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An Investigation of the Effects of an Authentic Science Experience Among Urban High School Students

Angela Chapman
University of South Florida, achapma2@mail.usf.edu

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by

Angela Chapman

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Major Professor: Allan Feldman, Ph.D.
Sarina Ergas, Ph.D.
Benjamin Herman, Ph.D.
Rosemary Closson, Ph.D.

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DEDICATION

To my parents, Richard and Treva Norris, and

to all of my former students for the inspiration

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ABSTRACT

Providing equitable learning opportunities for all students has been a persistent issue for some time. This is evident by the science achievement gap that still exists between male and female students as well as between White and many non-White student populations (NCES, 2007, 2009, 2009b) and an underrepresentation of female, African-American, Hispanic, and Native Americans in many science, technology, engineering, and mathematics (STEM) related careers (NCES, 2009b). In addition to gender and ethnicity, socioeconomic status and linguistic differences are also factors that can marginalize students in the science classroom. One factor attributed to the achievement gap and low participation in STEM career is equitable access to resources including textbooks, laboratory equipment, qualified science teachers, and type of instruction. Extensive literature supports authentic science as one way of improving science learning. However, the majority of students do not have access to this type of resource. Additionally, extensive literature posits that culturally relevant pedagogy is one way of improving education. This study examines students' participation in an authentic science experience and argues that this is one way of providing culturally relevant pedagogy in science classrooms.

The purpose of this study was to better understand how marginalized students were affected by their participation in an authentic science experience, within the context of an algae biofuel project. Accordingly, an interpretivist approach was taken. Data were collected from pre/post surveys and tests, semi-structured interviews, student journals, and classroom observations. Data analysis used a mixed methods approach. The data from this study were analyzed to better understand whether students perceived the experience to be one of authentic science, as well as how students science identities, perceptions about who can do science, attitudes toward science, and learning of science practices were affected by participation in an authentic science experience. Findings indicated that participation in an authentic science experience has a positive effect on science identities, scientist perceptions, science attitudes, and learning of science and is one approach to mitigating the effects of marginalization in the science classroom. Additional findings indicated that a relationship between the authenticity of the experience and the outcomes (science identity, perceptions about who can do science, science attitudes, and learning of science). This study provides empirical evidence to support authentic science learning as a means of improving students' learning, attitudes, and identities with respect to science. This study endorses authentic science experiences for all students, marginalized included. This has implications for how we prepare future and support current science teachers. In addition, this study shows how this model can be used to effectively implement science, technology, engineering, and mathematics (STEM) education.

CHAPTER 1: INTRODUCTION

Statement of the Problem

Science education has been encumbered with obstacles for some time. These obstacles have made it difficult to provide equitable learning opportunities for all students, made evident by the science achievement gap that still exists between male and female students as well as between White and many non-White student populations (NCES, 2007, 2009, 2009b). In turn, there is still an underrepresentation of female, African-American, Hispanic, and Native Americans in many science, technology, engineering, and mathematics (STEM) related careers (NCES, 2009b).

When socioeconomic status, ethnicity, and linguistic differences are examined, it suggests that these student populations are more likely to become marginalized with regard to their K-12 and postsecondary science education. Marginalization is manifested as a lack of interest in science, low performance in science classes, and underrepresentation in science related careers (Buxton & Lee, 2010). Many have argued that the persisting inequalities have led to lower academic achievement, resources, schooling practices, and school culture conflicts (Barton, 2001; Bryan & Atwater, 2002; Duncan, 2010).

Marginalized students in science education are also described as disengaged, lacking self-efficacy about their science abilities, and/or view science as irrelevant and boring (Barton & Yang, 2000; Basu & Barton, 2007; Seiler, 2001; Zacharia & Barton, 2004). With regard to academic achievement, marginalization is evidenced in part by low achievement on standardized science tests (Barton, 2001; Seiler, 2001; Tobin, Elmesky, & Seiler, 2005; Tobin, Seiler, & Smith, 1999) There is a large body of evidence that demonstrates a science achievement gap between White, African American[1], and Hispanic students on standardized science tests such as the Trends in International Mathematics and Science Study (TIMSS), and the National Assessment of Educational Progress (NAEP). In addition, these same students often have low participation in science, technology, engineering, and mathematics (STEM) related careers (NCES, 2007, 2009).

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[1] While recognizing that racial categories are socially constructed, the following operational definitions of White, African-American, and Hispanic are used. White**:** A person having origins in any of the original peoples of Europe, the Middle East, or North Africa. African American: A person having origins in Africa. African American is used interchangeably with Black. Hispanic: Persons having origins in Mexico, Puerto Rico, Cuba, Central or South America, Spain, or Portugal.

One factor attributed to the achievement gap and low participation in STEM career is equitable access to resources. The idea of resource inequities is multifarious in nature. For example, resources may either be school-based, home-based, or community-based. With regards to home-based resources, marginalized students often lack the cultural or financial capital needed to ensure success in science classes. For example, students from low SES families may find it difficult to bring in resources from home needed for projects in science classes, and parents may not know how to negotiate school cultures to ensure their child receives access to quality resources. With regard to community-based resources, marginalized students may not have access to scientists and other professionals in the community; while science fair competitions are common in elementary and secondary science classes; competition at regional, state, and international is highly competitive and considered elitist. Often, students that advance to regional, state, and international competitions are those that have access to scientists, equipment, and laboratories at research I or similar institutions (Bencze & Bowen, 2009). In addition, the majority of students are from middle or upper SES families who have the financial capital to help their children prepare highly competitive presentations or science fair boards.

My five years of experience as a science fair director supports these findings. It was a difficult and daunting task to provide my students with resources to develop projects that would be considered competitive for regional and state competitions. Regardless, while there seems to be more equal representation of male and female White and Asian students at higher-level science fair competitions, this is not the case for Hispanic and African American students of either gender. With regard to school-based resources, marginalized students often have limited access to current textbooks, scientific equipment needed to conduct experiments and other inquiry-based activities, or as highly qualified certified science teachers (Barton, 2001; Darling-Hammond, 1999; Oakes, 2000). In addition, schooling customs, especially in urban schools, often track students into low-level classes. Low level science classes are typically not designated as college track. Instead these classes the focus is often on rote memorization rather than higher level cognitive processes. For example, reading textbooks and worksheets are more commonplace than inquiry-based, hands-on activities that promote critical thinking (Oakes, 2000).

There is a considerable body of research examining the differences between school and home cultures (Barton & Yang, 2000; Buxton & Lee, 2010; Duncan, 2010; Ladson-Billings, 1995, 2000; O. Lee & Fradd, 1998). Often, there is considerable difference between values and beliefs of students' home culture and that of school culture. In addition, school cultures often create a dominant culture that reflects the culture of the teacher (Ladson-Billings, 2000). When individuals lack an understanding of other cultures, it can lead to conflict and power imbalances. If students lack access to the rules and norms of the dominant culture, they can become silenced.

If we want to ensure equitable access to high quality science instruction, then we need to find ways to eradicate the inequalities that exist in our current system of science education. All students deserve not only equal access to resources necessary for high academic achievement, but also to have their beliefs and values recognized in the classroom.

A lack of equitable distribution of resources and cultural conflicts in classrooms are issues that have persisted in science education. These issues have led to lower academic achievement in science, and underrepresentation of females as well as Hispanic, and African-American males in science, technology, engineering, and mathematics (STEM) related careers.

Rationale for the Study

Both authentic science experiences and culturally relevant pedagogy have been proposed as ways of improving science learning. Authentic science experiences are those in which students learn science in a way that reflects how science is performed by scientists rather than what is reflected in conventional textbooks as activities, while culturally relevant pedagogy calls for high quality learning while allowing students to develop a critical consciousness and cultural competence (Hsu, Roth, & Mazumder, 2009; Ladson-Billings, 2000).

If we want to reduce or even eliminate marginalization of student populations in science education, then we need to identify learning experiences for students that ensure they have the opportunity to engage in high quality science learning experiences. By doing so, we offer marginalized students the same opportunity for successful academic achievement in science and the opportunity to pursue science related careers based on choice rather than exclusion and lack of confidence to succeed. I sought to better understand how students' science identity, learning of, and attitudes toward science were affected by examining student experiences as well as outcomes of student participation in an original research project.

Several studies have examined the experiences of students and have exposed the conflicts and power differentials that arise from different cultures in the classroom and the need for culturally relevant pedagogy (Barton, 2001; Barton & Yang, 2000; Ladson-Billings, 1995, 2000). One aspect is the concept of differences with regard to students' and teachers' cultural and social capital. Cultural capital is defined as the advantages an individual has due to types of knowledge, abilities, and education that s/he possesses. Individuals with more cultural capital have a higher societal status (Bourdieu, 1986). Bordieu (1986) argues that students acquire cultural capital via transference from their parents, and this high level of cultural capital allows them to succeed in their educational system. Social capital is described as "access to advantageous social networks" and the gains that can come from those connections (Bencze & Bowen, 2009; Bourdieu, 1986). Bordieu (1986) posits that social capital often creates an atmosphere of exclusiveness rather than inclusiveness.

Those students with significant cultural and social capital are typically from high-SES families while students lacking cultural and social capital often do not have the knowledge of or access to the rules of the dominant culture. This can result in marginalization in the classroom. For example, I will show that several of the students that participated in this study lack the cultural and social capital needed to ensure they have had access to equitable resources necessary for a quality science education. In addition, all students participating in the project possess at least one marginalizing factor.

In addition, there is a significant amount of literature that suggests one way to improve science education is through student engagement in authentic science activities.

Often students are expected to learn science through cookbook labs and worksheets offered in most district-adopted textbooks. On the other hand, authentic science activities have been suggested as a way to improve student attitudes toward science, learning science, and motivation to pursue science related careers (Buxton, 2006; Chinn & Malhotra, 2002; Feldman & Pirog, 2011; Hsu et al., 2009; Sadler, Burgin, McKinney, & Ponjuan, 2010). However, what is missing in the literature is an understanding of the student's perspective with regards to the authenticity of the project, and the relationship between participation in authentic science and attitudes toward science, learning of science, and perceptions about who can become a scientist (Buxton, 2006; Chinn & Malhotra, 2002; Feldman & Pirog, 2011; Hsu et al., 2009; Sadler et al., 2010). While teachers and scientists may collaborate to design a project they believe to be authentic, do students share in this belief? One goal of this study was to gain an understanding of the students' beliefs, ideas, and perceptions about the authenticity of the project.

This study has been designed to investigate the effects of student participation in an authentic science experience. Students were allowed to develop critical consciousness and cultural competence during an original research project. As a result, I was able to investigate an authentic science experience as a form of culturally relevant pedagogy. I then investigated the effects of student involvement in an authentic science project with regards to their attitude, science identity, learning of scientific practices.

Purpose of the Study

The purpose of this mixed methods study was to better understand how students are affected by their participation in an authentic science experience within the context of an algae biofuel project. Participants in this study include high school students, their teachers, and university engineering researchers. The participants worked collaboratively at a local high school to investigate factors for optimal algae growth as part of regular classroom instruction. This took place as a pilot project in an agricultural science class, and then during a marine science class. An important aspect of this study is that it is modeled after a contextually based authentic science experience in that students will perform science in a manner that reflects how it is done by scientists and have a voice in what they investigate (Buxton, 2006). This involves performing original research, developing hypotheses and research questions, analyzing data, forming inferences and conclusions, as well as communicating their results and conclusions.

Research Questions

In this study I examined the effects of students' participation in scientific inquiry that was authentic to them and/or to the practice of science. The study was situated in a high school where a university-based environmental engineering research group (a faculty member and several graduate students) worked with the students and teachers to investigate algae as a biofuel. This study looked at the ways in which this type of experience affected student participants in terms of their attitude toward science, science identity, perceptions about who can do science, and their learning of science practices. In addition, the study investigated whether the experience was authentic to the student. The research questions guiding this inquiry were:

1. With regard to students' perceptions, was their involvement in this project an authentic science experience?
2. How did the participation of high school students in an authentic science project affect their identities as scientists and perceptions about who can do science?
3. How did the participation of high school students in an authentic science project affect their attitude toward science?
4. How did the participation of high school students in an authentic science project affect their learning of science practices?

Significance of the Study

This study contributed to a better understanding of student experiences in authentic science projects as it related to their learning of science, attitudes toward science, and possibly motivation to pursue science related careers. The need for the implementation of high quality models of effective science instruction is made evident by the inequalities that still exist in science education. One possible approach is to provide students with access to authentic science and practicing scientists in an environment that encourages them to ask questions and think critically as a means of improving their learning of science practices.

This study had several significant features. First, the study was situated within an urban high school with a diverse student population in which these students were conducting original research in collaboration with environmental engineering researchers. The majority of students in these classes did not have previous access to these types of resources, including the researchers, equipment, and opportunity to perform original research. In addition, all students possessed at least one marginalizing factor. This was important, as it offered marginalized students access to rich cultural and social capital, a type of capital that has been attributed to scientific academic success (Barton, 2001; Barton & Yang, 2002; Bencze & Bowen 2009; Lee & Buxton, 2010). Second, the study was designed to investigate the student's experience as well as how students were affected by participation in an authentic science experience: specifically, changes in science attitudes, learning of content, science identity, and perceptions about who is capable of becoming a scientist. Third, it allowed for an in-depth analysis of the effectiveness of a contextually based authentic science experience as a model of science instruction. Fourth, the study was designed to determine whether the students perceived the experience as authentic science rather than assume it was authentic to the student based on the perspective of the engineering researchers and educators.

While there is extensive literature examining the inequalities that exist in science education, many of the studies have examined individual experiences through a qualitative lens that utilized case study or ethnographic methodologies. This study used both quantitative and qualitative data analysis to better understand student experiences throughout the project in conjunction with student outcomes.

From a methodological perspective, this investigation provided useful results due to the nature of the mixed methods design. Combining quantitative and qualitative methodologies in a single study can serve the purpose of allowing data sources to complement each other (Creswell, 2007; Johnson & Chistensen, 2012; Tashakkori & Teddlie, 1998). This approach allowed for a more detailed and deeper understanding of student participation in an authentic science project. This was accomplished by measuring student attitudes toward science, perceptions about scientists, and understanding of science content at the beginning and end of the project in addition to examining the experiences of students. From a methodological perspective, this study added to the mixed methods research literature.

Researcher

My academic background includes a Bachelor of Science in Zoology and a Master of Science in Biology. During my last year as an undergraduate I had the opportunity to take part in an independent study project researching neuroanatomical structures related to sexual behaviors in rats. In spite of my lifelong desire to study science, this sadly was my first experience with doing what is I now understand is authentic science, as I was worked in a research lab with graduate students and a researcher professor. My previous undergraduate labs were standard cookbook type activities that had a predetermined outcome while my high school experience with science was limited to one earth science class.

While pursuing my Master's degree in Biology, I studied the development of the visual system in the leopard frog. Even though 20 years have lapsed, I still recall the excitement when I was sitting at the microscope at 2 a.m. and confirmed the presence of a novel neurotransmitter whose synthesis is activity-dependent. That was my first experience with the thrill of scientific discovery and I was instantly reminded of a statement often attributed to Francis Crick: that nothing is more exciting than making a discovery and knowing that for a brief moment in time, you are the only person with this knowledge.

While pursuing a Ph.D. in Physiology, I left graduate school to teach anatomy, physiology, and biology courses at a community college. From the beginning of my teaching career, wanting my students to know and experience the excitement that comes from self-discovery has been central to my teaching philosophy.

My early teaching career involved teaching of anatomy and physiology courses to pre-nursing and other allied health students, primarily at community college or four year college level. Due to the open admissions policies of these colleges, the classes I taught were a mixture of traditional and nontraditional students from very diverse backgrounds. The diversity of students was reflected not only in the level of preparation for rigorous science courses, but also socioeconomic status, and ethnicity.

My early and continued experience as a college instructor was that students often struggled to learn the material in spite of a strong passion to pursue a career in the medical field. Based on my professional experience and anecdotal observations, I found commonalities between low performing students were lack of academic preparation and being a first generation college student. Unfortunately, a disproportionate number of students that were academically underprepared and first generation college students were either female or students of color and least likely to be White male. In other words, I professionally witnessed what is referred to as the science achievement gap.

When I tried to have conversations with my colleagues about what I consider to be an unacceptable inequity, I was often met with a wall of resistance and indifference. In addition, my colleagues adopted teaching philosophies that resembled the traditional method of instruction they were exposed to during their undergraduate and graduate education. In 2004, I had the opportunity to teach middle school science, excited for the chance to better understand why students were not academically prepared for college science courses in spite of a great interest in pursuing a science related career. Within a very short period of time I became very aware of the inequities that are documented in the literature – unofficial tracking of students into low-level academic classes, lack of access to resources needed for effective learning of science, teacher preparation, and power struggles in the classroom due to cultural differences between students and teachers. While I continually sought to find effective teaching strategies for all my students, it was rarely an easy process and I was not always successful. I had to admit that I found myself in cultural conflicts (Duncan, 2010) with my students, and that my mere presence as a White teacher from a middle class background affected how some of my students were willing to respond to me or to interact with other students in the classroom. However, I continually worked to create an open atmosphere in which students felt safe to express themselves as I felt it was critical to student learning. It was the culmination of my experiences as an educator, first at the community college and then at the secondary level, which led to my decision to pursue a Ph.D. in science education.

My first reaction to taking graduate education courses was amazement at the difference in attitudes and method of instruction. With few exceptions, my undergraduate and graduate education in the sciences were traditional: the professor assumed the role of the "sage on the stage" and disseminated information that I was expected to synthesize and apply on my own. In other words, these classes were almost entirely teacher-centered. The instruction reflected the positivistic training of my professors, which emphasized becoming competent researchers rather than educators. In contrast, my graduate courses in the education program were almost exclusively student-centered and involved significantly more teacher-student interactions than my science courses.

The question I continually ask myself is "How do we intersect science content with science education" as they are sometimes viewed as mutually exclusive entities. Being a content expert does not guarantee being able to effectively teach students, nor does being an educator ensure that teachers have the necessary content knowledge needed to teach science content. My personal desire is to find a way to integrate these two worlds so that every single student has the opportunity to experience high quality learning of science, as well as an excitement and passion for science.

In this study, I assumed the role of researcher and administered informed consent forms, surveys, and tests at the beginning and end of the project and was responsible for data analysis. In addition, as the researcher I assumed the role of nonparticipant observer throughout the project in order to better understand the context of the project, and to develop trust and rapport with the participants.

Definition of Terms

The following key terms have been defined for the context of this study:

1. Authentic Science - forms of engagement that have a high degree of family resemblance with the real jobs of scientists and technicians in science-related fields (Hsu et al., 2009).
2. Researcher – One who performs scholarly or scientific inquiry. In the context of this study, there were education researchers and engineering researchers. I assumed the role of education researcher, while it is the goal of this project that the high school students, teachers, and USF Environmental Engineering professors and graduate students will assume the role of engineering and/or science researchers.

3. Marginalized student – one who has been excluded from mainstream education afforded to more privileged groups of students and can be attributed to the socioeconomic status, ethnic, and linguistic background of the student.

Summary

The purpose of this mixed methods design study was to gain insight into the experiences of students' involvement in an authentic science project as they collaborated with engineering researchers to investigate optimal growth of algae as a biofuel source. By collecting quantitative and qualitative data, I investigated how students were affected by their involvement in the project by examining students' experiences and outcomes.

Specifically, the study offered insight into the details of student learning and behaviors in a naturalistic setting. What students learned, as well as their thoughts, beliefs and perceptions about doing science with engineering researchers was analyzed from an interpretivist perspective.

CHAPTER 2: REVIEW OF THE LITERATURE

The literature guiding this inquiry comes from the following areas of research: (1) scientific practices versus the nature of science, (2) the science achievement gap and factors contributing to the science achievement gap, and (3) attempts to reduce the science achievement gap. While the theoretical framework guiding this inquiry takes an interpretive perspective, the design of the study was motivated by critical theory. In this chapter, I describe how critical theory shaped the study, but offer Interpretivism as a theoretical framework. This is followed by a review of selected studies that are relevant to these areas and finished with a discussion of the rationale to the proposed research questions.

Theoretical framework

Interpretivism as a theoretical framework guided this investigation. However, the design of the study was inspired by critical theory. Critical theory claims that our society, as a Western democracy, is made up of inequalities. These inequalities run along race, class, and economic statuses, and are maintained by dominant ideologies (Brookfield, 2005; Kincheloe & McLaren, 2005). Ideologies are the rules, habits, and beliefs held by society and often are used to convince its members that existing hegemonic structures are there for the good of society. With regard to education, a common ideology is that all students have an equal opportunity to learn. However, this belief fails to take into account the systemic inequalities that exist in our public schools, such as inequitable distribution of resources, funding disparities in different schools and districts, and cultural conflicts.

Critical theory seeks to critique existing societal ideologies with the purpose of creating a world that is more just and democratic (Brookfield, 2005; Kincheloe & McLaren, 2005). Critical theory in education seeks to liberate or emancipate students by giving them the opportunity to question existing dominant ideologies and structures. The idea is that exposing inequitable, dominant structures and breaking down hegemonic relationships between students and these structures will lead to a more just and democratic society.

Similarly, critical pedagogy seeks to design curriculum through the lens of critical theory. The goal is to empower students by encouraging them to reject injustices and inequalities in the classroom, and to recognize that their voice can be an instrument to dominant ideologies. According to the authors:

> "Knowledge is relevant only when it begins with the experiences students bring with them from the surrounding culture; it is critical only when these experiences are shown to sometimes be problematic (i.e., racist, sexist); and it is transformative only when students begin to use the knowledge to help empower others, including individuals in the surrounding community" (McLaren, Hammer, Sholle, & Reilly, 1994, p. 197)

I sought to understand if involvement in an authentic science experience improves student perceptions about who can do science, attitudes toward and learning of science, especially those who have become marginalized in the science classroom. My own experiences as a graduate student in the sciences and a science educator were the driving force behind my desire to address a social injustice in science education, and offer all students access to a resource often limited to students of privilege or from higher SES backgrounds. However, an interpretivist perspective guided this inquiry, allowing a focus on understanding the meanings of the actions of those being studied, and the significance of their experience. The manner in which a researcher arrives at an understanding of human actions and experiences is referred to as *verstehen* (Denzin & Lincoln, 2000). According to Erikson (1986, p. 156), "Interpretive research is concerned with the specifics of meaning and action in social life that takes place in concrete scenes of face-to-face interaction, and that takes place in the wider society surrounding the scene of action."

One aspect of interpretive research is that the process of finding meaning is both subjective and objective. The interpretivist process allows the researcher to make objective sense of the subjective nature of the participants' actions. That is, the researcher takes on the role of an objective observer in order to make sense of the actions and experiences of the study participants. While the researcher assumes the role of an objective observer, complete objectivity is not possible. It is important to acknowledge that the researcher must step into the intervention and become something of a participant observer. As a result, truths and the importance of the truths that emerge from research are affected by the personal beliefs and values of the researcher (Denzin & Lincoln, 2000; Erikson, 1986; Paul, 2005). For example, I have been committed to addressing social injustices that exist within science education, including those I have witnessed as a science educator. For this reason, critical theory is something that resonates within me, and I cannot assume I can completely separate these beliefs from the research conducted in this study. In the context of this study, understanding the students' experience in an authentic science project allowed for the opportunity to understand the significance of students participation in an authentic science project, and to also address an inequity in science education by offering marginalized students access to a resource typically limited to students with rich social and cultural capital.

