this study responded in one of two distinct ways. The first way was that they considered good scientific work to be good due to the quality of the work. The second way was the students considered the use of the work as being the determining factor, i.e. creating chemical weapons or bombs. Further research should be done in order to determine whether this perception is unique to this group or if this perception is held by other high school students. In this study was found that British students consider financial benefits as being the number one reason why an individual would become a scientist while the Hispanic students did not consider financial benefit to be a factor. There needs to be more research to identify why this difference has occurred. It was also found that Hispanic students did not consider indirect evidence as being a factor as it relates to why scientists do experiments. Further studies need to be done in order to identify why Hispanic students do not consider indirect evidence as being a factor. The Hispanic population is the fastest-growing sector in the United States. The Hispanic population has a very low representation in STEM fields. Further research needs to be done in order to develop a means for enhancing Hispanics’ interest in STEM fields.

5.3 LIMITATIONS

The connections between the cultural values and scripts were made based on the descriptions provided through the research. It is possible that the reason the students responded as they did was not due to their cultural background but for other reasons. The research was limited to the aforementioned questions answered during one interview. In order to make an absolute connection to these students’ responses and their cultural values and scripts more in-depth research needs to be done.
References


Minority population tops 100 million: Nearly one in three U.S. residents is a minority, U.S. census bureau reports. (2007). *Public Relations Tactics, 14*(7), 27.


Appendix

Pre-Interview Questions for High School Students Follow-Up Questions

Prompt Questions on “Nature of Science”


[10 second pause to allow student time to think.]

1. How do scientists decide which question to investigate?
   a. What do you think motivates scientists?
   b. Can you think of some of the factors scientists consider when deciding which question to investigate?

2. Why do scientists do experiments?
   a. What do you think are some of the important things a scientist may consider when they do experiments?

3. How can good scientific work be distinguished from bad scientific work?
   a. Can you think of any examples of good scientific work? What makes it good?
   b. Can you think of any examples of bad scientific work? What makes it bad?

4. Why do you think that some scientific work stands the test of time whereas other scientific work is forgotten?
   a. What are some of the things you think allows scientific work to stand the test of time?
   b. What are some of the things you think causes scientific work to be forgotten?

5. How are conflicts of ideas resolved in the scientific community?
   a. What if scientists have opposing opinions in regards to the same research?
   b. What if scientists come to different conclusions when analyzing the same data?

Prompt Questions on “Perception of Students Scientist Partnership”

1. What does a scientist mean to you?
   a. When you think of a scientist, what image comes into your mind?

2. What are some of the benefits you think high school students will have by working with scientists?
   a. What will the student get from the experience?
   b. Do you think it will have a lasting impact on the student?

3. What are some obstacles you think high school students will have by working with scientists?
   a. What problems will students face when working with scientists?

4. What are some benefits you think scientists will have by working with high school students?
   a. Do you think scientists receive anything of value by the experience of working with students? How will it help the scientist in the future?

5. What are some of the obstacles you think scientists will have by working with high school students?
   a. What do you think will be hard for scientists?

6. What would be the best relationship between high school students and scientists? Could you give a metaphor for this relationship? [At least a 15 second pause for this question]
   a. Can you think of any relationship between two groups that may be similar to the relationship between high school students and scientists working together?

   [What do you mean? Would you give me an example? Would you tell me more about that?]
Vita

Born in Albuquerque New Mexico and adopted by the Earl R. and Laverne A. Wilson I lived there with my adopted brother Douglas until the age of 13. In the summer of 1970 our family moved to El Paso Texas. I graduated from Eastwood high school in the spring of 1976. A few days after graduating from high school I started a two year technical training course in Wichita Falls Texas where I gained my Airframe and Powerplant mechanics certification. I worked nearly 30 years as an aircraft mechanic holding the position of Director of Maintenance for three different El Paso-based error charter corporations. I was awarded employee of the month on two separate occasions working in El Paso for a better charter corporation that was based in Addison Texas. I started working as a volunteer with youth and children in the early 90s and was one of the founding members of the Eastside youth connection, a nonprofit that works with and mentored young people. I received the honor of most popular adult youth worker in 1991 and 92. I wrote a grant proposal and received $10,000 funding from The Del Norte Health Foundation in 1992. In the mid to late 90s air charter businesses suffered a major downturn in El Paso. Not wanting to leave the city I decided to change directions in my career field to one that worked with youth. In the summer of 1998 I enrolled in the University of Texas at El Paso. I graduated in May 2012 Cum Laude with a Bachelor’s of Interdisciplinary Studies from the college of education focusing on the math and science. I am currently working towards my Masters of Art in Education degree at the University of Texas at El Paso.

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This thesis proposal was typed by Cameron Wilson.