Distinctions Between Scientific Practices and the Nature of Science

Scientific literacy for all has been an intense subject for some time in the United States and globally. Two very different yet somewhat overlapping aspects of scientific literacy are the eight scientific practices developed by the National Research Council (NRC) in 2012 and an understanding of the nature of science (NOS). NOS refers to the ontological and epistemological aspects of science that explains how scientific knowledge is constructed, or "the values and assumptions inherent to the development of scientific knowledge" (Lederman & Zeidler, 1987). Features of NOS are that construction of scientific knowledge is considered to be "durable" yet subject to change in light of new discoveries, a combination of logic and imagination, derived empirically through observation and inference, inherently biased, and a "complex, social activity" with cultural implications (Rutherford & Ahlgren, 1990).

In contrast, scientific practices refer to the abilities needed to carry out science (NRC, 2012). The recently released Next Generation Science Standards (NGSS) call for the implementation of eight scientific practices in K-12 education. These practices allow students to engage in scientific investigation as means of learning the content and the requisite skills. The eight scientific practices offered by the NRC's Science Framework for K-12 Science Education are:

1. Asking questions
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

While NOS and scientific practices are different, they are not mutually exclusive of one another as can be seen in this statement in the Framework for K-12 Science Education (Achieve, 2012), "Students cannot comprehend scientific practices, nor fully appreciate the nature of scientific knowledge itself, without directly experiencing those practices for themselves." This new framework posits that engaging in science learning by concentrating on facts without the context of how these facts are generated is a misrepresentation of science. It is important to emphasize that this study was investigating students' learning of science practices in the context of an algal biofuel project, and not their understanding of the nature of science.

One aspect of NOS relevant to this study is the interplay between two of its tenets: that science should be an objective, bias-free endeavor and the laws, theories, and findings of scientific endeavors are universal and transferrable (Rutherford & Ahlgren, 1990). Thus, research and the forthcoming results and analysis should be independent of gender, ethnicity, or nationality. However, the reality is that science is not entirely an objective endeavor, and even the scientists and the scientific community recognize that while scientists strive to use evidence to support or deny claims, their interpretation can never be completely free of personal beliefs and bias (Rutherford & Ahlgren, 1990; Kuhn, 1970). For example, the studies performed by male scientists of primates' social behavior specifically focused on competitive interactions between male primates. Not until female primatologists entered this realm of study did the focus shift to female primate behavior, their role in community building, and communication (Rutherford & Ahlgren, 1991; Haraway, 1989). Haraway contends that the nature of scientific construction of knowledge should be challenged as groups of individuals – often separated by gender, race, and socioeconomic status – have been historically excluded from the generation of scientific knowledge (1989).

My personal experience supports the idea that personal biases and beliefs influence what scientists investigate, how they carry out investigations, and their interpretation of results. My former advisor, a developmental neurobiologist, shared a foreword she and a male colleague were asked to write independently in an upcoming developmental neurobiology textbook. She described the process of how neuronal growth cones find their appropriate synapses as a neuronal process moves gently along a molecular path as feeling, probing, seeking its target. Her colleague described the same process as a ram battering through a molecular field, emerging to claim its target. This embodies the idea that science is not void of personal values, cultures, and beliefs, but rather that science is both socially and culturally constructed (Kuhn, 1970; Buxton, 2001; Atwater, 1996; Rodriguez, 1998). Thus, the person can never completely separate himself or herself from the doings of research.

In addition, the founding of science as way of generating, expanding, and revising knowledge is attributed to the European Scientific Revolution beginning in the 16th century as well as Europe's 18th century Age of Enlightenment (Heilbron, 2003). Thus, western science became the norm for the generation of knowledge that explained the natural world, as created by predominantly white male scientists. Given this historical perspective, it is no surprise that science education has not been equitable for all students, but rather has been at odds with the diverse student population in this country. Caution must be taken when exposing students to an endeavor that is traditionally marginalizing. While science is a way of knowing that produces knowledge with potential universal applicability, it is derived from a particular culture and social context. As a result, it undeservedly carries with it a privileged status.

Science Achievement Gap

Low science achievement on standardized science tests and low participation in STEM careers has been observed for African American and Hispanic students, as compared to their White counterparts (NCES, 2007, 2009, 2009b; Orlich & Gifford, 2006). One measure of what we know about science achievement comes from the Trends in International Mathematics and Science Study (TIMSS) that examines science achievement of 4th, 8th, and 12th grade students in more than 60 countries. Overall, the achievement gap is slowly narrowing on many levels, including the gap between the United States and other higher performing countries, as well as between White and African-American students, but the gap still exists (Buxton & Lee, 2010; NCES, 2007). Other sources of data such as the National Assessment of Educational Progress (NAEP), the Graduate Record Examination (GRE), and the Scholastic Aptitude Test (SAT) support these findings (Buxton & Lee, 2010; NCES, 2009; Orlich & Gifford, 2006).

When the TIMSS data from the United States is disaggregated by age, socioeconomic status (SES), ethnicity, or race, disparities become evident. For example, 4th grade U.S. students are one of the highest performing of all countries (NCES, 2007). However, there is a significant decline in the scores of 8th grade students, a trend that continues in the same direction through the 12th grade. This mirrors a trend observed in science education in general in that students tend to lose interest in science during late elementary or early middle school years. While this loss of interest is observed among all students, it is particularly pronounced among girls, African American and Hispanic students (NCES, 2007).

Specifically, the TIMSS data show that 8th grade U.S. African-American students rank behind all countries and Hispanic males rank behind all but two countries in science. Similar results are seen with 12th grade African-American and Hispanic students from the United States. While there has been significant narrowing of the gap between White and African-American students from time the TIMSS has been administered in 1995 until 2003, there are still significant differences between these groups. Table one shows the average scale scores for United States students based on race based on a scale range of zero to 1,000. As shown in table one, there was a 110-point difference in 1995 science achievement scores of 4th grade White and African American students. This gap narrows to 70 points in 2003 and remains unchanged in the 2007 TIMSS. With regards to 8th grade students, there is a 122-point difference in 1995 science achievement scores of White and African American students, which narrow to 91 points in 2003, and increases again to 96 points in 2007.

The differences observed between White and Hispanic students are less pronounced. As shown in table 1, there is a 69-point difference in science achievement scores of 4th grade White and Hispanic students in 1995, a 67-point difference in 2003, and a 65-point difference in 2007. Also, a 98-point difference was observed between 8th grade White and Hispanic students in 1995, a 70-point difference in 2003, and a 71-point difference in 2007.

Table 1 also shows that White students' science achievement scores did not change significantly from 1995 to 2007. This holds true for both 4th and 8th grade students, and for 4th grade Hispanic students. However, there were significant increases in science achievement scores from 1995 to 2007 for all African American students and 8th grade Hispanic students. Therefore, while there has been some improvement, there is still a gap in science achievement between White and African-American students as well as White and Hispanic students. Results of the 2009 NAEP science scores for fourth, eighth, and twelfth grade students supported the findings of the TIMSS data as there are significant differences between White versus Black and Hispanic students at all grade levels (NCES, 2009). These findings are summarized in table 2.

Table 1: Average science scores (TIMSS) of U.S. students, by race/ethnicity.

Race/Ethnicity	Table 1: Average Science Scores of U.S. Students by race/ethnicity (TIMSS)					
	Grade 4			Grade 8		
	1995	**2003**	**2007**	**1995**	**2003**	**2007**
All U.S.	542	536	539	513	527	520
White	572	565	567	544	552	551
Black	462*	486	488	422*	461	455
Hispanic	503	498	502	446*	482	480

No fourth-grade assessment was conducted in 1999. Multiracial data were not collected in 1995 and 1999. Race/ethnicity was determined by student self-selection. Black includes African American. Students who identified themselves as being of Hispanic origin were classified as Hispanic, regardless of their race. Data taken from NCES 1995, 1999, 2003, 2007. *p < .05 that the average score is significantly different from 2007 average score. The science score scale ranges from 0-1000.

Table 2: Average science scores of U.S. students on the 2009 NAEP.

Average Science Scores of Students by Grade and Race/Ethnicity (2009 NAEP)			
Grade	**White**	**Black**	**Hispanic**
4	163	127*	131*
8	162	126*	132*
12	159	125*	134*

Data taken from NCES 2009. The NAEP science scores range from 0-300. Analysis include public schools and are based on school reports. *p < .05 that the average score is significantly different from White student scores at same grade level.

With regards to science achievement scores, socioeconomic status (SES) is another important factor. A common measure of SES is the total number of students in a school or district that are on free- or reduced-price lunches. This is determined by the number of approved applications for free or reduced-price lunches, and is expressed as a percent of the school (or district population). However, it is important to note that this may not reflect the true number of students from low SES households as a family may choose not to apply even if they are eligible. As shown in Figure 1, as the percent of students from low SES households increases, the average science achievement score decreases (NCES, 2007). This is true for both 4^{th} and 8^{th} grade students. Examining scores within an SES group (reading across rows), 8^{th} grade students at schools with a high percent of students from low SES households (greater than or equal to 75%) have shown significant increases in achievement scores from 1999 to 2003 (21 point increase) and 1999 to 2007 (26 point increase). Results of student performance on the science portion of the 2009 National Assessment of Educational Progress (NAEP) supported the findings of the TIMSS findings, as students classified as low SES (eligible for a free or reduced price lunch) score significantly less than students of high SES (not eligible for a free or reduced lunch; NCES 2009). These findings are summarized in Table 3.

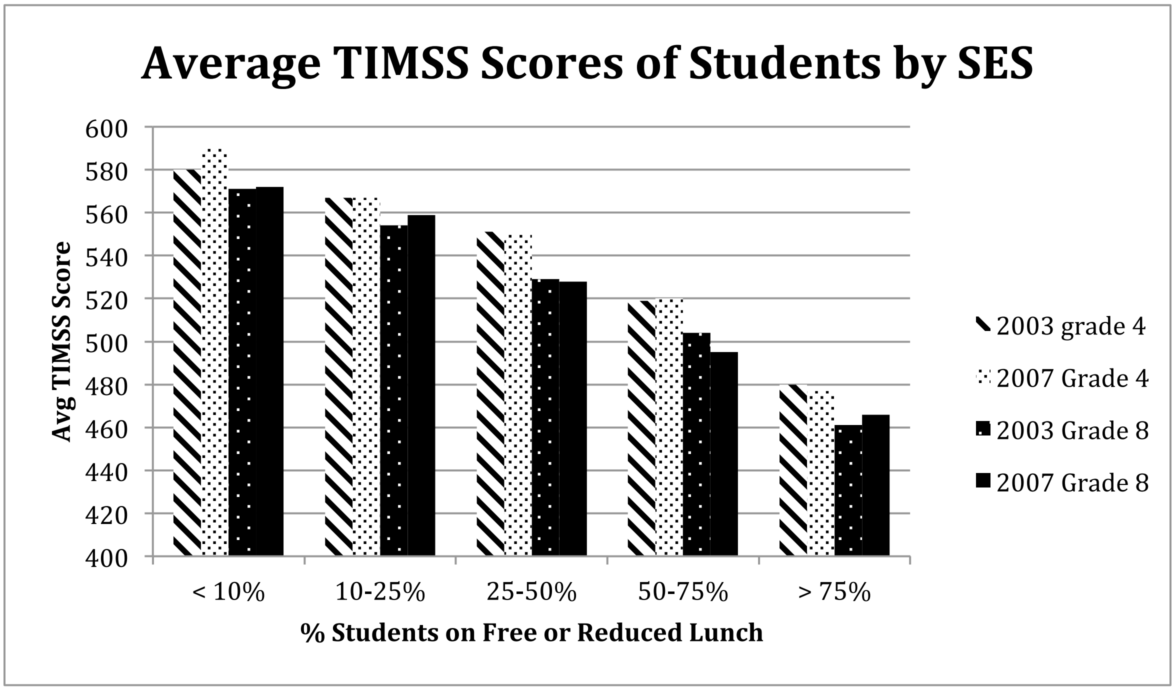

FIGURE 1: Comparison of student scores on the TIMSS based on SES
Data taken from NCES 2003, 2007. The TIMSS science scores range from 0-1,000. Analyses are limited to public schools only, based on school reports of the percentage of students in school eligible for the federal free or reduced-price lunch program.

Table 3: Average 2009 NAEP science scores of students by grade and SES.

Average Science Scores Students by SES (NAEP)		
Grade	**Low SES**	**High SES**
4	134*	163
8	133*	161
12	136*	159

Data taken from NCES 2009. The NAEP science scores range from 0-300. Analysis includes public schools and is based on school reports of the percentage of students eligible for the federal free or reduced-price lunch program. *p < .05 that the average score is significantly different from high SES Students

Table 4: Average science scores from the 2009 science NAEP

Average Scores for 2009 NAEP Science by Grade, Race/ethnicity and SES						
	Grade 4		**Grade 8**		**Grade 12**	
Race/ethnicity	**Low SES**	**High SES**	**Low SES**	**High SES**	**Low SES**	**High SES**
White	149*	168	148*	166	146*	161
Black	122*^	141	120*^	136	119*^	134
Hispanic	127*^	144	127*^	143	129*^	139

Data taken from NCES 2009. The NAEP science scores range from 0-300. Analyses include public schools and are based on school reports of the percentage of students eligible for the federal free or reduced-price lunch program. *p < .05 that the average score is significantly different for comparison between SES groups of same racial category. ^p<.05 that the average score is significantly different for comparison high SES Black or Hispanic to low SES White of the same grade.

A more alarming trend emerges when the data from the science portion of the 2009 NAEP are disaggregated based on race and SES (Table 4; NCES 2009). The average scores of low SES Black and Hispanic students are significantly less than low SES White students. This trend is observed for fourth, eighth, and twelfth grade students. In addition, the average scores of high SES Black and Hispanic students are significantly lower than the science scores of low SES White students at all three grade levels. It is important to note that there are significant differences between all groups in table 4. That is, there are significant differences between low and high SES within a racial/ethnic category. Clearly, SES is an important factor in science achievement as it crosses racial boundaries.

Similar trends are observed with regards to ACT and SAT scores of high school students. With regards to SES, both ACT and SAT scores increase with an increase in family income (Orlich & Gifford, 2006). In addition, both ACT and SAT scores of Hispanic and Black students are significantly different from White students. The data are summarized in tables five and six.

Table 5: Average high school ACT and SAT scores based on income

Average Test Scores (2005)		
Income (thousands)	**ACT**	**SAT**
< 18	17.9	872
18-24	18.6	887
24-30	19.3	926
30-26	19.8	960
36-42	20.3	989
42-50	20.9	1005
50-60	21.3	1017
60-80	21.9	1033
80-100	22.5	1057
>100	23.5	1115

Poor science achievement among Hispanic and African-American students has been attributed to underrepresentation of these students in STEM related careers (Buxton & Lee, 2010). For example, in 2009, 7.5% of STEM degrees were awarded to Black students, while 7% were awarded to Hispanic students in contrast to 57.3% awarded to

White students (NCES, 2009b). In contrast, according to the U.S. Census Bureau, the demographics was approximately 72% White, 13% Black, and 16% Hispanic (2012). These results are summarized in table 7.

Table 6: Average high school ACT and SAT scores based on ethnicity

Average Test Scores (2005)		
Race/Ethnicity	**ACT**	**SAT**
Black	17.0	857
Hispanic – Mexican-American, Chicano, Latino	18.4	909
Hispanic – Puerto Rican, Cuban, Other	18.9	909
White	21.9	926

A recent study examined why high school students might leave the science, engineering, and mathematics (SEM) pipeline (Aschbacher, Li, & Roth, 2010). They studied students from three different high schools representing a wide range of ethnicities (White, Black, Hispanic, and Asian). Students were categorized as a high achieving persistor, low achieving persistor, or lost potential. Persistors were students that continued to express interest in a SEM career while lost potentials made it clear they would not follow a SEM career after high school. The authors found that White students were least likely to be classified as a lost potential. In addition, high SES students were also least likely to be a lost potential.

Table 7: Percentage of STEM Undergraduate Degrees Conferred

Race/Ethnicity	**% STEM Degrees**	**% Population**
White, not Hispanic	57.3	63.7
Hispanic	7.0	16.3
African American	7.5	12.6
Asian, Pacific Islander, Native Hawaiian	9.5	5.0
American Indian, Native Alaskan	0.6	0.9
Two or more races	0.1	2.9

There are important limitations to consider regarding the use of standardized test data as a means of gauging science achievement. One is the nature in which ethnic and/or racial categories are defined. For example, Hispanic is a broad category that includes students from a variety of different backgrounds, including Cuba, Puerto Rico, Central America, South America, Mexico, Spain, and Portugal. Another is standardized tests are inherently limited in scope, as they do not always show what students know and are capable of doing. Standardized assessments have been criticized as being designed for ease in administration and scoring, politically motivated, and designed by individuals or organizations lacking content knowledge in the field being tested (Janesick, 2007, p. 239).

However, non-test based parameters, including types of science courses taken during high school (AP, regular, honors), entrance into and retention in college science-related majors, as well as entrance into and retention in science-related careers are additional measures of success (Buxton & Lee, 2010). While the consistent results across the TIMSS, NAEP, SAT, and ACT scores suggest the science achievement gap is real, it is possible that a portion of the gap is due to the nature of the instrument. If other parameters, such as types of classes taken in high school, are taken into account, the gap is narrower (NCES, 2009).

In summary, results of standardized tests demonstrate a science achievement gap between White, Black, and Hispanic students. While the achievement gap is narrowing in some respects, the gap still exists. In addition, there is still underrepresentation of Black and Hispanic students being awarded STEM degrees and in STEM related careers.

Science Identity

Science identity is considered an important factor when examining student success in science, and pursuit of STEM related careers (Carlone & Johnson, 2007). A student's science identity has been described as "the sense of who students are, what they believe they are capable of, and what they want to do and become in regard to science" (Aschbacher et al., 2010).

More recently, a multidimensional model of science identity has been proposed in that it encompasses competence, performance, and recognition (Carlone & Johnson, 2007). The competence domain is a measure of an individual's understanding of the content, while the performance domain measures one's ability to do science (use scientific tools, talk scientifically, and interact socially in science arenas). The recognition domain is a measure of an individual being acknowledged as a scientist, by self and others. Thus, an individual with a strong science identity would be highly knowledgeable, show strong performance, and be recognized by themselves and others as a scientist (Carlone & Johnson, 2007).

This model acknowledges the socially constructed nature of science identity, in that one's science identity is influenced by the nature of science instruction and what we expect students to do in the science classroom. When considering equitable science education practices, we must consider the diverse nature of students as they develop a science identity in and out of the science classroom. This concept and the science identity model are informed by the idea that science is performed within a community of practice

(Lave & Wenger, 1991; Wenger, 1998), and that one's identity is defined not only by self but by interactions with others (Buxton, Carlone, & Carlone, 2005; Wenger, 1998).

A similar concept is that of gender- and ethnic-matched role models. This model connects student achievement and interest in academics with exposure to role models of the same ethnicity and/or gender (Karunanayake & Nauta, 2004; Zirkel, 2002). For example, one study provided empirical evidence to support the race-similarity hypothesis as it showed a statistically significant connection between students' race and the race of their identified role model (Karunanayake & Nauta, 2004). Zirkel (2002) demonstrates a strong connection between students and access to race- and gender-matched role models. The study showed that access to race- and gender-matched role models is not only positively correlated to academic interest and achievement, but is a predictor of students' sustained interest in academic achievement. While this study shows a positive correlation between same race- and gender-matched role models, it is important to note that there is value in promoting student exposure to as many different role models as possible without eliminating same race role models (Karunanayake & Nauta, 2004). My study sought to determine if students were more likely to choose an individual they believed to be a scientist of their own race- and gender after participation in an authentic science experience.

Factors Contributing to the Science Achievement Gap

The inequalities that have been attributed to the science achievement gap have been conceptually separated into two broad categories. These categories are issues of school culture, and resources available to students. These factors are discussed in the following sections.

Cultural Issues in the Classroom

The underlying causes of the science achievement gap have been studied extensively. One factor attributed to the science achievement gap is the cultural issues that arise in many classrooms and relates to the cultural mismatch that exists between many teachers and students (Duncan, 2010; Ladson-Billings, 2000). For the purposes of this paper, culture is defined here as a "set of values and worldviews shared by members of a social group" (Buxton & Lee, 2010, p. 12).

From a cultural standpoint, many students, including Hispanic and African-American, enter school from a different starting point than do middle class White students. It is important to note that this does not imply that Hispanic and African-American students, by nature of their home-life, are behind White middle class students but rather that they bring different cultural experiences to the classroom. Because members of different cultures do not always understand the cultural norms of others, conflicts can arise in the classroom. In addition, the teacher's culture often becomes the dominant culture and can serve to suppress students that are not familiar with the norms and rules of the culture leading to a "culture of power" (Delpit, 1995; Duncan, 2010; Ladson-Billings, 2000).

While there has always been de facto desegregation, *Brown v. Board of Education* declared segregated schools unconstitutional. One of the early attempts at education reform in the post-*Brown v. Board of Education* era was the idea that equality meant education for African-American students should be identical to White students (Ladson-Billings, 2000). This in turn should lead to identical results for African-American and White students. However, this colorblind idea fails to recognize that cultural differences may influence learning as lack of understanding of different cultures in a classroom can lead to conflict and silence students of the non-dominant culture (Ladson-Billings, 2000).

An additional cultural consideration is the mismatch between teacher and student populations in the United States. While the student population is becoming increasingly diverse, the teacher population is still White female dominated (NCEI, 2005; NCES, 2009). In addition, the majority of teachers are White females from a middle class background with very different experiences than students in her classroom. As of 2008, 75% of United States public school teachers are female while 85% of K-12 teachers are

White, 7% are Black, 6% are Hispanic, less than 2% are Asian, and less than 1% are American Indian or Alaskan native (NCES, 2009). However, the student demographic is very different: 55% of students are White, 15% are Black, 22% are Hispanic, 4% are Asian, and 1% are American Indian or Alaskan native (NCES, 2009). Clearly, there is a mismatch between the teachers in our classrooms and the students they are educating that extends beyond the White female in a diverse setting. This mismatch is important as it contributes to a culture of power that can silence and marginalize students in their classroom. While this is discussed in more detail later, a culture of power is one in which existing political, social, economic, and education structures serve to allow a person or groups of people more control than other groups (Ladson-Billings, 2000).

From a national perspective, the cultural diversity of our student population is expected to continue to grow; for example, the Hispanic population is one of the fastest growing populations in the United States. However, a diverse population does necessarily mean that a school has a diverse student population. *Brown v. Board of Education* declared laws that segregated of students based on race were unconstitutional, and it paved the way for the eventual desegregation of public schools. However, Kozol describes an alarming trend towards resegregation of many urban schools. While some urban schools have maintained a homogeneous population (for example, almost 100%

Black), he claims that many urban schools became desegregated during the 1970s and 1980s only to see a reversal of this trend beginning in the 1990s. In addition, many suburban schools have maintained their segregated white upper middle class status (Kozol, 2006).

The segregated nature of our schools is only one of the problems faced by urban schools. Another is that they are often plagued with high turnover among teachers. The outcome is many urban schools are staffed with inexperienced or uncertified science teachers who struggle to not only teach but also reach the students they serve. In addition, they are often run by administrators who do not support highly effective science instruction methods (Ingersoll, 1999, 2001). Worse, severely impoverished schools in areas like Los Angeles and New York City often have more uncertified and unqualified teachers than certified, qualified teachers (Darling-Hammond, 1999). While this problem is not limited to urban schools, it is more pronounced.

While there are significant problems facing urban schools, many elementary and middle school science teachers across the country are not prepared to teach inquiry based science (Weiss, Pasley, Smith, Baniflower, & Heck, 2003). As a result, many teachers often fall back on traditional methods of delivery that are textbook and teacher-centered that push for rote memorization of facts.

The disparity between the teacher and student populations affects the learning environment and classroom atmosphere as it can create a culture of power in which students become silenced because their cultural background differs from their teacher's (Ladson-Billings, 2000). Whether intentional or unintentional, a culture of power is created by the one with the power, usually the teacher (Delpit, 1995). According to Ladson-Billings (1995) this culture of power often becomes part of the hidden curriculum.

The hidden curriculum was first used to describe the aspects of school that are not part of the traditional curriculum – school procedures, classroom policies, and school/classroom atmospheres (Jackson, 1968). It has also been defined as "the subtle or not so subtle messages that are not part of the intended curriculum" (Nieto, 2007). In addition, those with the power are often unaware or refuse to acknowledge that the culture of power exists. According to Delpit, "If you are not already a participant in the culture of power, being told explicitly the rules of that culture makes acquiring power easier" (p. 283). This disparity has also been observed in science classrooms as a conflict between the dominant culture and that of the students (Duncan, 2010; Seiler, 2001). Unfortunately, this conflict has not changed much since the early years of desegregation as White teachers complained that African-American students refused to engage in and answer questions during class. They labeled these students academically inferior to their White classmates (Ladson-Billings, 2000).

Lower academic achievement by African-American and Hispanic students is well documented from analysis of standardized tests such as the TIMSS data (NCES, 2007); and has been attributed, in part, to the disparity between the culture of the teacher and the culture of the student (Barton, 2000; Ladson-Billings, 2000). A teacher's lack of understanding of cultures other than their own creates barriers and conflicts between students and teachers, which is supported by other studies. For example, a lack of understanding of other cultures has been reported among African-American and Hispanic students (Gilbert, 2001). Specifically, their White male teacher often misunderstands the behaviors and attitudes of students in his regular and low track science classes. Additionally, conflicts between same culture groups can occur as high-achieving African-American and Hispanic students are sometimes the subject of scorn and ostracism by fellow classmates in the science classroom, and are given the label of "acting White" (Gilbert & Yerrick, 2001, p. 576). These issues are not only symptomatic of but may contribute to a culture of power in which many students, including African-American and Hispanic students, may become marginalized, silenced, and low achievers (Ladson-Billings, 1995). Marginalized students in science education are described as disengaged, lacking in self-efficacy about their science abilities, and/or view science as irrelevant and boring (Barton & Yang, 2000; Basu & Barton, 2007; Seiler, 2001; Zacharia & Barton, 2004).

Resource Inequities

As previously shown, SES is an important indicator when it comes to science achievement, and economically disadvantaged students score significantly lower on standardized tests, science included. SES has been long been argued as the only reliable predictor of academic success since the release of the Coleman report (Coleman, 1966). This is due partly to the fact that there is an inequitable distribution of resources that fall along economic class lines as low-income neighborhoods often have limited supplies and crumbling, unsafe, school buildings (Barton, 2001; Ingersoll, 1999; Kozol, 2006). In addition, a higher percentage of African American and Hispanic students live in poverty than do White students (Kozol, 2006).

Resources available to students may be school-based, home-based, or community-based. With regards to school-based resources, disparities have been evidenced by the fact that high school science classrooms often have poorly stocked laboratories, students have less access to experienced certified science teachers as well as less access to Advanced Placement (AP) and honors science classes (and simultaneous tracking of students labeled as low-achieving into vocational courses), and a lack of up to date science textbooks (Ingersoll, 1999; Buxton & Lee, 2010; Oakes, 2000). Thus, in spite of an interest in pursuing a STEM career, this inequitable distribution of resources means that students leaving high school are often unprepared for the rigor of science and mathematics courses in college.

With regards to home-based resources, the issue may be a matter of economics or an inability to negotiate the bureaucracies of the school culture. Low SES students may not have the financial resources to bring in items needed for projects in science classes. Compounding this problem occurs when a teachers creates a dominant culture of power. When this happens, students are often hesitant or too embarrassed to speak up and explain why they are not able to contribute to classroom supplies, in turn marginalizing them (Barton, 2001). Another aspect of home-based resource issues is that parents may not know how to negotiate school cultures to ensure their child receives access to quality resources. If parents have limited English proficiency, they often rely on their children to translate with school counselors and administrators. Regardless, when parents lack knowledge of the school's culture and the policies and rules that go with it, they often do not know how to gain access to high-level science classes, or after school curricula. To further compound the problem, it has been shown that low SES urban students are more likely to be tracked into low-level courses (Bryan & Atwater, 2002; Oakes, Gamoran, & Page, 1992) actively discouraged by school counselors from high-level or college prep science classes (Barton & Yang, 2001), or have limited high-level science classes to choose from when enrolling in classes (Oakes, 2000).

Scientists, engineers, and other professionals are examples of community-based resources, and access to these individuals is often very limited. Students that have the opportunity to successfully compete in high level science competitions (i.e.-science fair, science Olympiad, inventions and engineering, robotics) do so because they have access to scientists, engineers or other professionals and their facilities and equipment that propels them into a highly competitive category. What this means is that students with access to these types of resources often have a direct connection (a relative or family friend) to scientists and engineers. These students are said to be rich with respect both to cultural and social capital (Bencze & Bowen, 2009).

A more recent study (Lee, Mahotiere, Salinas, Penfield, & Maerten-Rivera, 2009) in which teachers' beliefs about barriers to science instruction in the elementary classroom are discussed, suggests these problems are not limited to high school classrooms. Teachers stated that some of the barriers to teaching inquiry-based science include inadequate time and a lack of science equipment and supplies for inquiry based investigations and/or experimentation. In addition, the pressures of high stakes testing contribute to the inadequate time spent teaching inquiry-based science. Standardized state exams are used to determine whether a student advances to the next grade, is placed in regular, honors, or remedial classes, and is also used to evaluate teachers. Most high stakes tests assess students in reading and mathematics, but not science. Thus, teachers are often under pressure from administrators to spend more classroom time on subjects that will be assessed on standardized tests. Administrators are more likely to allocate resources to the teaching of mathematics and reading, often at the expense of science.

In summary, several factors have been attributed to the science achievement gap. One factor is the cultural mismatch and subsequent conflicts between students and teachers, students and students as well as the ways in which science is taught. Additional factors include an inequitable distribution of resources among AP, honors, regular, and lower track science classes, as well as an underrepresentation of Black and Hispanic students in AP and honors science classes. It has been argued that these factors have marginalized groups of students in the science classroom (Atwater, 1996; Basu & Barton, 2007; Buxton & Lee, 2010; Gilbert, 2001).

Attempts to Reduce the Science Achievement Gap

There is considerable evidence demonstrating a gap in terms of science achievement and pursuit of science related careers, which naturally led to studying ways to reduce the gap, both in terms of achievement and success in STEM careers. This includes investigating inequities from social constructivist and sociocultural perspectives. In addition, there is a considerable body of literature arguing for culturally relevant pedagogies, as well as implementation of authentic science experiences in science classrooms. The literature supporting each of these perspectives is examined later.

Sociocultural Perspectives in Science Education

Qualitative studies suggest that personal experiences students bring to the science classroom need to be embraced rather than ignored (Barton, 1998a; Barton & Yang, 2000; Basu & Barton, 2007). This notion is embedded in the sociocultural theory that learning takes places in context of one's social environment (Vygotsky, 1986). Using a sociocultural theoretical framework, the researchers studied the learning of science among urban homeless students.

For example, a child named Kevin was part of a study at a homeless shelter in the urban northeastern United States. The purpose of this study was to examine the role of invention in science as one that is socially constructed. Children were given different kinds of soap to make bubbles. During the activity, Kevin decided to add hot chocolate powder to the mixture to see what would happen. The children, Kevin included, were engrossed in the different colors produced in what they called Bubble Mountain. While most of the children were very excited to discuss and write about what they called Bubble Mountain – the brown hot chocolate powder represented the dirt while the green soap represented the trees, Kevin was not. When the researchers tried to engage Kevin in writing about his Bubble Mountain, he repeatedly steered the discussion toward "inventing" soup from the ingredients he was given. It was apparent that availability of food was an important issue for Kevin and his family, this drove his desire to invent soups (Barton, 1998b). It was the value placed on Kevin's personal experiences that allowed him to invent and learn science. According to Barton, "It is not only the invention that is important, but also the inventor and their social and physical environments" (p. 136). While this type of learning may reflect more inquiry than science, this study supports the idea that science education should integrate social, culture and personal experience.

In a different study, Barton (2001) makes an argument with respect to the importance of teacher-student relationships. Barton studied the science learning experiences of two fourth grade Mexican-American students living in a homeless shelter.

Using a critical ethnographical framework, Barton created a collaborative environment between herself and the two students. As a result she was able to gain their trust and the students offered in-depth, meaningful information about their experience in the science classroom (Barton, 2001). For example, the girls openly discussed their conscious decision to sit in silence as a means of protesting their teacher's lack of understanding about their personal situation and why they were not able to bring supplies for an upcoming science project. The researcher admits that she attributed their silence to the dominant culture of the teacher, or pressure from the presence of boys in the class and was surprised to learn that they had taken a stand of "intentional resistance." From a sociocultural perspective, the researcher was able to obtain detailed, in-depth information about the students' thoughts and beliefs because she developed a trusting relationship in which the girls felt free to have open discussions. The idea of creating trusting relationships certainly transcends to the teacher-student relationship.

A purposeful case study of Miguel (Barton & Yang, 2000), a resident in an urban homeless shelter, allowed for the study of the social inequities that arise from the culture of power. Miguel was a married, young adult in his twenties who dropped out of high school. He had two children and considered himself a self-taught herpetologist. In spite of his lifelong - childhood included - interest in science, a culture of power thrust him toward the periphery in his science classes. For example, his guidance counselors never offered science classes as part of his curriculum, instead they pushed him into a vocational educational track while teachers often reinforced the idea that he should be getting ready for the workforce rather than college. Miguel expressed his feelings on how these interactions with teachers and counselors strengthened his belief that science and becoming a scientist were not attainable by someone "in the hood" (p. 872). Miguel is an example of a marginalized individual who – because of personal, cultural and social issues – lacked the understanding and ability to negotiate his way into the dominant culture (Barton & Yang, 2000). In other words, he lacked the cultural and social capital he needed to negotiate the educational system. As a result, became marginalized and was denied participation in a meaningful science education experience.

A sociocultural transformative constructive (STC) orientation has been proposed as a means of providing equitable science education that has the potential to empower underrepresented students (Rodriguez, 1998). This orientation serves to connect social constructivist ideas, embedded in the works of Vygotsky and Bakhtin (Bakhtin, 1981; Vygotsky, 1978, 1986) with culturally responsive or relevant pedagogies. While Bakhtin considers the importance of "historical, cultural, and institutional contexts" (Rodriguez, 1998), Vyogotsky was interested in the symbolic and semiotic ways in which these contexts influence social interactions and socially constructed meanings.

A sociocultural transformative emphasis merges high quality science instruction with culturally relevant ways of teaching. As stated by Rodriguez (1998):

> "Learning to teach for diversity again implies learning to teach in more culturally inclusive and socially relevant ways. Learning to teach for understanding involves learning to teach in more critically engaging and intellectually meaningful ways."

During classroom visits, students were often engaged in hands-on activities that had no relevance or connection to scientific content. While Rodriguez (1998) calls for more authentic science activities in classroom, he cautions about the importance of distinguishing between hands-on and hands-on/minds-on. In order for an STC orientation to work, it is important for students to be engaged in learning that allow students to learn content and discover socially related relevance. Furthermore, he calls for authentic science activities as one way of achieving STC in the science classroom.

Culturally Relevant Pedagogy

Culturally relevant pedagogy (CRP) is one way to address the disparity between student and teacher cultures (Ladson-Billings, 1995). Culturally relevant pedagogy looks to find ways for students to maintain their cultural self and academic performance. How is this accomplished? First, it is important to connect the personal culture of students to the content being taught in the classroom. Second, allowing students who might otherwise be marginalized to take on leadership roles gives them a voice and helps to shift the culture of power (Ladson-Billings, 1995). CRP is rooted in critical pedagogy as it encourages students, particularly marginalized students, to not only challenge inequitable power structures but associate these structures with knowledge (Kincheloe & McLaren, 2005).

Culturally relevant pedagogy arose from critical theory. Critical theory is embedded in the ideas of Paulo Freire, who argued for liberatory education, students acquire knowledge through inquiry rather than rote acquisition of knowledge. With acquisition of knowledge comes empowerment, and thus students should be encouraged to become causes of change as a means of addressing injustices in our society (Freire, 2000).

A culturally relevant pedagogy must also consider the student-teacher relationship in a way that moves away from considering non-White students as "other" implying that White students are the gold standard against which all others are measured (Ladson-Billings, 1995, p. 467). Teachers need to move towards having an understanding all cultures represented in their classroom, including their own, as well as the dynamics of student-student interactions and teacher-student interactions. In addition, it is important for all teachers, including non-White, to recognize that their own culture is the culture of power, and those of a different culture may not be aware of rules of the culture of power. Teachers must make the “rules” explicit so that all students understand them. An underlying current of culturally relevant pedagogy is that all - students and teachers - are members of something beyond the classroom - a community at large (Ladson-Billings, 1995).

Teachers that embrace culturally relevant pedagogy encourage student collaboration and hold high levels of standards for their students (Bianchini, 1999; Ladson-Billings, 1995). The criteria that a teacher has adopted culturally relevant pedagogy are (1) the promotion of academic achievement, (2) evidence of cultural competence or recognition and value for all cultures, and (3) critical examination of social underpinnings in the classroom environment (Ladson-Billings, 2000). In addition, a culturally relevant pedagogy treats knowledge as dynamic in the sense that it should be shared and constructed among students and teachers of all cultures, something to be viewed with a critical lens, and authentically assessed. A study of a middle school science classroom described as ethnically diverse supports this idea (Bianchini, 1999). The study showed that while the amount of time students’ talk during group work leads to significantly different increases in test scores, differences in students’ gender and ethnicity are not a factor. Therefore, the more students talk during peer group work, the more science they learn.

Rather than relying on standardized tests as the sole measure of achievement, culturally relevant pedagogy uses multiple forms of authentic assessment to gauge student achievement (Ladson-Billings, 1995; O. Lee, Mahotiere, Salinas, Penfield, & Maerten-Rivera, 2009). The value of authentic assessment extends beyond culturally relevant pedagogy, and is considered part of effective teaching (Janesick, 2007). Indeed, standardized science assessments have been challenged as being culturally biased (Lee & Buxton, 2010) and criticized as being designed for ease in administration and scoring, politically motivated, and designed by individuals or organizations lacking content knowledge in the field being tested (Janesick, 2007 p. 239). By contrast, an authentic assessment of student performance should not only match the objectives, but should also be realistic, necessitate critical thinking, provide the student with the opportunity to do what they know - using more than one skill or method to do so, and allow for students to practice, improve, and receive feedback so that s/he can achieve mastery. Examples of authentic assessments include portfolios, journal writing, peer evaluations, and doing or performing a task to demonstrate a skill.

High academic achievement, cultural competence for all students, and an atmosphere that allows students to connect personal life to school life are characteristics of culturally relevant pedagogy (Ladson-Billings, 1995). Unfortunately, many urban and low-income classrooms are quite the opposite: science teachers lack understanding of effective pedagogy, are inadequately prepared to teach content, and lack an understanding of how to create a classroom atmosphere that recognizes and values all student cultures. These schools are also under resourced in terms of money, science equipment, and other materials (Atwater, 1999; Gilbert, 2001). In addition, not only is tracking African-American students into less competitive science classes a common practice, but a study of gifted African-American male students suggests that their beliefs in their own abilities are influenced by the attitudes of their science teachers(Atwater, 1999; Rascoe & Atwater, 2005). The result is not only low achievement but marginalization of these students in a culture of power.

A Culture of Power in Science Classrooms

The culture of power also extends to the effect science teachers have on their students' ability to learn science as they influence student's self-perceptions and ability to create a science self-identity (Rascoe & Atwater, 2005). Self-perception about science refers to a students' confidence in his or her ability to learn science and perform science tasks. Science self-identity refers to a student's beliefs or feelings that they can perform science and see themselves in the career of a scientist. The value of self-perception is echoed by a different study that demonstrates that students cannot move toward performing higher-level scientific inquiry that is more student- and less teacher-structured if they lack confidence and strong self-perception about science abilities or a strong self-science identity. Rather, students expect to be taught by rote memorization and to accept facts at face value (Tobin et al., 1999). This type of learning typically ignores the social, cultural, personal context needed for students to identify value in what they are expected to learn about the content (Barton & Yang, 2000; Buxton & Lee, 2010; Ladson-Billings, 1995).

Zacharia and colleagues have argued that students of low socioeconomic background demonstrated positive reactions to the learning of science from a critical school science approach – one that takes into account the experiences of the student and community in relevant, real-life context such that "scientific concepts emerge from dealing with societal problems and the needs of the local community" (Zacharia & Barton, 2004). Moreover, the teacher-student relationship is situated within an environment of critical pedagogy allowing for questioning, and open, two-way communication between students and teachers. More recently, it has been suggested that students maintain an interest in science when they can "choose science projects that connect to their own vision of science," especially in the context of project based real-world science (Basu & Barton, 2007, p. 487).

Embracing the idea that all students are the same or that teachers should view their classroom through a colorblind lens, ignores the valuable differences that students bring to school. When we fail to recognize and value the culture of our students, we risk their marginalization in the science classroom (or any classroom) as their personal, social, and cultural experiences are silenced. In contrast, culturally relevant pedagogy values differences over homogeneity and believes the solution lies in finding how to incorporate cultural differences into the learning process (Ladson-Billings, 1995). It is important to find balance between valuing individual differences as well as commonalities from a humanist perspective (Postman, 1996, p. 110).

With regards to cultural differences in the science classroom, communication and interaction patterns among teachers and students of dissimilar cultures are an important factor of how knowledge is shared. For example, a study of middle school students in the Kickapoo Indian tribe in Texas showed that while teachers and students shared some common perspectives and beliefs with regards to learning science (for example, group work and cooperative learning), there were many disparities. Specifically, students disagreed with teachers on a wide range of perspectives, including what teachers believed to be effective teaching strategies, acceptable classroom behavior, and the role humans play in the natural environment (Allen & Crawley, 1998). In addition, the researchers found that the two teachers participating in the study created a cultural conflict because they were unsuccessful in acknowledging these student perceptions and beliefs. The researchers argue that these disparities contribute to students' lack of success in the science classroom.

Similarly, a study of Yup'ik students in Alaska demonstrate that these students do not learn best by traditional forms of science instruction, but rather observation and guided practice while working side by side with adults (Lipka, 1998). These students learn science in an apprenticeship setting that is practical and emphasizes their personal connection to the environment in which they live. This type of learning is not only inconsistent with traditional Western science education that "organizes learning around short and frequent class periods and expects students to listen passively to teachers, follow directions, and respond to question verbally or in writing," but is a more effective mode of instruction for all cultural groups (Buxton & Lee, 2010, p. 52).

Another study of elementary students science beliefs regarding weather and climate was conducted in Miami. The results of the study suggested that White students and middle class SES students were more likely to attribute the cause of hurricanes to scientifically accepted explanations (ocean conditions, weather patterns), while Hispanic, African-American students, and low SES students were more likely to attribute hurricane causes to problems in society such as crime or spiritual powers such as "God made it rain" (O. Lee, 1999). All of these studies indicate the need for teachers to better understand the cultural backgrounds and beliefs of all students (Buxton & Lee, 2010).

A quantitative study examined the pre- and post-test scores of African-American students that were offered culturally congruent instruction (Parsons, 2008). According to Parsons:

> "Culturally congruent instruction addresses the mismatch between school norms and values and those of the homes and communities of ethnic minorities. Cultural congruence can be enacted in several ways (e.g., teaching content via relevant examples, structuring instructional questions) (p. 667)."

These students test scores were compared to African-American students who were offered traditional instruction (control group). In comparison to the pre-test scores, the post-test scores of students in the control group declined, but there was a significant increase in the post-test scores of students offered culturally relevant instruction increased.

Others have demonstrated the importance of personal experiences through investigation of science learning employing a sociocultural framework. Specifically, African American students participated in a Science Lunch Program at an inner-city high school. These students learned science through supportive conversations that built upon each other, which contributed to building their own community. Importantly, students were allowed to use their own language rather than being required to use complex science terminology they did not understand or had trouble pronouncing. For example, they might use street slang or everyday language to explain a scientific process. By creating a community atmosphere that allowed students to use their everyday language to describe scientific processes, there was a shift in the students' attitudes toward and understandings of science and the content (Seiler, 2001).

In a separate study, African American students participated in a class in which they were to learn about Newton's laws while designing model drag racing cars. The students were engaged in the design and building of the cars, but were repeatedly resistant to applying the activity to scientific inquiry or learning the content. While the teacher thought this to be an engaging, inquiry-based lesson, the students did not. In addition, the lesson became very teacher-centered rather than student-centered, as the teacher was the one deciding the content, the questions, and what was important. The conclusion was drag racing lacked relevance with respect to the lives of these inner city students (Seiler, 2001). This reflects the conflicts and barriers that can arise between teachers and students of different cultures, and a lack of understanding of those cultures by the teacher.

The contextual model for authentic science argues that the values and beliefs of students as stakeholders should be recognized and thus students should be allowed a decision in what they investigate (Buxton, 2006). In addition, this model of authentic science gives equal status to the learning of science content and the social issues surrounding the content. The model is a hybrid of canonical authentic science that has been described as "scientist's science" reflective of more traditional Western science and student-centered authentic science which puts greater emphasis on student interests. The latter often seeks to empower marginalized students (Buxton, 2006).

Student centered models proposed by Barton are based in critical theory as she posits that science education research must commit to the "struggle for liberation and in defense of human rights" (2001, p. 899). A contextually based authentic science was couched from Buxton's perspective of "pursuing one's own commitment to liberatory education that promotes social justice" while meeting the required curriculum in science classrooms (2006).

Student centered and contextually based authentic science models have many similarities to culturally relevant pedagogy (Ladson-Billings, 1995, Ladson-Billings, 2000). Three basic features of culturally relevant pedagogy are high academic achievement, development of a critical consciousness, and development of cultural competence. While student centered authentic science models focus on cultural competence, that is a focus on students' culture, their community, and what students consider important; contextually based model of authentic science strive to bring provide equal status to high academic achievement and the development of a critical consciousness. For example, in Buxton's 2006 study, students were learning about marine ecosystems, and local food supply issues. As evidenced in this study, many of the students and their families eat local seafood such as crayfish. By the end of the lesson, students not only learned about ecosystems, but also were more aware of possible health issues stemming from pollution in the area. From a CRP perspective, expectations of high academic achievement and critical consciousness were evident in this study. While cultural competence is less evident, it was not a focus of Buxton's study.

The algal biofuel project examined the three dimensions of CRP, including high academic standards, developing a critical consciousness, and developing cultural competence. The authentic science project was designed for students to engage in the learning of science that required them to utilize higher order skills needed to carry out science practices. The project also allowed students to develop a critical consciousness about environmental issues related to the use of fossil fuels and the importance of developing alternative energy sources. When considering the fields of engineering and science as a culture, a cultural competence was developed from the perspective of the students' ability to effectively communicate and interact with members of the science and engineering community.

Preparation of Teachers for Culturally Diverse Classrooms

Studies have focused on the need of preparing science teachers for urban teaching (Duncan, 2010; Fradd & Lee, 1999; O. Lee, 2002, 2003; Tobin et al., 1999) (Jegede & Aikenhead, 1999; Parsons, 2000, 2008; Songer, Lee, & McDonald, 2003). Specifically, there is often a disconnect between novice science teachers expectations and students abilities that is embedded in the culture of power (Tobin et al., 1999).

Duncan (2010) explores this issue more thoroughly in what she refers to as tri-cultural conflict. That is, the conflict between school cultures, community cultures, and personal cultures. Conflicts can arise because there is a lack of understanding among the different cultures, such as between teachers and students, between urban school culture and the White middle class teachers' culture; and between the urban school culture and the students' culture. Conflicts were observed between White middle class teachers and non-White students, as well as between the culture of middle class African-American teachers and urban students (Duncan, 2010). While teachers were able to help students successfully negotiate the school culture, they were unsuccessful when it came to dealing with the conflict between teachers and students. Duncan recommends that teacher education programs need to be reorganized so that new teachers of urban students have the opportunity to "either increase their cultural sensitivity, or align their own cultural belief systems in order to develop the necessary skill set to become successful science teachers in urban districts" (p. 59).

Existing political, social, economic, and education structures serve to allow groups of people (historically White, male, heterosexual, upper middle class) more control than other groups. As previously described, this creates a culture of power. For example, low SES or low achieving students may be steered away from science courses into a vocational track in spite of an expressed interest, as in the case of Miguel discussed earlier (Barton & Yang, 2001). If students are unable to negotiate the system, they are less likely to challenge the courses offered by their guidance counselors or the curriculum offered in the classroom. Rather, they become disengaged, disinterested, and often become low performing students. The study by Aschbacher & Roth (2010) supports these findings. Students that demonstrated a positive attitude toward a SEM career (persistors) stated they had experienced success in science classes as well as received support from the school and home. In contrast, lost potentials stated they found school science to be too hard, received very little or no support at home or school, and had very little opportunity to interact and work with real scientists. These students with a negative attitude toward a SEM career, or lost potentials, also stated they were actively steered away from science courses by guidance counselors, often being told these types of classes were not for them. The students inferred that guidance counselors were telling them the science courses in which they expressed an interest were too hard for them (Aschbacher et al., 2010).

Through research of the two homeless Mexican American students, Barton (2001) argues that the teacher's lack of understanding of student's culture creates a culture of power, which can have profound effects on the student's attitude toward and achievement in science. Classrooms that successfully integrate culturally relevant pedagogy can be described as having cultural competence. These classrooms recognize the potential negative effects of a culture of power and strive to create an atmosphere that recognizes all of the cultures represented in their classroom (Barton, 2001; Ladson-Billings, 2000).

Shifting the culture of power by drawing from nontraditional funds of knowledge results in improved student performance in science (Tan & Barton, 2010). Specifically, when personal experiences and interests are connected to the content, students become more engaged and active learners of science. For example, a culminating activity of a nutrition unit had students bringing in healthy appetizers to present and share with the class and school administrators (Tan & Barton, 2010). During the unit, discussions took place regarding food choices that students make at home. During the course of these discussions, Barton argues that students were drawing on funds of knowledge such as family funds and community funds. An example of a discussion involving family funds of knowledge revolved around family traditions regarding types of food eaten and how food is prepared. As a result, the teacher and students were able to learn of different family and cultural traditions regarding nutritional choices. While different from the cultural competence demonstrated in the algal biofuel project, this demonstrates a form of cultural competence, as a student's personal culture was bridged to the classroom-learning environment. In a high school science classroom, a student discussed how he tunes his set of drums. This student was showing that he understood the relationship between vibration and frequency – in his own words rather than scientific terminology (Seiler, 2001). What these experiences have in common is that they connect science to their personal life in a way that makes them authentic or genuine and culturally relevant to the student.

In summary, several solutions for improving science education for marginalized students have been offered. This includes increasing the cultural awareness of teachers, providing culturally relevant science pedagogy, and reducing the inequitable distribution of resources.

Authentic Science

Science education reform has involved a move away from traditional instruction that places teacher-centered lectures, rote learning, and textbooks at the center of the classroom. There has been a call for science education to be student-centered, content-rich, and inquiry-based (NRC, 2001). This aligns with National Science Education Standards' (NSES) position on inquiry. Specifically, students should develop the skills and abilities needed to perform scientific inquiry, and that a teacher's role is to help students learn the content using an inquiry approach (Olson & Loucks-Horsley, 2000). This is in agreement with the NGSS and how science should be taught (Achieve, 2013). Thus, the teacher's role is envisioned as a facilitator and enabler, rather than a traditional lecturer. However, this is not common in schools.

For example, there may be conflicts between the pedagogies of a preservice intern and their cooperating teacher. An investigation of science teacher interns' field experience with implementing inquiry was examined (Crawford, 2007). The intern participants in this study represented a broad range of science teaching practices from teacher-centered, lecture driven lessons to high level inquiry based projects. The interns' experience was examined during their year-long experience and it was found that even though an intern might have a strong understanding of inquiry based science teaching practices, they might not be fully implemented if the cooperating teacher does not share the same teaching practices. For example, an intern with a thorough understanding of inquiry based practices was paired with a cooperating teacher that used more traditional teaching strategies. The result was less implementation of inquiry-based strategies on behalf of the intern in spite of knowledge of and commitment to inquiry based teaching. In contrast, a traditionally based intern was paired with a traditionally based cooperating teacher and the result was implementation of traditional teaching strategies. The author concludes that the interns "intentions and abilities to teach science as inquiry" can be influenced by the teacher's "complex set of personal beliefs about teaching and science" (Crawford, 2007).

In a different investigation, a study of nine upper elementary and middle school science textbooks found the majority of activities described as inquiry lessons were primarily simple inquiry activities that led to obvious conclusions (Chinn & Malhotra, 2002). The authors concluded that what many textbooks present as inquiry-based activities do not reflect authentic science. As a result, textbook inquiry tasks assume an epistemology that is entirely at odds with the epistemology of real science. One remedy to this problem is to provide students with authentic science experiences, in which students are allowed to experience real science that is as similar as possible to the work of scientists (Hsu et al., 2009). Authentic science is defined as "forms of engagement that have a high degree of family resemblance with the real jobs of scientists and technicians in science-related fields" (Hsu et al. 2009, p. 481).

Models of Authentic Science

According to Buxton (2006), there are numerous models of authentic science. Several definitions are developed on a canonical model in which authentic science closely resembles the work of real scientists. The canonical model draws on traditional, universalistic perspectives in that science develops knowledge in a culture- and bias-free manner (Buxton, 2006). In this regard, authentic science is described as activities in which students are involved in problem-solving, experimentation, and inquiry so that students are developing reasoning and critical thinking skills (Bencze & Hodson, 1999; H. Lee & Songer, 2003; NRC, 1996; Shimoda, White, & Frederikson, 2002; Toth, Suthers, & Lesgold, 2002). In addition, canonical models also put students in direct contact with scientists and other professionals (Lee & Songer, 2003).

In contrast, a student-centered model of authentic science has been described as one in which questions and inquiry originates with the students (Barton, 1998a). This model provides students and their community with a voice, and empowers students by allowing them to decide what they feel is important and/or needs investigation (Barton, 1998a; Eisenhart, 2001; Warren & Rosebery, 1993). Taking into account what is important to both students and community leaders gives students the opportunity to become agents of social change in their community (Eisenhart, 2001).

Last, a contextual model for authentic science is a merge of canonical and student-centered models, namely one that allows students to develop questions, learn scientific content, and engage in science as a social activity. This model emphasizes the complex exchanges and relationships between students, teachers, and scientists/professionals as they relate to a student's involvement in their community (Anderson, 2001; Anderson, Holland, & Palincsar, 1997; Buxton, 2006; Rahm, Miller, Hartley, & Moore, 2003).

Student engagement in science and understanding of science improves when students engage in canonically based authentic science activities as opposed to more traditional forms of delivery (Lee & Songer, 2003). For example, 6^{th} grade students from an inner city school studied advanced weather patterns using Kids as Global Scientists

(KGS) technology and by collaborating with meteorologists via an online blog. What the researchers found is that authentic science must strongly connect a real-world authentic experience to the students' content knowledge, and be developed in context of the students' ability to understand. That is, it is important to use real-world situations that are not too complex for the students to understand. By limiting the scope to fronts and pressure systems in the KGS curriculum, students were able to better understand how to make accurate weather predictions. The result is that students not only better understand the science content, but also have a deeper, more meaningful understanding of scientific practices. This type of learning environment provides students with authentic science experiences with real-world application. Authentic science experiences with real-world application allow students to develop strong science identities and better prepare students to become social agents of change in their community. Thus, students are better able to make informed decisions about how to prepare for changes in weather. This could be as simple as deciding appropriate clothing to wear on a hot or cold day or how to help their family prepare for an upcoming "cold spell" (Lee & Songer, 2003).

Another authentic science project that reflects the contextual model, in which Western science was incorporated with a student-centered approach, was performed at an elementary school in Louisiana described as one of the lowest performing schools in the state. Buxton (2006) describes the staff and students as having an "overwhelmingly Black student body and faculty" (p. 718). Teachers that expressed interest in the project were allowed to participate in this multi-year project. Students and teachers worked collaboratively with the researchers to choose a topic to research, in this case the effects of pollution on the local crawfish population.

This project had the elements of being a contextually based authentic science project as it allowed students to voice what they believed to be important about health in their community, while taking the learning outside of the classroom. According to Buxton (2006), it aligned to the Louisiana Department of Education standards pertaining to food chains and ecosystems. However, at the end of the study the author considers the project partially successful. While student learning and empowerment took place, the teachers that were involved in the project were those that expressed an interest from the onset. However, administration and staff at the school did not necessarily share in the interest and excitement of the teachers. Thus, the lack of administrator and staff support in essence served to marginalize the teachers involved in the project. A culture of power existed including those teachers involved in the project. The students and teachers made statements that suggest they do not understand each other. For example, teachers often compared the behaviors and academic skills of the students in their classrooms to their own elementary age children at home. In addition, teachers made reference to the fact that they live in very different neighborhoods from their students (Buxton, 2006). This only serves to further strengthen the barriers and conflicts that give rise to the culture of power.

In yet another study, research groups composed of researchers, elementary teachers, and students have shown to be an effective way to simultaneously help teachers learn the content and research skills necessary to help students learn science in an inquiry based, authentic context (Feldman & Pirog, 2011). As participants in the STEMRAY project in rural Massachusetts, a university researcher concerned with arsenic levels in the environment teamed with elementary teachers and students in an after school project in which students tested local playgrounds and their water supplies for arsenic levels. Teachers progressed from expressing concern about the lack of content and research methodology understanding to being able to discuss the content and research confidently as well as to facilitate students' participation in the project. While different from the KGS weather project, this type of authentic science experience can improve students' science identity and provide them with valuable information to inform their decision-making process about their personal lifestyle.

According to Buxton (2006), key elements of contextually based authentic science are (1) teaching and learning are taking place outside of the classroom that places students and teachers in the natural environment, (2) students are the originators of scientific inquiry based questions, (3) students are given an appropriate amount of time to investigate the problem or question, and (4) relationships between students, teacher, professionals, and the community are valued. This type of scientific learning environment promotes a student-centered, higher-order inquiry based environment that implants students into the community as important members of the community. This type of learning environment has the potential for students to become agents of change in terms of social justice.

While authentic science mirrors the work of real scientists, allowing students to do science like a scientist, often by engaging in original research, is different from what Barton (2001) refers to as experiences that are authentic to the student. In this case, students are allowed to investigate in a way that allows them to use science as a means of making sense of their own world. It is important to note that the two are not mutually exclusive as an authentic science experience can also be authentic to the student.

An important consideration is in the design of authentic science classroom lessons and activities. The presence of University researchers in the classroom and exposure to authentic science experiences does not guarantee authenticity of the experience from the student's perspective (Feldman, Chapman, Ozalp, Vernaza-Hernandez, & Alshehri, 2012). Students at an urban magnet middle school participated in a stormwater retention project in conjunction with environmental engineering researchers from a local university. The researchers sought to uncover students' knowledge of retention ponds, students' beliefs about their relationship with the environment, how technology use affected their learning and motivation toward science, and how students' participation affected their attitude toward science. While students participated in inquiry based, hands on activities and helped to restore a stormwater retention pond, they also were exposed to more traditional lecture style forms of instruction and had limited access to scientific instruments used to test stormwater. It was concluded that the structure of the activities and instructional strategies were important considerations when planning authentic science experiences and that the activities ought to look more like what graduate students experiences and less like traditional instruction (Feldman et al., 2012).

According to the Banks model of multicultural integration, contextually based authentic science experiences represent a higher level of inclusion (Banks, 1998). The Banks' model categorizes multicultural inclusion into four levels. The first level, the contributions approach, and the second level, the additive approach, add multicultural concepts without changing the curriculum timelines. Not only do they not disrupt the status quo, but also serve to keep marginalized students out of the center of instruction. Examples of the levels one and two include a celebration of holidays or events of culturally diverse groups or individuals. The first two levels are superficial at best, and are probably the most common type of multicultural inclusion in today's classrooms. The third level, the transformation approach moves toward true integration into the curriculum, as it affects students' thinking and allows students to develop and understand different perspectives. The fourth level, the social action approach, allows students to take their transformed ideas outside of the classroom and use them in a real-world setting to solve social problems (Banks, 1998). This model aligns with the contextually based authentic science model as it provides opportunities for students to work with scientists and other professionals while giving them a voice as to the what, how, and why of what they are investigating as it relates to the content they are expected to learn. With careful planning, authentic science can be one path for providing culturally relevant pedagogy in the science classrooms by providing high quality science learning experiences, allowing students to develop a critical consciousness about the subject matter, and developing cultural competence. Cultural competence could be developed within the culture of science or the classroom.

Scientific Research Experiences for Students

There is a considerable body of literature investigating research experiences for secondary students. The majority of these studies fall into one of two models – extracurricular programs or classroom based student-science partnerships or SSPs (Sadler et al., 2010). With the exception of one program, the extracurricular programs were conducted during the summer in which the participants were paired with a scientist mentor. Students learned as apprentices by working alongside faculty or graduate students.

Often it is assumed that participation in a research project such as an SSP will lead to increased knowledge of science content. While numerous research experience programs have explored student learning of science content, there is sometimes a lack of evidence to support a finding of whether student learning changed as a result of participation in the program. For example, studies have used faculty member interviews to indicate student learning had improved (Hunter, Laursen, & Seymour, 2007; Lewis et al., 2002; Seymour, Hunter, Laursen, & Deantoni, 2004). However, significant increases in understanding of science content were demonstrated in a recent study of high school students involved in a 1 month research program (Charney et al., 2007). A significant gain in learning of science content was revealed through responses to questions on the students' Advanced Placement (AP) biology exam. It should be noted that the student population represented in this study were described as Caucasian, East Indian, and Asian.

Sadler et al., (2009) reviews the literature of the effects of secondary research programs in sustained interest in pursuing a STEM related career. Student participation in research programs have been shown to increase interest in science careers, retention of undergraduate in STEM related studies, interest in pursuing a graduate degree. However, a criticism of these findings is that there may be considerable self-selections on the part of the student to participate in a university based research project as part of an SSP. According to Sadler, "This raises interesting questions regarding the extent to which these programs serve as recruiting mechanisms to increase the science pipeline versus providing enrichment activities for keeping students in the pipeline" (2009, p. 251). Thus, in order to determine if research experiences for students influences their learning, attitude toward science, and interest in pursuing a science related career, then we need to investigate students who do not see themselves as part of the STEM pipeline.

A different study of research experiences examined how graduate and undergraduate students learn to do science (Feldman, Divoll, & Rogan−Klyve, 2009). The researchers found that engineering and science students learn to do science as an apprenticeship after completion of subject matter coursework, and how they learned science depended on the type of research they were performing. Students working in more traditional laboratory settings were described as part of a tightly connected research group characterized by multiple levels of interactions, and opportunities for students at different levels of expertise to learn from each other. In this situation, the laboratory served as the "center of action." In contrast, students engaging in fieldwork were described as members of a loosely connected research group with the professor serving as the center of action. This type of research experience was characterized by less frequent interactions between graduate students as the professor often met with students individually to analyze and discuss data (Feldman et al., 2009). This is an important consideration as it reflects the diverse nature of scientific research. Depending on the field or branch of science, the daily activities of scientists can be vastly different. For example, some scientists (for example, molecular and cellular biologists) often engage in laboratory-based research, a stereotypical perception held by many students (Finson, 2002; Walls, 2012). In contrast, other scientists (such as evolutionary biologists) might use computer modeling to perform their research, while field biologists might collect data outdoors and use computers to analyze their data. Thus, the context of the research experience, doing science is characterized by different levels of social interaction.

Summary and Study Rationale

This literature review demonstrates a need for changes to the existing science education practices in order to meet the call for educating our children so they have a better understanding of science practices as conventional forms of science instruction and materials fail to provide students with a realistic view of how science is really performed. In addition, existing dominant power structures may silence and marginalize populations of students who lack an understanding of the rules. Marginalization also stems from cultural mismatches between teaching practices of culturally relevant science and how science is actually taught, as well as a mismatch between the cultures of students and teachers. Marginalized students are in turn more likely to become low achievers in science. Miguel became a marginalized science student when his voice was not heard and he was steered into vocational classes instead of the more academically science classes he was interested in taking. Likewise, two middle school girls who were not able to bring in supplies for a science project took a position of silence and disengagement. Clearly, it is important for teachers to recognize the culture of power and create a classroom atmosphere in which all cultures are understood and valued. One possible remedy to this is the use of culturally relevant pedagogy as it values both high academic achievement as well as the cultures of everyone in the classroom.

In addition, authentic science experiences provide opportunities for students to learn and do science as similar as possible as that of real scientists. For example, while students were learning about food chains and food webs, students decided to research the health of seafood harvested locally. In this case, a contextually based model of authentic science that allowed students to assume the role of a real scientist while having the power to decide what is important to them, their families and/or communities. This model allows students to perform problem-based inquiry that might involve hypothesis testing and experimentation, and gives students a voice in deciding what problems are important, relevant and should be investigated.

This study adds to the current literature by studying high school students' participation in an original research project investigating algae as an effective biofuel source. Drawing on a sociocultural transformative orientation (Rodriguez, 1998) and a contextually based authentic science model (Buxton, 2006), students and teachers worked with environmental engineering researchers from a local university at their high school. The study reflects the key elements of contextually based authentic science experience as students and teachers are outside of the classroom, students were allowed to originate scientific questions to investigate, students are given an appropriate amount of time to investigate the problem or question, and relationships between students, teacher, professionals, and the community were valued. In addition, it provided teachers with the opportunity to learn with the students and gain experience and confidence in the implementation of authentic science experiences (Feldman & Pirog, 2011).

There is a considerable body of literature examining research experiences for precollege students, including a recent review by Sadler (2009) showing an increase students interest in STEM careers, improved learning of the content as well as an increase in their confidence regarding their scientific abilities. While my study reflects some of the elements in the existing literature, this investigation has distinct differences. First, I studied the experiences and outcomes of students involved in the project. I wanted to not only interpret the experience of the student, but how the experience affected their learning of the content, their attitude toward science, and their perception about who can become a scientist. Second, I wanted to understand the experience and outcome of not only students with a positive attitude toward science and an expressed interest in pursuing a science related career, but those with a negative attitude toward science and lack of interest in STEM type careers. Because a single instrument often fails to provide a complete picture of the complex thoughts, beliefs, and perceptions of a student, multiple data collection tools were utilized (Walls, 2012). Third, this study was situated in the high school. Instead of bringing students to the university to conduct research, the researchers positioned themselves in the classroom to work alongside of students. Fourth, a mixed methods design was utilized to investigate the student experiences and the student outcomes. I hoped to better understand the experience of the students, as well a how students responded to being involved in an original research project in which they had a say in what they were investigating. Did they perceive the experience as authentic? How did their involvement affect their science self-identity, learning, and attitude toward science and STEM careers?

CHAPTER 3: METHODS

Purpose of the Study

While extensive bodies of literature provide evidence for the importance of authentic science activities in the curriculum, less is known about how these authentic activities affect marginalized students with regards to their identity, attitudes, perceptions about who can do science, and learning of science practices. In this study I examined the effects of students' participation in scientific inquiry that is authentic to them and/or to the practice of science. The study was located at an urban high school in which scientists and other professionals worked with the students and teachers as they formed a partnership to investigate means of improving biofuel production from algae. This study looked at the ways in which this type of experience affected all student participants in terms of their attitude toward science, self-perceptions about doing science, and their learning of science. The research questions that guided this inquiry were:

1. With regard to students' perceptions, was their involvement in this project an authentic science experience?

2. How did the participation of high school students in an authentic science project affect their identities as scientists and perceptions about who can do science?
3. How did the participation of high school students in an authentic science project affect their attitude toward science?
4. How did the participation of high school students in an authentic science project affect their learning of science practices?

Research Design

This study utilized a fully mixed concurrent dominant status methods approach to data collection and analysis (Leech & Onwuegbuzie, 2009). A mixed methods research design is a procedure for the collection and analysis of both quantitative and qualitative data at some point during the investigation (Creswell, 2007).

With regard to the quantitative aspect of this research design, the researcher forms a hypothesis, then collects and analyzes numerical data in an attempt to establish cause and effect relationships that lead to generalizations about a population. One approach is to isolate and test variables to establish relationships and test theories. It is important to note that researcher subjectivity is an important consideration in quantitative research as the researcher decides which variable(s) to investigate, and which instruments to use to analyze the data.

In contrast, qualitative research is described as "an inquiry process of understanding" (Creswell, 1998, p. 15) where the researcher develops a "complex, holistic picture, analyzes words, reports detailed views of informants, and conducts the study in a natural setting" (Creswell, 1998, p. 15) In qualitative research, the investigator is situated within the study so that s/he is able to collect in-depth and detailed data about the everyday experiences in order to identify patterns and themes. Qualitative research recognizes that human behavior is flexible and changing due to contextual, temporal, and spatial considerations.

A mixed methods research design is embedded in pragmatist beliefs that qualitative and quantitative research methods are compatible and that "thoughtful mixing" of the two can provide a more complete picture of the problem under investigation (Johnson & Chistensen, 2012, p. 32). Employing only one method, quantitative or qualitative, may not depict all of the details of a situation. By employing quantitative and qualitative research methods either sequentially or concurrently within a single study, a more complete analysis of the data is allowed. Mixed methods designs serve as a means of research triangulation and improve the credibility and validity of the results (Creswell, 2008; Johnson & Christensen, 2012).

While designing a mixed methods study, three elements need to be considered: level of mixing, time, and emphasis of approach (Leech & Onwuegbzie, 2009). Level of mixing indicates if the quantitative and qualitative methods are completely or partially mixed. A partially mixed design involves the mixing of data after collection and analysis are complete – at the interpretation phase. In contrast, a fully mixed design indicates there is mixing of quantitative and qualitative data throughout the research process (Leech & Onwuegbzie, 2009). Time indicates whether the mixing of quantitative and qualitative methods occur at the same time (concurrent) or at different stages (sequential) of a single research study. Emphasis of approach indicates whether the quantitative and qualitative methods are given equal weight or if one method dominates the other.

In this study a fully mixed, concurrent, dominant status paradigm was utilized (Leech & Onwuegbzie, 2009). This mixed methods paradigm meant qualitative and quantitative data were collected simultaneously during the research process (concurrent), fully mixed throughout the research process and qualitative data sources were given more consideration (dominant status).

Multiple methodologies and forms of data were collected on students, teachers, and researchers over several weeks. Quantitative and qualitative data were collected from a science attitude survey, scientist perception instrument, and pre/post-assessments. Purely qualitative data were collected from interviews of students, field notes, and journals.

One of the objectives of this study was to gain understanding of how participation in the algal biofuel project affected students' attitudes toward science and perceptions about who can become a scientist. Quantitative data were collected from a modified science attitude survey and the Identify-A-Scientist (IAS; Walls, 2012), a photo eliciting activity instrument. The science attitude survey is composed of 32 statements in which students responded using a 5-point Likert scale. However, Likert scale type responses often fail to reveal more in-depth understanding of students' beliefs and attitudes (Walls, 2012). Thus, the IAS was utilized to collect both quantitative (Likert response) and qualitative responses. Data from interviews, science attitude surveys, and the IAS were triangulated in order to better understand how students were affected by participation in the project.

The pre- and post-assessments were designed for students to respond to open-ended questions. This provided an understanding of what students learned by being involved in the algal biofuel project. Student responses were analyzed for correctness as well as common themes.

An additional level of analysis included comparing individual student responses to responses on the IAS, and science attitude survey. Qualitative analysis of the interviews and journals was used to corroborate themes emerging from surveys and tests about how student involvement in the algal biofuel project affected their thoughts, beliefs and perceptions about science and scientists, and to determine whether the activities were truly authentic to the students involved in the project.

Theoretical Framework: Interpretivism

Interpretivist research seeks to understand events, actions, and experiences (Erikson, 1986). As an educational research perspective, interpretivism allows the researcher to attach significance to the event, and to recognize the subjective nature of the process.

An interpretive perspective warrants the researcher being present during the study so that a detailed recording of events is possible. This includes collecting data from multiple sources such as interviews, observational field notes, and student journals followed by a thorough analysis and re-analysis of data leading to both rich descriptions of individual events as well as general accounts of events. This took place throughout the algal biofuel project.

According to Patton (2002), interviews are one source of data for this type of research. Specifically, interviews allow the researcher “to find out what is on someone else’s mind” (Patton, 2002) and help to limit the imposition of researcher perceptions onto the meanings of the participants’ experiences.

I chose data collection methods that allow for the investigation of the student experience in a contextually based authentic science experience, including interviews and journaling. Analysis of these data sources allowed for in-depth, detailed insights into the students’ experiences. It focused on “descriptions of what people experience and how it is that they experience what they experience.” (Patton, 2002; p. 107).

Site Selection

The study took place at an urban high school in the southeastern United States. The high school was originally established as a segregated high school in 1934 for African American students. Currently, it offers several magnet programs. During the 2011 school year, 31% of 9th grade and 11% of 10th grade students received a passing grade on the reading section of the Florida Comprehensive Assessment Test (FCAT). In addition, 43% of 10^{th} grade students passed the Mathematics portion of the FCAT and 28% of 11^{th} grade students passed the Science portion of the FCAT.

This school is located in an urban setting and has a high percentage of low socioeconomic (SES) students, and a diverse student population. For the 2011-2012 academic year, this high school has approximately 1600 students of which 71% are Black, 14% are White, 11% are Hispanic, and 2% are Asian. In addition, 64% are eligible for a free or reduced fee lunch.

Twelve students in an honors Marine Science class were participants in this study. Table 8 summarizes the demographics of students participating in the study. Gender, magnet status, and SES were reported by the students' teacher, while ethnicity was self-reported.

Intervention Design

Students at an urban high school engaged in science activities in partnership with an environmental engineering research group from a local research-intensive university. The research group consisted of two graduate students (Grace and Katia) and a faculty member (Professor Berber). Members of this research group are currently engaged in studying algal biofuel production from wastewater nutrients. The teachers (Ms. Prescott and Mrs. Bodin) served as facilitators, and ensured that students collected data, and maintained their bioreactors. However, neither teacher had ever participated in this type of project, so they were learning with the students.

Table 8: Demographics of students participating in final project

Demographic	Number of students
Gender	8 male, 4 female
Ethnicity	2 White, 3 African American, 5 Hispanic, 1 Asian, 1 multiracial
SES	8 (free and/or reduced lunch)
Enrollment status	6 magnet, 6 non-magnet
ELL	1

A pilot study took place in the spring of 2012, in which Katia and Professor Berber worked with students in Ms. Prescott's agricultural science class at the high school. Students worked with the environmental engineering researchers to study algae as a biofuel. Initially, students built bioreactors and then cultured algae in a greenhouse located on the high school campus. Over the course of 4-6 weeks, students monitored algae growth conditions including biomass production, pH, temperature, and natural light conditions in an effort to determine optimal growth conditions for algae. Each student group maintained three bioreactors that had a specific ratio of nitrate and ammonia. In addition, each student maintained a journal that included descriptions of what they were doing in the project as well as writing a research summary. During this time, student groups were responsible for maintaining a laboratory notebook of their methods and data as well as an oral presentation of their findings at the end of the project.

The pilot study provided valuable insight for education and engineering researchers, allowing us to make changes to the study design for the next school year with Mrs. Bodin's marine science class. For example, one significant change was creating two phases to the project. During the first phase, the students were provided a more guided research question in order to determine the best ratio of nitrate and ammonia for optimal algal growth. During the second phase, students generated their own research question to investigate by working in groups and collaborating with Professor Berber. Their data and findings from phase one were used to generate a research question in phase two. This aspect of the intervention was designed to allow students to have a voice in what they were investigating while ensuring that they were creating a research question that remained within the parameters of Professor Berber's research group.

During the fall of 2012, the project was implemented a second time, with a different teacher, Mrs. Bodin, who teaches Honors Marine Science. During this time, Grace worked with students to study algae as a biofuel source. As described above, the students engaged in collaborative research during two phases. Student groups also maintained a laboratory notebook, and individual students maintained a journal. The journal allowed students to write research summaries for each phase of the project.

During the middle of the project, students had the opportunity to participate in a field trip to the university. During this field trip, students attended an engineering graduate student symposium, listened to a keynote address from an engineering faculty member, and were given a tour of Professor Berber's lab. It is important to note the high school students interacted with graduate students and faculty were diverse in terms of age, gender, and ethnicity.

At the end of the project, each student group prepared a PowerPoint presentation in order to present their findings. Members of the audience included Professor Berber, a science education professor, the students' teacher, as well as school and district administrators. The presentation was modeled after typical conference presentations in which a Q&A session followed each presentation.

It is important to note that students were participating in a project that has many aspects of laboratory-based science in that they were collecting data regarding the growth of algae. Also, the classroom and greenhouse setting lent itself to a closely connected research group setting where all members (engineering researchers, students, and teachers) had the opportunity to discuss the data and findings of their experiments. At the end of phase 1, Professor Berber met with the students to help them generate research questions for phase 2 of the project. This type of research group also allowed students to make explicit connections between the algae biofuel project, authentic science, and specific scientific practices. The presence of engineering graduate students, faculty, and myself while students were participating in the daily activities of the project, helped students to understand that science can be a collaborative endeavor. In addition, this experience also helped students make explicit connections between what they were doing and authentic science (i.e. – performing original research).

However, the laboratory-based aspect of the study design was a limitation in that it may have reinforced stereotypes students have about scientists and how science is performed (Finson, 2002; Walls, 2012). As a result, the study provided students with insights into other areas of science and ways of doing science that might be experienced by taking part in an authentic science experience reflecting non-laboratory based research practices such as computer-, field-, or theoretical-based research.

Data from the first phase experiments were collected and analyzed by marine science students and engineering researchers. The marine science students and researchers used the data obtained from the first phase to determine the direction and nature of the experiments conducted (second phase). This approach helped to validate the authenticity of the experience for these students as they had a voice in deciding what experiments will be carried out during phase 2. This was in agreement with the tenets of a contextually based authentic science model (Buxton, 2006).

Students worked in groups of three, and were responsible for investigating algal growth under certain conditions. Each group was responsible for maintaining and collecting data from three bioreactors so that the data could be averaged. For phase 1, each group added a different ratio of ammonia (NH_3) and nitrate (NO_3) to each of the three bioreactors. The four groups ratios were 100% NH_3, 100% NO_3, 50% NH_3/50% NO_3, and 75% NO_3/25%NH_3. Each group was responsible for the daily monitoring of bioreactors for flow of oxygen, amount of light exposure to alga, pH, and total solids. Mrs. Bodin, like Ms. Prescott, had no prior experience with this type of research project.

Participant Selection

Ms. Prescott and Mrs. Bodin were selected based on recommendations from school administrators. One of the teachers involved in the project, Mrs. Bodin, teaches honors marine science and biology while the other, Ms. Prescott, teaches agricultural science. Students taking either marine science or agricultural science participated in the algal biofuel project. Ms. Prescott is new to teaching (less than five years), and has a degree in Elementary Education. Mrs. Bodin has more than ten years experience, and has a degree in Biology. She is considered a veteran teacher and is well respected by her colleagues and administrators. My observations found her to be exceptional with regard to her interactions with her students and abilities in the classroom. As described earlier, there is considerable diversity of students in these classes, based on enrollment status, socioeconomic status (SES), and ethnicity.

Data Collection and Analysis

For this study a fully mixed, concurrent, dominant status paradigm was utilized (Leech & Onwuegbzie, 2009). This type of mixed methods paradigm has three elements. First, a fully mixed study is one in which qualitative and quantitative methods are mixed throughout the study. Second, a concurrent design is one in which qualitative and quantitative data are collected simultaneously. Third, dominant status in this case, indicates that qualitative data were given more consideration (Leech & Onwuegbzie, 2009).

Quantitative and qualitative data were collected from a science attitude survey, scientist perception instrument, and pre/post-assessments. Purely qualitative data were collected from interviews of students, teachers and engineering researchers, field notes, classroom observations, and journals from students. An overview of the data collection timeline is shown in Figure 2.

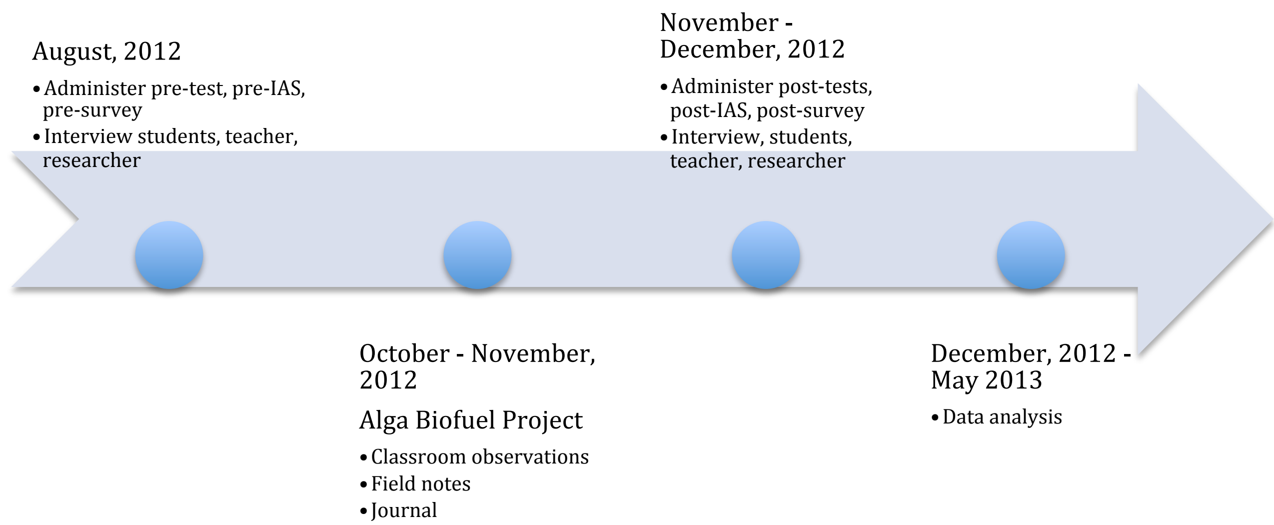

FIGURE 2: Project timeline

Because the study was designed to investigate how students were affected by their participation in a contextually based authentic science experience, I wanted to better understand the students' experiences during the algal biofuel project. Specifically, how did this experience affect their attitudes toward science, perceptions about who can become a scientist, and their learning of science? In order to understand their experience, data were collected from interviews and corroborated with open-ended responses to surveys and tests as well as classroom observations and student journals. In addition, the structure of the science attitude survey and IAS allowed for quantitative data collection and analysis that was used to validate and verify data from qualitative methodologies.

Qualitative Data Collection

The qualitative data in this study were collected at all intervals of the project, and were used to both triangulate quantitative data and provide in-depth, rich descriptions about the students' experiences being participants in an authentic science experience.

One technique was to administer the science attitude survey, IAS, and assessment at the beginning and end of the project. Individual interviews of all students were also conducted after the project was completed. I also wanted to understand those students who initially exhibited a negative attitude toward science, as well as those who may be marginalized with regards to their science career. However, I believe it is also important to understand how students demonstrating a positive attitude toward science were affected by involvement in the project. Johnson & Christensen (2012) state that phenomenological research has the ability to illuminate similar and different experiences of a common event.

Also, students kept a journal during the project. Journals allowed students to reflect on different aspects of their experience as well as write procedures, and summaries of their findings. Last, classroom observations and field notes were recorded.

Triangulation of different data sources is an important aspect of qualitative research as these different sources can serve to complement and validate each other (Patton, 2002).

Qualitative Data Analysis

In addition to the data analysis steps described below, interim analysis and memoing of data from the survey and IAS were used to analyze qualitative data (Johnson & Chistensen, 2012; Miles & Huberman, 1994). Interim analysis allowed for repeated and deeper examination of data throughout the research study and allowed for a more in-depth analysis and understanding. Memoing is a researcher reflexive tool that allowed the researcher to reflect and make notes or memos about what they learned throughout the study (Johnson & Christensen, 2012).

First, all audio data was transcribed into typed text using Dragon software. All handwritten data from journals and classroom observations were transcribed into typed text as well. Next, all transcribed data from the surveys were coded and analyzed for themes. Qualitative data analysis included the following sequence:

1) Initial examination of the data by reading and rereading the transcripts and written responses.
2) The data from interviews, surveys, IAS, journals and classroom observations were analyzed for similarities and/or differences so that each data piece was sorted into

meaningful segments that relate to the research questions. Segments may include words, sentences, or passages from any of the data sources.

3) Labeling the segmented data with inductive codes. When a meaningful segment of data was identified, it was assigned an inductive code. Inductive codes were generated after the data was collected, and as the researcher was examining the data.
4) Generating frequency distributions of codes. Each unique code was assembled into column 1 of a table. Then, the frequency at which each code occurred was determined and placed in the second column. Last, the frequencies were converted to percentages.
5) Examining the codes for similarities and grouping the similar codes together.
6) Development of themes or categories from grouped codes and code frequencies.
7) Examination of the themes in order to make sense of student experiences in the project as well as to identify interconnections and interrelationships among themes, and uncover patterns of high school students' behaviors, beliefs, and perceptions.
8) Created a description and an interpretation of the students' beliefs, thoughts, and behaviors as they related to their involvement in the authentic science experience.

9) In order to improve the credibility and reliability of the findings and conclusions, member checking and peer review were utilized through the analysis (Johnson & Chistensen, 2012; Miles & Huberman, 1994). Member checking took place throughout the study with the teacher, and at the end of the study with the students during the post-interview. Students were asked specific questions about responses made on surveys and in journals. The purpose was to confirm the accuracy of the students' responses. In addition, peer review took place after the project, and throughout the analysis process. Peer review usually took place during weekly group meetings with a science education professor and three science education graduate students.

Quantitative Data Collection

The quantitative phases of data collection occurred at the beginning and end of the project with administration of the pre- and post- science attitude survey, IAS, and assessments. Qualitative data were also collected from the IAS. The science attitude survey is a 32 item, 5 point Likert scale instrument designed to assess students' attitudes toward science at the beginning and end of the project. In addition, data from administration of the pre-science attitude survey and IAS were used to help in the identification of students who have a negative attitude toward science as students who may have a high degree of marginalization.

Quantitative Data Analysis

Quantitative data were analyzed using descriptive and inferential statistics. Individual and grouped item Likert-type responses to the attitude survey and IAS were analyzed by calculating the median, average and frequency distribution to each response. In addition, responses to the pre- and post- version of the IAS, science attitude survey and assessment were analyzed for statistically significant differences. Inferential statistical analysis included the use of the Wilcoxon signed ranked test with a confidence interval of 95% (Grimm, 1993) to determine if there were differences between pre- and post- median scores.

Measurement of Science Attitudes

Because I am interested in better understanding students' attitudes toward doing, learning and pursuing science careers, I administered a survey that addressed both scientific skills and attitudes. The scientific skills survey is a modified version of one that has been used to measure undergraduate perception of their scientific skills before and after participation in a research education undergraduate (REU) experience (Kardash, 2000). The science attitudes portion of the survey specifically assessed student attitudes, beliefs, motivations, and abilities. This survey was administered to students before the project began and again at the conclusion of the project.

The surveys served two purposes. First, it allowed me to determine if science attitudes and interests changed during the course of the project. Second, the pre-survey allowed me to identify students who have become marginalized with regard to their science education as it would be expected they would exhibit negative attitudes and/or interests. Data from the pre-IAS and classroom observations were used to verify these students from the attitude survey. All students were interviewed to determine the extent to which involvement in an authentic research experience affected their attitudes toward and learning of science. I wanted to better understand their attitudes and ideas in addition to what they learned at the beginning, through out, and at the end of the project. For example, did they view the experience as authentic science? How were they affected by collaborating with teachers, researchers, and other students? Did it change their self-perception about their own ability to learn science or pursue a science related careers?

Likert-scale data from the pre- and post-surveys were analyzed quantitatively. In order to determine if statistically significant differences regarding science attitudes existed between the pre- and post-surveys, scale scores for the pre- and post-surveys were compared using the Wilcoxon signed rank test (Grimm, 1993).

Identify-A-Scientist

The identify-A-Scientist (IAS) instrument was developed to examine students' view of scientists, science, and self- perception of doing science (Walls, 2012). Walls developed the IAS to be used in conjunction with the Draw-A-Scientist test (DAST) tool. The DAST was developed to examine students' stereotypical conceptualizations about scientists including gender, race, types of scientific instruments used, how they dress, and how they perform their work (Chambers, 1983). During the DAST, students were asked to "draw a picture of scientist" and then the pictures were analyzed based on the presence of certain items such as whether the drawn figure was wearing a lab coat, wearing eyeglasses, and the presence of facial hair. However, critics have argued that DAST produces a simplified drawing (i.e. – monochromic stick figures that may or may not be gender neutral in appearance) that fails to reveal a students' intricate and multi-faceted perceptions of what they believe a scientist looks like. A single and simplistic drawing of a scientist may not expose a students' multifarious conception of their views of a scientist (Flick, 1990; Fung, 2002; O'Maoldomhnaigh & Mhaolain, 1990). The newly developed IAS allows participants to select the person they believe to be a scientist, from a photo array of eight photos representing both genders and different ethnicities. IAS has been implemented with elementary students and the results support the argument that a single instrument, such as the DAST, does not necessarily reveal all of a student's complex perception of what a scientist looks like. Walls (2012) found that 3rd grade African American students most often drew an African American or non-White scientist on a modified version of the DAST (M-DAST). In contrast, the same students most commonly chose a White scientist on the IAS. While the M-DAST allows students to report their conceptualization of scientists, the IAS allows students to report their perceptions of scientists (Walls, 2012). As research question two in this study sought to better understand student perceptions about who can do science, only the IAS addressed how students' perceptions about who can do science were affected by participation in the algal biofuel project.

High school students were administered the IAS perception instrument individually at the beginning and end of the project. Students were asked to choose the one person they believe to be a scientist from a PowerPoint projection showing eight different scientists. Then, students will be asked two follow-up questions: (1) On a scale of 1 to 5, how confident are you of your selection, and (2) why did you choose that particular individual? This process was repeated ten more times, using ten different photo arrays. Results were subjected to both quantitative and qualitative analysis.

A percentage frequency distribution was determined for each of the ten photo arrays to summarize which individuals were selected as the scientist (student response to the first question). The gender and ethnicity of each person in the photo was documented. In addition, each student was asked the ethnicity of the person in the photograph. A total score was calculated ranging from 0-10 with points ascribed to choices that were not White male. The frequency distribution was averaged from the ten different photo arrays shown to the students. Student responses to the first follow-up question (a Likert scale response) were analyzed using the same methods as the Likert responses to the science attitudes and research skills surveys. Using the Wilcoxon signed rank test, these results from the pre- and post- IAS were compared for statistically significant differences. Student responses to the last follow up question were qualitative in nature and will be analyzed using previously described process for segmenting and coding of data.

Learning of Science Practices

Pre- and post-assessments were designed collaboratively between the teachers, as well as engineering and education researchers. Students were given pre- and post – tests at the beginning and end of the project. Analysis of the project included both quantitative and qualitative methods. First, student responses to open-ended questions and research summaries were analyzed and coded for (1) emerging themes and (2) whether responses were right or wrong. Qualitative analysis involved the process previously described. Next, individual responses on the pre- and post-tests were triangulated with data from the science attitude survey, IAS, and interviews as a means of validating student experiences in the authentic science project.

Classroom Observations & Field Notes

By assuming the role of nonparticipant observer (Patton, 2002; Johnson & Christensen, 2012), I was able to provide rich details about the classroom, learning environment, culture, and provided context for the data collected from interviews, surveys, tests, and journals. By acting as a nonparticipant observer, I explained to students why they were being studied and spent a considerable amount of time with the participants during the authentic science project. This allowed for a detailed recording of experiences that occurred during the project including level of student engagement, interactions among researchers, students, and teachers as well as what the participants did during the project.

Interviews

In order to better understand the effects of participation in the algal biofuel project, interviews of students were conducted. From an interpretivist perspective, the interviews provided data about the experience from the perspective of the individual, and what it is they experienced during a particular event. I sought to understand how the experience affected the students. In addition, I wanted to understand the beliefs, attitudes, understanding as well as scientific skills and knowledge of these same individuals. The interview data, in conjunction with journal, presentations, and classroom observations allowed me to identify shared experiences among participants. It is important to note that my role of nonparticipant observer also helped to gain rapport and trust with participants, as this is considered a critical element of conducting successful interviews (Johnson & Christensen, 2012).

All participants were interviewed using a series of semi-structured open-ended questions (Appendix A). This allowed for general questions to be asked, but gave flexibility in creating spontaneous follow-up questions based on responses to the general questions. The questions were designed to help better understand the students' experience in the project. Specifically, the questions sought to better understand what they learned, their thoughts and beliefs about the project, and whether their participation in the project affects their attitude toward doing and learning science. In addition, I wanted to better comprehend the students understanding of what authentic science is and how this experience compared to the school science they experienced before the project.

Student Journals

Students kept an ongoing, individual journal in addition to a group laboratory notebook. The journal allowed students to record their thoughts, emotions, and experiences during the authentic science project. Specifically, the journals were a place for students to explain the results of their experiment as well as their thoughts on the project as authentic science. Data from these journals were analyzed using the nine-step qualitative analysis described previously to identify emerging themes and validate data from interviews, surveys, and assessments.

As part of the field notes, I kept a researcher journal to record interactions between myself and researchers, myself and students, as well as myself and teachers. This is significant; as it is important that I "suspended any preconceptions I have about the phenomenon" (Johnson & Christensen, 2012) I also recognized that it is impossible to completely separate my personal beliefs from the research process. Thus, my journal allowed me to examine how my personal beliefs may have influenced my observations and other forms of data collection. My researcher journal served as an avenue for reflecting and exposing my frustrations, biases, and other feelings during the project. Table 9 summarizes the tools and instruments that were used to answer each of the research questions.

Table 9: Overview of data collection instruments

RQ/ Data	Research Skills Survey	Attitude Survey	IAS	Test	Classroom Observations	Journal	Interview
1	✓					✓	✓
2			✓			✓	✓
3		✓			✓	✓	✓
4				✓	✓	✓	✓

Establishing Credibility and Reliability

As a veteran science educator who has seen students some students excel and some struggle in science classes, I had a strong personal interest in this study. From an interpretivist standpoint, the experience of the participants and the researcher as an observer were both important perspectives. I recognized that my personal desire was to see all students excel in science, and to want to intervene when a student is struggling. I attempted to be critically self-aware of this trait as it is impossible or at least highly improbable to have completely disengaged my personal feelings and beliefs from the data collection and analysis.

In establishing credibility in qualitative studies, it was important that I recognized and remained aware of my own personal biases and beliefs. To determine the credibility of the findings in this research study, the following strategies were utilized. First, both data and methods triangulation were employed. Data from multiple sources and methodologies were used for corroboration (Johnson & Christensen, 2012). Second, member checking was utilized through out the study to provide verification of and additional insights into the findings. Third, peer review was conducted with other educational researchers to discuss findings. Fourth, researcher reflexivity was accomplished through journaling to ensure that I was aware and able to critically reflect on my personal beliefs and biases.

Advantages & Disadvantages

Like any research design, mixed methods research has strengths and weaknesses. An important consideration is that researcher bias is an issue in both quantitative and qualitative research. It is impossible to separate one's personal beliefs, thoughts, and perspectives from a research project that is driven by personally compelling interests. The strengths of the proposed research design were that it answered research questions and offered different perspectives and insights that a single study (qualitative or quantitative) could not answer alone. In addition, mixed methods designs can help triangulate data sources and methods. Weaknesses of mixed methods studies are that they can be more time consuming in terms of data collection and analysis, they require knowledge of both types of methodologies and may offer incompatible results.

Ethical Considerations

Ethical issues were addressed at all stages of the study. In compliance with the regulations of the Institutional Review Board (IRB), the permission for conducting the research was obtained through the University of South Florida IRB office. This included the development of all necessary informed consent and assent forms as well as ensuring the privacy of participants.

CHAPTER FOUR: ANALYSIS AND FINDINGS

Introduction

The purpose of this study was to explore the effects an authentic science experience had on urban high school students. Specifically, I wanted to better understand how this experience affected students' attitudes toward science, learning of science, and their science identity. In addition, I sought to determine whether the students perceived this experience as authentic science. The research questions guiding my inquiry were:

1) With regard to students' perceptions, is their involvement in this project an authentic science experience?
2) How does participation of high school students in an authentic science project affect their identities as scientists and perceptions about who can do science?
3) How does participation of high school students in an authentic science project affect their attitude toward science?
4) How does participation of high school students in an authentic science project affect their learning of the science practices?

In this chapter I will first present the findings of each student as it relates to the research questions. Next, I will address the four research questions by triangulating the quantitative data from the pre- and post-Identify-a-Scientist (IAS), science attitudes, research skills survey, and tests with qualitative data from student journals and interviews.

RQ1: With regards to students' perceptions, is their involvement in this project an authentic science experience?

Authentic science experiences for students have been described as those that are as similar as possible to the daily activities of scientists in science related careers. One model of authentic science, namely a contextual model, is one that allows students to develop questions, learn scientific content, and engage in science as a social activity. This model considers the interactions between all stakeholders - students, teachers, and scientists/professionals (Anderson, 1997; Buxton, 2006; Rahm et al., 2003). Thus, to answer research question one, it is important to consider whether the students consider their involvement in the experience to be one of authentic science. Research question one is designed to determine if students perceived the experience as one of authentic science. In order to answer research question one, data were analyzed from two items on the research skills survey, the post-interview, and journals.

Two items in the research skills survey were designed to better understand if students perceived their experience as one of authentic science. The first was "I participated in the Algae Biofuel Project like a real scientist", while the second item was "I felt like a real scientist when I participated in the Algae Biofuel Project." With regards to these two items, the median score on the pre-survey was 8.0 and the average score on the post-survey was 8.5. A Wilcoxon signed-rank test of both items showed there was not a statistically significant difference between the median pre- and post-responses to these two items. The median score on the pre-survey was high (8.0), indicating the students expected their experience to be one of authentic science. One possible explanation for the minimal difference may be due to the high scores students were reporting at the beginning of the project, leaving small room for growth. There were similar findings with the science attitudes instrument and is discussed in more detail in the next section (research question 2). The slight increase in the median score on the post-survey in conjunction with qualitative data from interviews and journals show that students believed their participation in the algal biofuel project to be one of authentic science.

It is important to note that one item is asking students about their perception with respect to their participation in the project, while the other item is asking how they felt by participating in the project. Most often, student increases in one item were mirrored by an increase in the second item. There were two students who are an exception to this trend, and they are discussed in the individual student profiles that follow.

Qualitative data from student interviews support the findings from the survey, as all but two of the students indicated that they "felt" like a real scientist and that their activities were similar to those of what a scientists does at work. To provide an in-depth understanding of student perceptions, individual profiles are included. The data are presented for each student, followed by an overall summary of the findings.

Table 10: Summary of student perceptions regarding research skill abilities

Items	Statistical Analysis
I can create a research hypothesis.	Median (Pre): 24.5
I can design a scientific experiment.	Median (Post): 27.0
I can make observations and collect data.	Z=2.463
I can figure out what the data means.	p=0.014
I can explain to others the results of the research.	r= 0.71

In addition, student perceptions about specific research skills were assessed at the beginning and end of the project. The results are shown in table 10. The median score for these items increased from 24.5 to 27.0. Wilcoxon signed rank analysis suggests these differences are statistically significant ($n=12$, $z=2.463$, $p=0.014$) with a large effect size ($r=0.71$). The extent to which students understood the experience as authentic science was determined by analysis of interviews and journals, and is addressed in the next section. The extent to which students learned science practices is addressed later in this chapter (research question four).

Simon

Simon is an African American male and a senior in high school. He is a student in the magnet program. He is taking the marine science course as a science elective and hopes that it will help "boost his GPA." Simon plans to study mechanical engineering after high school at a state research-intensive university.

Simon's initial response to the statement "I will participate in the algal biofuel project like a real scientist" was a 4 on a 5-point Likert scale, meaning that he agreed with the statement. His pre- response to the statement "I will feel like a real scientist when I participate in the Algae Biofuel Project" was a 3. Thus, Simon had an expectation that he would participate in the project like a real scientist.

Comparing Simon's pre- and post-responses to these two items show an increase with regards to the statement that he felt like a real scientist by participating in the algal biofuel project. His response to the statement "I participated in the Algae Biofuel Project like a real scientist" remained unchanged. While this might suggest little or no change, he stated during the post interview that he felt what he was doing was "very similar" to that of what a scientist does and “they probably just use more, um, higher technology than what we do, but it is pretty much the basics...a little, like we tested the algae growth and we got good results and stuff” and that “they (they meaning Professor Berber and her research group) might want to take notes from what we did into their classroom.” Another strong statement was his response to asking how he felt about how Professor Berber might use their results in her research. A portion of the transcript is shown below.

> Angela: so how does that feel?
> Simon: it feels really good, to know that we could do something like that. And scientists spend their whole day working on something like this and we could come up with that.
> Angela: so what do you think they will do with the results?
> Simon: they will like test on it more and use their technology to better our results, see the different growths they can get, see if they can get it higher - like a sustained growth instead of letting it drop down and stuff.

These statements support the finding that Simon felt his experience to be one of authentic science. The definition of authentic science is one that allows students to experience science in a way that resembles, as closely as possible, the day-to-day work of practicing scientists. He makes reference to what he is doing as having a high degree of familiarity with what scientists are doing. These statements also suggest he felt he was being recognized as a scientist by someone who is a practicing scientist, which is a domain in the science identity model. I address this finding in more detail later. In addition, he sees the results of his experiment as useful to the research group at USF. In all, these data suggest that he believed his experience to be one of authentic science.

Jessie

Jessie is an Asian American female and a sophomore in high school. She is also a student in the magnet program. Her favorite subjects in school are math and science. She is taking marine science because she thought it would be interesting and taking care of fish would be fun (students are required to maintain a marine aquarium while taking the class). Jessie plans to study medicine at a major research-intensive university in the East after graduation from high school so that she can help people.

Jessie's pre-survey responses to the statements "I participated in the Algae Biofuel Project like a real scientist" and "I felt like a real scientist when I participated in the Algae Biofuel Project" were both a 4 (on a 5 point Likert scale). Thus, Jessie had a high expectation that she would participate in the project like a real scientist. Both of her post-survey responses increased to a 5, or strongly agree. She had high expectations that she would participate in the project like a real scientist before the project and her perception was strengthened after the project was completed.

Jessie's post interview suggested that she is making a strong connection to what scientists do and what she was doing. A portion of the transcript is shown below.

> Angela: In terms of thinking about what a scientist does on a day-to-day basis, compared to what you are doing how do you think those to compare?
> Jessie: I think there are some similarities, I mean of course they had to analyze the data and record it, their equipment would be more advanced than just bottles.
> Angela: in terms of what you were doing, do you think what you are doing reflects what a scientist does on a day-to-day basis?
> Jessie: I think so, I think a scientist is like on a daily basis is doing research, collecting data, collect samples, they would probably collect more samples more often than we did.

Jessie makes specific reference to the idea that practicing scientists would be using more advanced equipment and collecting samples more often. However, she specifically refers to the fact that she was collecting samples and data, and was analyzing data. Importantly, she sees that as something that scientists do on a regular basis. The data support the finding that she believed her experience to be one of authentic science.

Alex

Alex is a Hispanic male and a junior in high school. While this high school is a STEM magnet and enrolls students from anywhere in the district, it is also a neighborhood school that enrolls students who live in the schools' zone as determined by the district. Alex attends this high school because it is in his zone, but he is not a student in the magnet program. Alex stated that he is taking this class "to get more credits" and that he decided to stay in the class because it was "kind of fun." He plans to attend a local community college after high school. He wants to study welding so that he can "make and build stuff."

Alex's pre-survey responses to the statements "I participated in the Algae Biofuel Project like a real scientist" and "I felt like a real scientist when I participated in the Algae Biofuel Project" were both a 5 (on a 5 point Likert scale). Thus, Alex had very high expectations at the beginning of the project that he would participate in the project like a real scientist. In addition, his post-survey responses were both a 5. Thus, Alex maintained these expectations throughout the experiment. His pre- and post-survey responses are summarized in the table below.

Alex showed small gains in his learning, and struggled expressing his understanding of simple biological concepts such as photosynthesis during this post interview, something I will address in research question four. However, he makes reference to the authenticity of the experience and originality of the research in his interview with the statement "We were taking a lot of data, and we made it like from nothing, and we put everything together ourselves." While this statement was not as sophisticated as some other students' responses, he clearly recognized that he was performing original research, in that they collected data that did not exist before and that they had to analyze the data. When asked to tell me more about some of the things that specifically helped him feel like a real scientist (his pre- and post-survey response), he responded, “We had to mix chemicals, find data, and use tools that I've never seen like the meter, the light meter. I had never seen that before” refer to specific research skills performed by scientists.

My classroom observations showed him to be engaged throughout the project, especially with the day-to-day activities of maintaining the bioreactors, and collecting data (pH, total solids, light levels). While his learning gains were less than other students, his statements and responses indicated that he believed his experience to be one of authentic science.

Isabella

Isabella is a Hispanic female and a senior in high school. She is not a student in the magnet program. Her favorite subjects in school are math and barbering. Isabella plans to attend a local community college after graduation and then transfer to a local research-intensive university so that she can pursue a career in nursing, specifically labor and delivery. It is important to note that the first day in the greenhouse she experienced an allergic reaction to mold. Because of this, it was decided that her involvement in the project would be to weigh samples after they were brought back to the classroom. As a result, her participation in the project was limited because of her mold allergy.

Isabella’s pre-survey response to the statement “I participated in the Algae Biofuel Project like a real scientist” was a 4, while her pre-survey response to the statement “I felt like a real scientist when I participated in the Algae Biofuel Project” was a 3 or “unsure” (on a 5 point Likert scale). Thus, overall Isabella had a high expectation that she would participate in the project like a real scientist. Both of her post-survey responses remained unchanged. Thus, she expected that she would participate in the project like a real scientist before the project and maintained this perception after the project. Interesting is her pre- and post-responses to the statement “I felt like a real scientist when I participated in the algal biofuel project” which remained unchanged at a 3. This may be explained by the medical condition that prevented her from taking part in the activities in the greenhouse. The pre- and post-survey results are shown in the table below.

Isabella made specific comments during the post interview to support the finding that she believed the experience to be one of authentic science. A portion of the transcript is shown below.

> Angela: What was the most exciting part of this project for you?
> Isabella: The best part of any project is figuring out what you did what worked or didn't work and the most exciting part for me was when we got to put all of our data together and did a graph and see what really happened. I would like to see how much biofuel we created. Maybe next year we could measure how much fuel.

> Angela: How does this experience compare to what you normally do in science labs or science class?
> Isabella: yeah the labs we get they're more like this is what you do, this is the steps, and this is what you're supposed to get at the end. And if you don't get it they made you think you did something wrong and you usually go step-by-step and you get to the right solution…. this is very different because we got procedures but everybody got to do their own thing and see what they got out of it and then what they wanted to do, their idea.
> Angela: In terms of thinking about what a scientist does on a day-to-day basis, compared to what you are doing - how do you think those two compare?
> Isabella: I think the roles are the same, we did the same thing we took the same amount of solution, we dried it weighed it and we did the same thing every day to see if it (algae) was growing or dying or the same.

For example, the statement "we got to put all of our data together and did a graph and see what really happened" is significant because it suggests that she believed the results were original and there was not an expected outcome. The later statement referencing how this project was very different from many science experiments that have a predetermined outcome indicates that she is making the distinction between authentic science and more traditional science learning experiences. Also, she makes a connection between what she was doing (weighing and measuring total solids to determine the amount of algal growth) as to what she believes a scientist would be doing a day-to-day basis.

While her participation was limited to weighing and measuring samples (this took place in the classroom, not in the greenhouse), my classroom observations indicate she was very involved in all other aspects of the project, was very articulate, and assumed the role of team leader within her research group. Thus, the data suggest she perceived her experience as one of authentic science.

Sophia

Sophia is a Hispanic female and a junior in high school. She is not a student in the magnet program. Her favorite subjects in school are math and psychology. While she claims that "science is something I'm not very good at it, I hate it," she enjoys the marine science class and would consider studying it in college. Sophia plans to attend a local research-intensive university so that she can pursue a career in criminal justice. Based on her attitudes survey (discussed later), as well as her post interview comments that she hates science and believes she is not very good at it, I consider Sophia to be a highly marginalized science student. As discussed in chapter 2, a marginalized student is one who is typically disengaged from learning science, and has a negative attitude toward science. While all students in this class are marginalized to some extent, Sophia exhibited more marginalization than other students.

Sophia's pre-survey response to the statement "I participated in the Algae Biofuel Project like a real scientist" was a 5 or strongly agree, while her pre-survey response to the statement "I felt like a real scientist when I participated in the Algae

Biofuel Project" was a 3 or "unsure" (on a 5 point Likert scale). Thus, her pre-survey responses suggest that she believed that she would participate like a real scientist, but was unsure as to whether she would feel like a scientist.

Her post-responses to the research skills surveys are noteworthy. Her response to the first statement remained unchanged while her response to the second statement decreased from unsure to disagree (a 2 on a 5 point Likert scale). This distinction is important, because it suggests she recognizes the experience as one of authentic science, but that the experience did not help her to "feel" more like a scientist. This divergence between participating like a scientist and feeling like a scientist was not found with any of the other students. I believe this disparity represents her lack of interest in the algal biofuel project as well as her belief that she can only carry out certain aspects of research, which is addressed in more detail below and in the next section. Her pre- and post-responses to the survey are summarized in the table below.

Sophia's post interview responses may help explain the decrease in her "feeling" like a real scientist. When asked about her responses to the research skills survey, and how she feels about her skills now, Sophia responded "Like me coming up with a research question that's not going to work, but if somebody comes up with the research question and I take down the data, like you write out the experiment for me, and I come up with a solution that would be okay" and "when Professor Berber asked what can we do to make the project better or something like that, what would be the next step. I don't know what would be the next step because I'm not that into it. I don't know exactly what was the first step, so how could I take that to make a new step in the project?" These specific responses indicate she feels more confident that she can perform certain research skills such as performing tests, collecting data, and analyzing data but that she does not believe she has the ability to come up with the ideas and design experiments, thus limiting her "feeling" like a scientist. Thus Sophia believes she can carry out the technical aspects of doing scientific research as long as she is given guidance with regards to designing experiments and creating research questions. An additional statement supports this finding that she did not feel like a scientist as she commented "afterwards, I still didn't understand it completely – the whole project, why we did it". In summary, her survey responses and comments indicate she believed the experience to be one of authentic science, but that she did not necessarily "feel" like a scientist during the project. Again, this separation of the authenticity of the experience from her feeling like a real scientist is unique from other students. I will discuss this in more detail later.

Tyler

Tyler is a Hispanic-White male and a sophomore in high school. He is also a student in the magnet program. He plans to pursue graduate degrees, including a PhD, in aerospace engineering. He is taking marine science because he needs a science credit, and because his brother is majoring in marine science in college. He states it "would be cool for me to do this and talk to him about it." He was the only student in the class to use the data from the project for a science fair project.

Tyler's pre-survey response was a 5 (strongly agree) to the statement "I will participate in the algae biofuel project like a real scientist" was a 4 (agree) to the statement "I felt like a real scientist when I participated in the Algae Biofuel Project." This suggests Tyler had a high expectation that his experience would be one of authentic science. His post survey responses to both statements were a 5 or strongly agree. The data indicate Tyler expected the experience to be one of authentic science, and he perceived the experience to be one of authentic science after the project was completed.

In his post interview statements, Tyler said "the algae project was pretty much the basics, we generated hypothesis and came up with conclusions, which is the normal standard. But we really didn't think outside the box at all like a scientist would. Like what if we did this and everything would change. By controlling the pH with different chemicals instead of baking powder? Or baking soda I think it was. And using other chemicals to assist with pH balance. That would be a next possibility." This suggests that he felt limited in what he was doing in the project, that scientists do "more" than what he was doing in the project, and that he views university level research as far-reaching and well beyond the scope of what he can do at the high school level. He doesn't make the connection to "what if we did this and everything would change. By controlling the pH with different chemicals" as something that he did in phase 2 of the project. During phase 2, the students were responsible for creating their own research question, conducting an experiment, analyzing the data, and forming conclusions.

In spite of the high perception at the beginning of the project, and an increase in the perception score, his disconnect between what he was doing and what he perceives scientists as doing suggest that he did not believe his experience to be an authentic science experience.

Jared

Jared is a Hispanic male and a sophomore in high school. He is also in the magnet program. Jared is taking the class because he thought it would be fun and because he likes animals. He plans to pursue a degree studying computer programming or gaming after high school.

Jared's pre survey response was a 4 ("agree") to both statements in the research skills survey (see table below). Thus, Jared had a high expectation that he would participate and feel like a real scientist with regards to the algal biofuel project. His post response to the statement he would participate like a real scientist remained unchanged, while his post response to the statement that he felt like a scientist by participating in the project increased to a 5 or strongly agree. Thus, like most students, Jared had a high expectation that the experience would be one of authentic science, and showed a slight increase in this perception after the project was completed.

During his post interview, Jared was asked, "What do you think a scientist does on a day-to-day basis?" His response was "collecting a lot of data from whatever experiments they are doing right now and trying to see what the data means." And, when asked how this compares to what you did in the algae project, he responded "pretty much the same thing." Jared's brief responses were typical during the interview, and when I followed up by asking him how this compares to what he does in a science classroom on a typical day, he responded "we didn't ever go outside and do an actual trial or something, we usually just follow instructions and that's it" and that was different with this project because "we were just trying to see what would happen." I believe his minimal responses do not reflect a lack of interest in science overall nor do they take away from the authenticity of the experience on his part. The survey responses and the statements he made in the interview support the finding that he believed his experience to be one of authentic science.

Keith

Keith is a Hispanic male and a senior in high school. He is not a student in the magnet program. Keith is taking marine science because he likes animals and the underwater world. After high school, he plans to study sports management at a local private college.

Keith’s pre- survey responses to both statements were a 5 or strongly agree. Thus, he had high expectations that his experience would be one of authentic science. His post survey responses to both statements remained unchanged. Thus, Keith had high expectations that this would be an authentic science experience, and maintained this perception after the project was completed.

Keith’s post-interview statements support the findings from the research skills survey. When asked how what he typically does in science class, he responded “usually like in other science classes they don't have the, they don't get to do things that we did like the hands-on things, we did the experiments and we gave our data to the colleges. And that's really cool.” This suggests he perceives this experience as doing original research and very different from typical science classroom experiences. When asked how what he did compares to what a scientist does on a day-to-day basis, his response was "I think it's similar, every day that we had class we would go to the greenhouse, and just repeatedly take samples. And I believe that's what scientists do but they would probably do it every day but we didn't have class every day" and "and probably like we do different trials and how our class was split up to do different parts." These statements show that Keith is making explicit connections between his activities and that of scientists – collecting data, and doing repeated trials. In addition, the statement about the class being split up to do different parts not only suggests that he perceives his class in a collaborative manner, but also that this is something scientists do in their daily experience. Thus, data from the survey and interviews support the finding that he believed this experience to be one of authentic science.

Katie

Katie is a White female and a sophomore in high school. She is enrolled in the magnet program. She stated she is taking marine science because she needs it as a prerequisite to Advanced Placement Environmental Science. However, Mrs. Bodin stated this is not a requirement. Katie plans to study zoology after high school so that she can work in wildlife conservation.

Katie, like Keith, strongly agreed (a 5 on a 5 point Likert scale) with both statements on the pre survey. Her post-survey responses remained unchanged. Thus, she had high expectations that the experience would be one of authentic science and she maintained this perception after the project was completed.

However, her post interview statements appear to contradict this finding. When asked about why she felt ambivalent about her experience in the project, she responded "because the project was already picked out and we already knew what the results were going to be and I guess a part that would really make me feel like a scientist is taking the data and figuring out what is it the results I wanted or would help advance whatever I'm trying to help. And we were really just collecting samples and recording data." Her statement "because the project was already picked out" refers to the algae biofuel project itself, while her statement "we already knew what the results were going to be…and we were just collecting samples and recording data" is referring to her disappointment with the fact that her group was responsible for generating the control group data based on the phase one results. So, she felt that what they were doing lacked originality as compared to the other groups. The data suggest that she did not find the experience to be one of authentic science.

Neal

Neal is an African American male and a sophomore in high school. He is not enrolled in the magnet program. He is taking marine science because "he was put there," but states that he enjoys the class and enjoys learning about underwater life. Neal plans to attend college after high school, but is unsure what he will study. He is interested in engineering.

Neal's pre-survey responses to both statements were a 4 or agree. His post-survey response to the first statement that he participated in the project like a real scientist increased to a 5, while his post-survey response to that he "felt" like a scientist remained unchanged. Thus, his survey responses indicate that he expected the experience to be one of authentic science and that his perception increased slightly after the project was completed.

During his post interview, Neal was asked how this experience compared to what he normally did in the classroom. His response was "this was a new experience because usually when we do labs the teacher already has the data and the research, so basically we have to plug it in. But with our experience we had to find it out for ourselves and added to the experiment as we go," and this clearly indicates that he felt the project was more like original research rather than labs that have predetermined outcomes. In addition, when asked how he felt about the experience, his response was “it made me feel like an actual scientist, like it made you feel good. It made you feel like you could do it and ended showing you how to do it and stuff and get you prepared.” His survey responses and interview statements support the finding that he believed this experience to be one of authentic science.

Research Question 1: Overall Findings

A Wilcoxon signed test was performed to examine differences between median pre- and post-responses to the two items on the research skills survey. With regards to these two items, the median score on the pre-survey was 8.0 and the median score on the post-survey was 8.5. The analysis showed this was not a statistically significant difference ($n=12$, α=o.05). However, students reported a statistically significant increased perception about their ability to perform research skills ($n=12$, $p=0.014$).

While students often made reference to scientists having access to technology more advanced than what they used, common themes emerged to support the finding that they perceived this experience as one of authentic science. The most common theme was that students believed their experience had a high degree of similarity with the daily activities of a scientist, with ten of twelve students making reference to this belief in their post interview and/or journals. Additional beliefs that contributed to the authenticity of the experience were explicit references to collecting data (reported by seven students), and analyzing data (reported by six students). Additional themes included references to original research, especially as different from typical science labs (five students), and discussing findings or collaborating with professionals and/or other students (4 students). The teacher made statements during her interview to support the finding that students believe their experience to be one of authentic science. When asked how her students were affected by the project, she responded, “I think they realized they could indeed be a “real” scientist. At the beginning a lot of them thought the project would be too hard and above their capabilities.”

Table 11: Relationship between feeling and participating like a scientists

	Yes	No
Felt like a scientist	9	3
Participated like a scientist	11	1

Table 11 shows the comparisons between participating and feeling like a scientist. Nine of twelve students reported that they both participated and felt like a scientist. Two students reported that they participated like a real scientist, but did not “feel” like a real scientist. One student did not perceive his experience to be one of authentic science.

RQ 2: How does participation of high school students in an authentic science project affect their identities as scientists?

In order to better understand how students’ science identities were affected by participation in an authentic science experience, I first report findings from the analysis of the Identify-a-Scientist (IAS; Walls, 2012). This allows for a better understanding of how students perceive who can do science, and whether they select individuals of their own gender and/or ethnicity. Then I discuss the findings from interviews, journals, and oral presentations showing that students exhibited characteristics of scientists during the project, as described in Carlone & Johnson’s (2006) science identity model.

Identify-a-Scientist

A recently developed instrument, Identify-a-Scientist (IAS; Walls, 2012) was used to measure student perceptions about who can do science and how it relates to their own science identity. The IAS, along with interviews and journal responses, were used in this study to examine student perceptions about who can do science before and after the algae biofuel project.

Students were administered the IAS at the beginning and end of the project. They were given a series of 10 sets of photographs; each set containing 8 photographs, and were asked to choose the one individual in the group they believe is the scientist. In addition, each student was asked to elaborate on why they chose that individual and what they believed to be the ethnicity of the individual they chose. Along with interviews from journals and interviews, the data were collected in order to determine if students' science identities are affected by participation in the algae biofuel project.

Student responses from the ten sets of photographs were analyzed for frequency of their choice as scientist based on gender and ethnicity. These findings are shown in figure 3. At the beginning of the project, students selected a White male scientist with a frequency of 42.5%, a White female with a frequency of 6.7%. Other choices were African-American male (3.3%), African-American female (10.8%), Asian male (10%), Asian female (4.2%), Eastern male (13.3%), Hispanic male (5.8%), and Hispanic female (2.5%). After the project, students chose a white male with a frequency of 31.7%. Other choices on the post-IAS were White female (13.3%), African-American male (5.8%), African-American female (5.0%), Asian male (9.2%), Asian female (6.7%), Eastern male (18.3%), Eastern female (2.5%), Hispanic male (4.2%), and Hispanic female (3.3%).

A total score was calculated ranging from 0-10 with points ascribed to choices that were not White male. The median pre-IAS as a 4.0, and the median post-IAS was a 3.0. A Wilcoxon signed rank analysis of the pre- and post- median scores indicates a statistically significant difference with regard to the choice of non-White male scientist ($n=12$, $z=2.356$, $p=0.018$). This is considered a large effect size ($r=0.68$).

As seen in figure 3, there was an increase in the following gender/ethnic categories: African American Male (AAM), White Female (WF), Eastern Male (EM), Asian Female (AF), and Hispanic Female (HF). Three explanations for this finding are 1) the two USF researchers students interacted and collaborated with were White Female and Asian Female, 2) the students attended a research day conference at USF in which they encountered a diverse group of graduate students giving poster presentations of their research, and 3) an increase in their choice of individuals who resemble their own gender and ethnicity. Their responses in the interview support these three explanations. While this change was encouraging, this analysis does not address how student's individual science identities are affected by participation in the project. Thus, findings from individual students are shown next.

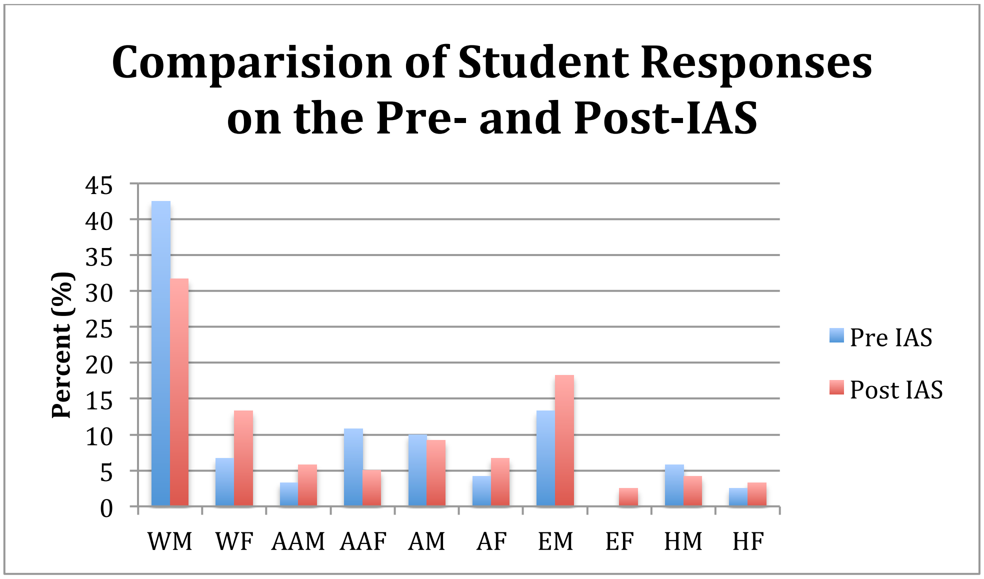

FIGURE 3: Changes in students' choice of scientist

Examining individual responses on the pre- and post-IAS helped to explain the pre/post changes in selection of scientists. First, six students chose an individual that more closely resembled their own gender and ethnicity on the post-IAS, referred to as gender- and ethnicity-matching. Second, students were much more diverse in their choices. Thus, students were not only selecting someone that more closely resembled themselves, but also chose scientists of varying ethnicities and genders. These findings are summarized in Table 12. Ethnicity and gender were all self-reported by the students during the interview at the end of the project. Each time a student chose an individual with the same ethnicity and gender as themselves, they were assigned a score of 1, all other choices were assigned a score of 0.

Table 12: Changes in students' gender- and ethnicity-matched scores

Student	Ethnicity & Gender	Before	After
Simon	AAM	0	1
Jessie	AF	2	3
James	AAM	0	1
Alex	HM	0	0
Isabella	HF	1	1
Sophia	HF	0	3
Tyler	WM	4	2
Jared	HM	1	0
Daniel	HWM	1	0
Keith	HM	0	1
Katie	WF	0	1
Neal	AAM	0	0

Note: Asian Female (AF), Black Male (AAM), Hispanic Female (HF), Hispanic Male (HM), (HWM) Hispanic-White Male, White Female (WF), White Male (WM).

As seen in table 12, six of the twelve students showed an increase in their gender- and ethnicity-matched score from the pre- to post-IAS. This includes Simon, Jessie, Katie, Keith, Sophia, and James. Simon is an African American male who plans to study engineering at a local research-intensive university after high school. Simon did not choose any individuals on the pre-IAS that were African American males. However, on the post-IAS he chose one individual who was African American male. Thus, he showed an increase from 0 to 1 in gender- and ethnicity-matching between the pre- to post-IAS. Jessie is an Asian American female who plans to attend a major research-intensive university to study medicine. Jessie's pre-IAS score was 1 and post-IAS score was a 2. Katie is a White female who plans to study Zoology in college so she can to work with animals in a zoo or wildlife conservation setting. Her gender- and ethnicity-matched score increased from 0 to 1 between the pre- and post-IAS. Keith, a Hispanic male, is a senior who plans to study sports management after high school graduation. His gender- and ethnicity-matched score increased from 0 to 1 between the pre- and post-IAS. Sophia is a Hispanic Female, was the student in the class with the least positive attitude toward science at the beginning of the project. One specific comment during the interview was "Science is not something I'm really good at …I hate it; When I first heard about the algae project I was like I don't want to do this – this is so stupid and I don't understand it." However, her beliefs and attitudes changed dramatically at the end of the project. For example, her gender-match and ethnicity-match increased the most from a 0 to 3 between the pre- and post-IAS. James is an African American male and a senior in high school. He plans to study business in college. His gender- and ethnicity-matched score increased from a 0 to 1 between the pre- and post-IAS. With regard to these students, the increased gender- and ethnicity-matched score supported an increase in their science identity. There was no change in the pre- and post-IAS gender- and ethnicity-matched scores for Alex, Isabella, and Neal, while Jared and Daniel reported a decrease in their gender- and ethnicity-matched score. However, data from interviews, journals, and presentations support a strong science identity. These findings are discussed in the next section. Tyler was the only White male student in the class, and reported a decrease in his gender- and ethnicity-matched score. Tyler's identity is also discussed in more detail in the next section.

When students were asked why they made a particular choice, common themes emerged, regardless of the gender or ethnicity of the individual. Their responses related to common stereotypes about scientists (Chambers, 1983). The common explanations offered on the pre- and post-IAS are summarized in the table 13. It is noteworthy that two of the stereotypical attributes (older and wearing glasses) decreased from the pre- to post-IAS. Additional themes that emerged on the post-IAS were adventurous, serious, happy, looks like a scientist one might see in a movie, looks like someone who works in a lab, and looks like Professor Berber. Many of these post-IAS responses could be attributed to the engineers they interacted with during the project such as Professor Berber and Grace, as well as graduate students they interacted with during the field trip.

Science Identity Model

Science identity has been described as what students believe they are able to do, what they would like to do, and who they are with regard to science (Brickhouse, 2001).

More recently, a model of science identity has been proposed as multidimensional in that it encompasses competence, performance, and recognition. Therefore, an individual with a strong science identity would be highly competent, show strong performance, and be recognized by themselves and others (Carlone & Johnson, 2007). Competence is described as "knowledge and understanding of science content" while performance includes the ability to "talk science" and use scientific tools, and recognition means self-recognition as well as recognition by others as being a science person. In addition, this model assumes that gender, race, and ethnic identities affect one's development of a science identity.

While the IAS data were able to show changes in gender- and ethnicity-matched scores, the data did not allow for a more in-depth analysis and whether characteristics of their science identity emerged as a result of participation in the algal biofuel project. Thus, data were analyzed from the post-interviews and journals separately to better understand how their participation in the project affected their science identity. For this analysis, Carlone & Johnson's (2007) model of science identity was used to identify explicit statements made by students that reflect one of the three domains of science identity (performance, recognition, and competence).

Table 13: Summary of pre- and post-IAS reasons for choice of scientist

Attribute	Pre IAS	Post IAS
Not sure	55	34
Beard	1	2
Glasses	8	4
Professional dress (i.e. – medical scientist)	14	14
Casual dress (i.e.- field scientist)	4	0
Looks confident/smart	4	1
Age (older)	7	4
Looks adventurous	0	1
Looks serious	0	2
Smiling/happy	0	2
Media	0	2
Looks like Professor Berber	0	1
Looks like someone who works in a lab (i.e.- working with test tubes)	0	3

A 4-point rubric was used to determine the strength of a student's science identity as it related to their participation in the algal biofuel project. The three domains of this model are competence, recognition, and performance. With regard to each domain, student responses were assigned to one of four levels. For example, with regard to the recognition domain, a level 0 indicates no evidence for being recognized (by self or others) as a scientist. A level 1 response indicates that a student acknowledges he or she is a scientist, while a level 2 response indicates that the student acknowledges he or she is a scientist and offers a reason, suggesting a stronger connection to the feeling. A level 3 response indicates the student acknowledges he or she is a scientist by making a connection to a scientific practice. This rubric developed from Carlone & Johnson's (2006) model was used to determine if students with a strong science identity were more likely to self-identify as a scientist.

Like the recognition domain, student responses reflecting competence or understanding of science practices were assigned one of the four levels (0-3). A level 0 score reflects no evidence to support competence, while a level 1 response indicates the student made a specific statement about an increase in his or her scientific knowledge or ability to engage in a scientific practice. A level 2 response indicates the student made a level 1 response and explained in detail what he or she learned or is able to do, while a level 3 indicates the student made a statement or suggests what he or she learned or is able to do can be used by others.

Responses reflecting performance were also assigned one of four levels (0-3). A level 0 indicates no evidence to support performance, while a level 1 response indicate the student made a statement about his or her performance. A level 2 indicates the student describes the performance in detail, while level 3 responses indicate the student describes the procedure in detail and describes why it was done. Table 14 summarizes the rubric used to determine a student's level of science identity, followed by the analysis.

Table 14: Science Identity Rubric

Domain	**Levels**			
	0	1	2	3
Recognition	No evidence	Student acknowledges he or she is a scientist.	Student acknowledges he or she is a scientist and offers a reason.	Student acknowledges he or she is a scientist by making a connection to a scientific practice.
Performance	No evidence	Student names what he or she did.	Student describes the procedure in detail.	Student describes the procedure in detail and describes why it was done.
Competence	No evidence	Student makes a statement about an increase in his or her scientific knowledge or ability to engage in a scientific practice.	Student makes a level 1 statement and provides details about what he or she learned or are able to do.	Student makes a statement or suggests what he or she learned or is able to do can be used by others.

Student responses from journals, interviews, and an oral presentation were analyzed for evidence of competence, recognition, and performance domains of the science identity model. Within each domain, student responses were assigned a level (0-3), and given a score that reflects at least one statement from the highest level. For example, in order for a student to obtain a level 3 score in any domain, they must have made at least one statement representative of level 3. In addition, in order for a response to be coded a level 1, 2, or 3, the statement must have been made in the first person ("I" or "we").

For the competence domain, of the twelve students, six made at least one statement that reflected a level 3 competence, while five made at least one level 2 competence statement, and one made a level 1 competence statement. Thus, all the students demonstrated a minimal level of competence with regards to their science identity. The example of level 1 competence statement was "I learned how to make a spreadsheet." This represents level 1 because the student (Katie) was making a statement of what she did without providing details or connecting it to how it could be used by others. Examples of level 2 competence statements include:

> "I actually learned a lot and was surprised at how much interested me, how polluted things are and how something like algae something we don't

> pay mind to, then not take away the problem but disperse or lower pollution. I've never paid mind to algae it's just there." (Isabella)
>
> "I learned it all depends on the location, what is put into it, how you do it, I learned a lot from it. I learned about the efficiency and cheapness (of algae). How much better it (algae) is than fossil fuels, and it's more biodegradable." (Neal)

Both Isabella and Neal stated what they learned and have provided details about they learned from the project, and thus demonstrate level 2 competence with regard to their science identity. Examples of level 3 competence statements include:

> "I think it's possible they could look at it (data) more because algae tends to self-shade. Self-shading could cause the other algae to die. So you wouldn't want that. You would want more algae to reproduce. So I think that's something they (Professor Berber's group) could look into." (Jessie)
>
> "I think that doing this project has taught me more about how experiments work…My group's research question was how pH affects algae growth. Our data show that increasing the pH dramatically improves the growth rate of algae. The control's algae did not grow as much as ours. Maybe next time we should measure the amount of oil produced. Just because we have a lot of algae, that does not mean we have a lot of oil. I think we should try to maximize the amount of oil produced." (Jared)

Jessie's statement reflects a level 3 competence because she was not only describing what she learned, but believes the data her group generated would be useful to USF researchers. Jared's statement also reflected a level 3 competence that he states that he learned a scientific practice ("how experiments work") and made a connection that their findings warrant additional research ("I think we should try to maximize the amount of oil produced").

In the performance domain, of the twelve students, seven made at least one statement that reflected level 3 performance, and five made at least one level 2 performance statement. Thus, all the students demonstrated at least a level 2 performance with regards to their science identity. Examples of level 2 performance statements include:

> "We switched roles. One week I was collecting data and measuring light inside of it and how much algae it was and another week I was making sure the bubbles were forming." (James)

> "I had to help put it together, put the whole reactor together. I had to take data, I had to extract some of the water from the syringes, I had to put some of the in the weighing pan, it was teamwork." (Neal)

A level 2 performance means that a student was not only stating what they did, but offered details of the scientific practice. When James made the statement "I was collecting data" he named what he did. When James stated "measuring light inside of it how much algae it was and another week I was making sure the bubbles were forming" he offered details of the procedure with regard to performance. Neal also stated what he did "I had to help put it together, put the whole reactor together. I had to take data," and offered details of the procedure with the statement "I had to extract some of the water from the syringes, I had to put some of the in the weighing pan, it was teamwork." Thus, both Neal and James demonstrated a level 2 performance with regard to their science identity. The difference between a level 2 and 3 performance was level 3 includes a level 2 statement and offered a reason for what they did. Examples of level 3 statements include:

> "And we measured the pH because the acidity can tell you whether the algae are healthy or not or dying off." (Tyler)
>
> "We had to maintain our bioreactors and then we had to pull samples out and test for pH and take out to check for total solids." (Keith)

Tyler made a level 2 statement, specifically "We measured the pH," and explained why with the statement "Because the acidity can tell you whether the algae are healthy or not or dying off." Keith also made a level 2 statement when he said "We had to maintain our bioreactors and then we had to pull samples out", and explained why when he stated "we had to pull samples out and test for pH and take out to check for total solids." Thus, both Keith and Tyler demonstrated level 3 performance with regard to their science identity.

For the recognition domain, of the twelve students, two students made at least one statement that reflected level 3 recognition, seven students made at least one level 2 recognition statement, and three students did not make any statements to demonstrate the recognition domain of the science identity. Examples of level 2 recognition include:

> “It (the project) made me feel like an actual scientist, like it made you feel good. It made you feel like you could do it and showed you how to do it and stuff and get you prepared.” (Neal)
>
> It feels really good, to know that we could do something like that. And scientists spend the whole day working on something like this and we could come up with that. (Simon)

Neal demonstrated level 2 recognition acknowledging himself as a scientist with the statement “It made me feel like an actual scientist”, and he offered a reason with the statement “It made you feel like you could do it and showed you how to do it and stuff and get you prepared” as to why he felt like a scientist. Similarly, Simon acknowledged he was a scientist when he said “It feels really good, to know that we could do something like that,” and offered a reason as to why he felt like a scientist when he stated “scientists spend the whole day working on something like this and we could come up with that.” In contrast, level 3 recognition was demonstrated when students made a connection to their feeling of scientist and that of a scientific practice. For example, Keith made the statement:

> “Every day that we had class we would go to the greenhouse, and just repeatedly take samples. And I believe that's what scientists do but they would probably do it every day but we didn't have class everyday. And probably like we do different trials and how our class was split up to do different parts.”

In this statement, Keith believed what he was doing is like what a scientist does, and he made reference to the specific scientific practice of collecting samples and doing repeated trials.

Two students did not make any statements to support that they recognized themselves as a scientist. Therefore, they were assigned a level 0 with regards to the recognition domain. One student, Katie, made a statement during the interview that helps explain the low recognition score.

> "Because the project was already picked out and we are ready knew what the results were going to be and I guess a part that would really make me feel like a scientist is taking the data and figuring out what is it the results I wanted or would help advance whatever I'm trying to help. And we were really just collecting samples and recording data."

This statement referred to the fact that her group was the control group during phase 2. This indicates they did not generate a research question like the other three groups, but were responsible for replicating the optimal growth conditions determined during phase 1 of the project. It is important to note the other two students in her group (Simon and Keith) did not share these sentiments and reported higher science identity scores in all three domains, including the recognition domain.

The other student assigned a level 0 recognition score was Tyler. Tyler also made statements during his interview that explained his low recognition score.

> "What will we do any algae project was pretty much the basics, we generated hypothesis and came up with conclusions, which is the normal standard. But we really didn't think outside the box at all like scientist would. Like what if we did this and everything would change. By controlling the pH with different chemicals instead of baking powder? Or baking soda I think it was. And using other chemicals to assist with pH balance. That would be a next possibility."

While I considered what he was doing as that of a scientist such as generating hypotheses and coming up with conclusions, he did not. In addition, the statement "what if we did this and everything would change" is describing changing the independent variable in an experiment. However, he did not make the connection between the similarities of what he was doing and what a scientist does. Thus, his perception suggested he does not recognize himself as a scientist within the context of the project.

The level of science identity for each domain and student, a total science identity score, as well as mean scores and standard deviations are summarized in table 15. Given the highest level for each domain was a three, the highest possible total score was a nine. With the exception of Katie and Tyler, the data support the finding that student's show a strong science identity because of their participation in the algal biofuel project.

Table 15: Individual Student Science Identity Scores

Domain	Competence	Recognition	Performance	Total
Simon	3	2	3	8
Jessie	3	2	2	7
Alex	3	2	2	7
Isabella	2	3	3	8
Sophia	3	2	2	7
Jared	3	3	2	8
Daniel	2	2	3	7
Neal	2	2	3	7
Tyler	2	0	3	5
Keith	3	3	3	9
Katie	1	0	3	4
James	2	2	2	6

Overall Findings: Research Question 2

With regard to the gender- and ethnicity-matched scores generated from the IAS, six of twelve students showed an increase in their science identity. Three students' scores did not change while three students showed a decrease in their score. In addition, there was a statistically significant decrease in the choice of White male from the pre- to post-IAS. These findings suggest that students' participation in an authentic science experience has the ability to influence their perceptions about who can do science, and therefore their own science identities.

Science identity scores were generated based on student responses made during an oral presentation at the end of the project as well as interviews and journals. The highest levels were observed with the performance and competence domains.

Changes in gender- and ethnicity-matched scores on the IAS were compared to science identity scores. Five of the twelve students (Simon, Jessie, Sophia, James, and Keith) showed an increased gender- and ethnicity-matched score and a medium (5 or 6 on 9 point scale) or strong (at least 7 on 9 point scale) science identity score. In addition, Tyler showed a medium science identity score of 5, and a decrease in his gender- and ethnicity-matched score. While this finding might suggest that the experience had a negative impact on his science identity, interview data suggests otherwise. It is important to note that Tyler was the only White male in the class. The decrease in his gender- and ethnicity-match score suggests he has become more diverse in his perception of who can do science, while his science identity score, suggests that Tyler has maintained his science identity while becoming more diverse in his perceptions about who can do science.

As described earlier, Tyler was engaged in the project and in science. He plans to study aerospace engineering after high school. However, he made several statements showing his perception of the algal biofuel project was not the same as what a scientist would be doing. This is one explanation for his lower score.

Three students (Alex, Neal, and Isabella) showed a strong science identity score with no change in their gender- and ethnicity-matched score while Katie showed an increased gender- and ethnicity-matched score with a low science identity score. In addition, two students (Daniel and Jared) showed a decrease in their gender- and ethnicity-matched score with a strong science identity score. One explanation for the disparity between Katie’s and Jared’s scores is their disappointment and disinterest with the project itself. However, these disparities suggest there is something deeper meaning regarding science identities that was not uncovered during this investigation. This finding merits further study to uncover the complex and multifarious nature of science identity.

Individual science identity scores were compared to the findings regarding the authenticity of the experience from the student perspective. Ten of the twelve students participating in this project believed their experience to be one of authentic science with the exception being Daniel and Katie. Also, Katie was the only student to demonstrate a weak science identity score.

The data suggest the students' perspective regarding the authenticity of the experience may influence their science identity as ten of twelve students demonstrated a moderate to strong science identity and believed the experience to be one of authentic science, while one student did not perceive the experience to be one of authentic science and exhibited a weak science identity score. Only one student, Daniel, was an outlier as he had a strong science identity score but did not believe the experience to be one of authentic science based on comments he made during the post-interview. However, the authenticity of the experience from the students' perspective is not an indicator of the outcome of the gender- and ethnicity matched scores from the IAS. Again, the inability to triangulate the IAS and science identity findings may reflect the complexities of science identity that were not revealed in this study.

RQ 3: How does participation of high school students in an authentic science project affect their attitude with regards to doing and learning science?

Science Attitude Survey

To determine if science attitudes and interests change during the course of the project students were administered a pre- and post-science attitude survey, and were interviewed after the project was completed. The survey instrument is a 5 point Likert-scale survey consisting of 32 items that were categorized into one of the following domains: academic motivation, science self-concept, attitude toward science, interest in science, future interest in science, and world views toward science. I report here findings from analysis of the class data within these domains as well as median responses to individual statements.

In order to determine if statistically significant differences regarding science attitudes exist between the pre- and post-surveys, median scores for the pre- and post-surveys were compared using the Wilcoxon signed rank test (Grimm, 1993). The median pre- and post-test responses are shown in table 16 below. Based on the survey data alone, most of the students had a positive attitude toward science at the beginning of the project, and maintained their attitude toward science. Even though there were both positive and negative changes, based on Wilcoxon signed rank analysis, student responses within domains did not change significantly. In addition, overall median scores for all 32 items did not change significantly.

However, when the pre- and post- individual items (a total of 32) were analyzed individually, one item showed a statistically significant change ($z=-2.072$; $p<0.05$). This item was "Science is useful for the problems of everyday life." The increased score suggests that students connected the algal biofuel project to being helpful to their everyday life. Interview and journal data support this finding. However, when these statements are considered with all other science self-concept statements, the median score remains unchanged at 4.0.

Table 16: Median pre and post responses by domain

Domain	Pre	Post
Academic Motivation	3.75	4.0
Science Self concept	4.0	4.0
Attitude Toward Science	4.25	4.25
Interest in Science	3.55	3.5
Future Interest in Science	4.0	4.5
World Views Toward Science	4.5	4.0
Overall	4.0	4.0

The lack of change in pre- and post- survey is in conflict with interview data as ten of twelve students made statements about their participation in the project as one that was a positive experience. Their teacher and student interview as well as student journal responses suggested that they enjoyed the project, and found the research they were doing to be important for society as a way of reducing or dependence of fossil fuels. For example, specific journal entries from six students include:

> "The algae project was an amazing experience, the fact we're helping USF with an actual project they're working on is great." (Jessie)

> "The project overall was exciting and captivating and helped me understand the true meaning of being a scientist or researcher. Definitely, this is something I would want to do again." (Jessie)
>
> "My experience with this whole project was very interesting it was a real eye opener to new ways on how to save our planet and keep it going in years to come and how we can use the things we already have available to us." (Isabella)
>
> "I think that doing this project has taught me more about how experiments work. It was fun, but makes a lot of work." (Chris)
>
> "After doing the project, I believe that I am more confident in my lab skills." (Chris)
>
> "Now that the experiment is over, I see how much fun it was. Doing the experiment w/ USF made it feel more professional and serious." (Neal)

In addition, several students expressed that this project was very different from their typical science classroom experiences, and expressed an increased interest in doing this type of project as opposed to more traditional instruction. Mrs. Bodin stated "my highlight was watching shy, uncertain student turn into confident leaders" and her students became "more self-confident" and had an "improved love of science."

One explanation for this disparity is the limitation of a 5-point Likert scale survey in that they do not provide students the opportunity to elaborate on their selections and may not be an accurate representation of their attitude or belief. Another explanation for this disparity is that students showed a high attitude score at the beginning of the project. Because students' pre-attitude median scores (overall 4.0 on a 5.0 scale) are already approaching the high end of the instrument, it may not be sensitive enough to detect attitude changes or growth.

Overall Findings: Research Question 3

In summary, the findings from the science attitude survey indicate students had a positive attitude toward science at the beginning of the project and maintained a positive attitude toward science after the project was completed. Statements from the teacher supported this finding. Statistically significant changes were limited to one individual item, and not the entire survey. In contrast, interview and journal data show that ten of twelve students made statement to suggest they found the experience to a positive one, a finding supported by statements from their teacher. Thus, high positive attitudes at the beginning of the project as well as the nature of the survey instrument may not be sensitive enough to understand how students' attitudes are affected by participation in an authentic science experience.

Findings from research question one (authenticity from students' perspective) were compared to findings regarding science attitudes and science identity. Eight of the twelve students perceived the experience to be one of authentic science and demonstrated a positive attitude toward science. Ten of twelve students perceived their experience to be one of authentic science and demonstrated either a moderate or strong science identity. Also, nine of twelve students demonstrated a positive attitude toward science and either a moderate or strong science identity. These findings, summarized in table 17, suggest that authenticity from the students' perspective has the ability to influence their attitude toward science and science identity.

Table 17: Comparison of authenticity, science attitude, and science identity

	Authenticity (Yes)	Authenticity (No)	Science Identity (Moderate or strong)	Science Identity (weak)
Positive Science Attitude	8	2	9	1
Negative Science Attitude	2	0	2	0
Science Identity (Moderate or strong)	10	1		
Science Identity (weak)	0	1		

RQ 4: How does participation of high school students in an authentic science experience affect their learning of scientific processes?

The goals of this study were to better understand if students perceive the project authentic as well as how students' science identities and attitudes are affected by participation in an authentic science experience. In one sense, answering these questions required an emic interpretivist perspective that allowed the students to share their experience. However, I also wanted to determine what students learned by participating in this project. While I am not necessarily trying to make broad generalizations, I took something of an etic perspective as an observer in order to answer this question.

Data were analyzed from pre- and post-open-ended questions, and summaries of each phase (one and two) of the research project. The assessment used can be found in Appendix C. First, I report the findings for the two open-ended questions as well as evidence of learned science practices followed by the findings for each individual student.

Open-Ended Questions

There were two open-ended questions that were designed to assess student understanding of the content. The first question asked students to explain the difference between renewable and nonrenewable resources. According to the EPA (2013), renewable energy "generally refers to electricity supplied from renewable energy sources, such as wind and solar power, geothermal, hydropower, and various forms of biomass. These energy sources are considered renewable sources because they are continuously replenished on the Earth" while a nonrenewable resource cannot be replenished on a human time frame. Based on this definition, student responses were coded as incorrect, partially correct, or correct. On the pretest, five of the twelve students offered a partially correct response to this question, while seven students offered a correct response. An example of a partially correct response is "Renewable resources can be regrown, non renewable take too long to make." This is considered partially correct because the student correctly references renewable resources as being able to be regrown (i.e. – algae). However, other renewable resources like solar and wind energies, while not grown, are considered renewable. This same student's posttest response was "Renewable is a resource that can be replenished quickly; nonrenewable takes much longer to be replenished or not at all." This is considered an accurate statement because the student is offering a broader explanation that encompasses all types of renewable energy sources. In addition, the student offers an accurate explanation of nonrenewable resources. There were no incorrect responses to this question on the pre- or post test. Given that there was an increase from two to ten students who offered a complete and accurate explanation, as opposed to partially accurate explanation, students demonstrated an increased understanding of renewable and nonrenewable resources.

The second question was "What benefits are obtained from growing algae?" Expected student responses would make connections to algae as photosynthetic organisms, and algae as an alternative energy source, specifically a biofuel. An additional common theme that emerged from student responses was that algae are good for the environment. Student responses "I don't know," "No answer," or that were incorrect were coded together.

Table 18: Frequency of pre- and post-test responses

What benefits are obtained from growing algae?	**Pre**	**Post**
Good for the environment	20%	35%
Alternative energy (biofuel)	20%	40%
Photosynthesis	13.3%	20%
Research & Development	6.7%	0%
I don't know/No answer/Incorrect	40%	5%

The frequency of these responses is shown in table 18 as a percent of the total responses for the pretest and also for the posttest. There was a decrease in the last category (I don't know, no answer, or incorrect answer) from 40% to 5%. Additionally, the largest increase was referencing algae as biofuel sources followed by an increase in reference to algae being good for the environment. There was a small increase in the description algae as photosynthetic organism on the posttest. Overall, the data suggest an increase ability to explain the role of algae in our environment including their use as a biofuel and photosynthetic organism.

Science Practices

Students were asked about to rate their perceptions (on a scale of one to five) with regard to specific research skills before and after the project. These findings were reported earlier with research question one. These statements were:

1) I can ask a scientific research question
2) I can create a research hypothesis.
3) I can design a scientific experiment.
4) I can make observations and collect data.
5) I can figure out what the data means.
6) I can explain to others the results of the research.

In order to assess their learning of science practices as it relates to the algal biofuel project, students were asked to write a summary with regard to each phase of the research project. In addition, classroom observations, interview and presentation data were analyzed with research summaries from student journals. It is important to note that each group of students gave an oral presentation of their findings at the end of the project, and students took turns presenting different sections of their project. Therefore, while the presentation data is a rich source of qualitative data, it is not a complete source of data for each student. The prompts provided to students for each phase were:

Phase one Prompt:

Write a summary of phase one.

1. Explain what happened.
2. What are the results?
3. What are the conclusions?
4. What is your research question for phase 2?

Phase two Prompt:

Write a summary for phase two.

1. What was the research question?
2. What are the results?
3. What are the conclusions?
4. If this project continued, what would be the next experiment?

Four data sources were coded using the rubric shown in table 19. With the exception of students collected data, there were four levels of coding. A level zero indicated that the student did not respond. Students who did not respond were excluded from the statistical analysis. A level one indicated the student responded but there was no evidence of an accurate response. The results of this analysis are shown in table 20. First, the students' phase one and phase two research summaries in their journals were analyzed for their ability to ask a research question or create a hypothesis, analyze data, and explain the results of their research. With the exception of the item "student collected data," the maximum possible score for each item was a three, with a maximum possible score of fourteen.

Based on what constitutes a scientific explanation, explaining the results was divided into two sections – connecting evidence to their research question and connecting the evidence to a scientific principle. Each component was assigned a maximum score of three. Most students did not make specific whether they collected data or not. Because of this, classroom observation, interview, and oral presentation data was used in addition to journals to determine whether they collected data.

Table 19: Rubric for learning of science practices

Scientific practice	Level 0	1	2	3
Student asked a scientific research question OR created a research hypothesis. (Q)	No response	No evidence	Student offers a naïve response, for example explains what they were going to do but does not phrase it as a research question or hypothesis.	Student proposes a testable research question or hypothesis that is specific to the study performed by their research group.
Student collected data. (D)	Not observed	No evidence of collecting data (from observations and interviews)	Student was observed collecting data during all observations OR referred to doing so during the interview	NA
Student analyzed data. (A)	No response	No evidence or inaccurate analysis of data	Student offered an incomplete, but accurate, analysis of data.	Student offered an accurate and complete analysis of data.
Students explained the results of the research. A scientific explanation connects the evidence to the original hypothesis or research question, and then connects the evidence to scientific principles. (E/R)	No response	Does not use data as evidence to support the research question, or provides inappropriate evidence that does not support the research question.	Uses the data appropriately, but insufficiently as evidence to support the research question. May include some inappropriate use of data.	Uses the data appropriately as evidence to support the research question.
	No response	Does not provide reasoning, or only provides reasoning that does not link evidence to the research question.	Provides reasoning that links the research questions and evidence. Includes some scientific principles, but is incomplete.	Provides reasoning that links evidence to the research question. Includes appropriate and sufficient scientific principles.

The scale range for the total science practice score was 0-14 for each analysis (phase one summary, phase two summary, and total science practice score). When comparing the phase one and phase two summaries, ten of 12 students showed an increased score. The two students' scores decreased. This was because they did not complete both research summaries. Specifically, Simon did not complete a phase two summary, while Katie did not complete either a phase one or phase two summary. In addition, Daniel's large increase was because he did not complete a phase one summary. The score they did receive was due solely to evidence from classroom observations, presentations, or post-interviews that they collected data. Based on the rubric, they received a score of zero on all other items, as they did not complete the assignment and there was no response. Those scores that reflected a no response are represented with an asterisk table 20.

Wilcoxon signed rank analysis was performed to compare students' learning of science practices with regard to their phase one and phase two summaries. Students that did not write either a phase one or phase two summary were excluded from the analysis. The median phase one summary was nine, while the median phase two summary was 11. Based on this analysis, there was a statistically significant difference between phase one and phase two summaries (n=9, z=2.533, p=0.011). This is considered to be a large effect size (r=0.844; Cohen, 1988). Individual student responses and analysis follows.

Table 20: Assessment scores of students' learning of science practices

Student	Phase 1 Summary	Phase 2 Summary	Total Science Practice Score
Simon	11	2*	12
Jessie	9	13	14
Alex	7	8	8
Isabella	9	12	14
Sophia	8	9	9
James	9	11	11
Tyler	7	11	12
Jared	10	12	14
Daniel	2*	13	14
Katie	2*	2*	4
Keith	9	9	10
Neal	7	10	11
Median	9	11	11.5
Average	8.3	10.6	11.1
z-value	2.533		
r	0.844		

Simon

Simon's phase one summary score was an eleven and his phase two summary score was a two. This decrease is because he did not complete the phase two summary in his journal, and was assigned a score of two because he was observed collecting data and stated during his interview: “I collected data and made charts.” Simon’s phase one summary demonstrated the strongest evidence of science practices:

> “In our experiment, we began with 50% NO_3 and 50% NH_3. The growth rate for our algae wasn’t the fastest, but we had no sign of algae loss and our growth began to zero out at about 800 mg/L of algae. We believe that the NO_3 helped the algae grow while the NH_3 keeps it from dying.”

The statement “we began with 50% NO_3 and 50% NH_3 indicates what his group was doing in phase one. While it provides specific details about what they were doing, he does not offer a hypothesis or research question and was assigned a score of two. The statement “The growth rate for our algae wasn’t the fastest, but we had no sign of algae loss and our growth began to zero out at about 800 mg/L of algae,” was a complete and accurate analysis of their data and was assigned a score of three. Last, Simon makes a connection to the content as he explains what nitrates and ammonia provide in the bioreactors with the statement “We believe that the NO_3 helped the algae grow while the NH_3 keeps it from dying.” Within the context of the entire summary, Simon uses the data from their experiment as evidence to support the original claim and connects it to scientific principles (growth requirements for algae). Each part of the scientific explanation was assigned a score of two because each was considered accurate but incomplete as he did not make an explicit connection between the data and original claim, nor did he offer a complete explanation with regard to the nutrient requirements for algae.

While Simon did not complete a phase two summary, data from his interview and his group's oral presentation at the end of the project were analyzed. During his interview, he was asked to explain what his group did during the phase two experiment. His response was "We were the control group, we were trying to copy the first trial." Also, during his group's presentation, he stated "Ours was used as a control group for everyone else to compare to" which was coded as a level three research question/hypothesis statement. A research question or hypothesis was not appropriate for this group. However, he does explain the purpose of their experiment ("ours was used as a control group") and the importance ("for everyone else to compare to"). In addition, he offers an analysis of the data with the statement "Algae increased and then dropped a little." This statement was coded with a score of two, as it was accurate but incomplete. Last he states, "we were able to fully replicate the data from the first trial because of the actual environment, how it rained, or how much sunlight or the actual temperature and that had an effect on our data. So we were able to completely replicate data." These statements were coded with a score of three for connecting the evidence to the purpose, and a score of two for connecting the evidence to scientific principles, in this case understanding the importance of a control and replication of data. Overall, this suggests that Simon made learning gains with regard to the algal biofuel project.

Jessie

Jessie's phase one, phase two, and total science practices scores were nine, 13, and 14, respectively. Jessie's phase one summary was:

> "My results for 75% NH_3/25% NO_3 were the algae growth slowly declined as well as the pH. In the discussion they stated that the pH declined when the algae growth declined. In the discussion they stated the algae degrading due to microbes breaking algae down."

The first part of the statement ("My results for 75% NH_3/25% NO_3") was given a research question score of two, and a data analysis score of two as the statement "were the algae growth slowly declined as well as the pH" is accurate but incomplete. Last, the statement "In the discussion they stated that the pH declined when the algae growth declined. In the discussion they stated the algae degrading due to microbes breaking algae down." was coded as a two for connecting the evidence to their research question/hypothesis and a two for connecting the evidence to scientific principles. Both parts of these statements are accurate, but incomplete. Jessie's phase two summary was:

> "My groups research question was how does diffusers effect algae growth. <u>Our data explains we had some exponential growth</u> but *declined due to possible environmental factors (rain and cloudy skies) & possible self-*

> *shading of algae*; <u>our growth increased</u> *after that period possibly due to more light. Our conclusion is that we did better than the control group with growth because at the end we had a bit more growth.* <u>This is so because in our data near the end of the table the graph for the control compared to ours stated we had a bit more growth."</u>

The first sentence is a specific, testable research question and was scored as a level three. Several parts of the summary were coded as an accurate, but partial analysis of the data. These statements are <u>underlined</u> in the above summary. Statements that were coded as a three for both aspects of a scientific explanation are *italicized*. Jessie's post-interview and oral presentation also demonstrated additional evidence with regards to her ability to analyze the data, explain the results of her data. During her group's presentation she stated,

> "<u>As you can see from the graph we are 75% ammonia and 25% nitrate as you can see at first we had good growth and then suddenly it declined.</u> *We thought it declined because of the 75% ammonia. Like our fish tanks for example if we have too much ammonia are fish will possibly start to die. Just like any other organism algae and water could possibly die off because of too much ammonia.* <u>Here's our data from phase 2 and you can see our bottles are kind of brown. You can see we had some good growth and some decline</u> *and our conclusion was we had some possible environmental like there was a lot of rain and possibly the algae wasn't taking in as much light and also this decline could also be from self shading which is when the algae clump together and the algae in the front of the bottle shade the algae in the middle and the algae in the middle can't take in enough light which causes algae in the middle to slowly die. As you can see it came back up possibly those in terminal factors there was more sunlight and the algae could taken the light."*

The underlined statements were coded as a level two for her ability to analyze data, and the italicized statements were coded as a level three (both aspects). In addition, during her presentation, she was asked about why alga is used as a biofuel (instead of fossil fuels). Her response was "Algae takes CO_2 out that's why we would use them. Yes that's true what you said about the fossil fuels but the algae uses the carbon dioxide as food and makes sugars and oxygen and to grow." This statement shows she is connecting algae growth to the scientific principle of photosynthesis, and was coded as a level three for offering reasoning regarding connecting evidence to a scientific principle.

Jessie also made significant statements in her post-interview that demonstrate her ability to analyze data and explain the findings. During her interview she stated, "I think it's possible they could look at it more because algae tends to… Self shade. Self-shading could cause the other algae to die. So you wouldn't want that. You would want more algae to reproduce" when asked what would happen to the results of their experiment. Again, she is showing an ability to connect the evidence from their experiment to a scientific principle of self-shading. Overall, Jessie demonstrates a strong and improved understanding of the content.

James

James' phase one, phase two, and total science practices scores were nine, 11, and 11, respectively. James' phase one summary was: "During the experiment it was positive then it turned negative due to the pH level, lack of air and sunlight." This data were coded as a one for research question/hypothesis, and a two for analyzing data, and each component of a scientific explanation. The statement "During the experiment it was positive then it turned negative" offers an in appropriate explanation of the data as he is explaining the growth of algae based on the growth curve generated by his research group. The remainder of the statement, "due to the pH level, lack of air and sunlight" suggest an incomplete connection of the evidence to their claim and to scientific principles. James' phase two summary was:

> "My research question was will an extra diffuser help the growth of algae in the bottle? <u>Throughout the experiment the algae had a steady growth</u> *and some environmental factors had effect on the growth*. <u>When we added an extra diffuser it sped up the growth process."</u>

The first sentence is coded as a level three for research question/hypothesis as he offers a specific research question. The underlined statements are an accurate but incomplete analysis of their data and were coded as a level two. The italicized statement was coded as a level two for providing connecting the evidence to scientific principles and a level two for connecting the evidence to their research question. In addition to my classroom observation that James was collecting data, he made this statement during his post-interview:

> "After we let the algae grow for a while we took out 20 mL samples with syringe and we checked the light with the light meter front and back and we put 10 in a test tube and 10 in the weighing pan. We put the weighing pan in the drying oven to evaporate the water so we could check for solids. And we put the 10 in the two we used to check the pH."

These data were coded as a level two for collecting data. Overall, James shows gains in his learning of the content related to the project.

Alex

Alex's phase one, phase two, and total science practices scores were seven, eight, and eight, respectively. Alex's phase one summary was:

> "Our group had kept on going up in algae and sometimes going down and the 50/50 was the best that grew in our bottles."

This summary was coded as a level two for analyzing data as it is an accurate but incomplete analysis, and a level one (no evidence) for all other categories. Alex's phase two summary was:

> "We got to go to the greenhouse and take samples of our algae & check how much our data was with the light meter from the front & back angles from each of the 3 algae bottles then we had to come back to the class. To heat up

> 10 mL of algae in the heating pan for a day so when can find out how to get a better result but once we started putting pH in our bottles witch was baking soda we started to get better results in our project … our data everything came out perfect since we used 50/50 instead of nitrite because nitrite gave us a high result in data."

The first part of this statement provides evidence that he collected data and was coded as a level two. The remainder of the statement "<u>our data everything came out perfect</u> *since we used 50/50 instead of nitrite because nitrite gave us a high result in data*" was coded as a level two for analyzing (underlined) and a level two for connecting the evidence to their research question/hypothesis (italicized). Alex made statements in his post-interview that supported he collected data and could analyze the data. However, these statements were both coded as level two and did not change his total score. While his total score is the lowest of all students, Alex shows improvement in his learning of science practices.

Isabella

Isabella's phase one, phase two, and total science practices scores were nine, 12, and 14, respectively. This suggests that her learning of science practices increased as demonstrated in her research summaries. In addition, her interview and presentation statements showed further understanding of science practices. Isabella's phase one summary was:

> "Our bottles had the 100% ammonia our growth was minimal and *died very quickly*. The bottles that had the most growth was the 50/50 and maintained good growth so they should *stay controlled* and see if the changed variables help get better results than the 50/50 our group would like to add light to our bottle."

The statement "Our bottles had the 100% ammonia" was coded as a level two for research question/hypothesis. In addition, she made statements that demonstrated an accurate but incomplete analysis of their data. These underlined statements were coded as level two. The italicized statements were coded as a level two for connecting the evidence to the original research question/hypothesis. Isabella's phase two summary was:

> "Our research question was how constant light effects the growth of algae. Our data showed that the constant light on the algae did make it grow better but killed it a lot faster *because the algae could not go through its natural process of photosynthesis*."

The first sentence is a specific research question and was coded as a level three for research question/hypothesis. She also shows a partial analysis of the data (underlined). In addition, the last statement shows that she is implicitly connecting the evidence to the hypothesis (level two) and a connection of the evidence to the scientific principle of photosynthesis (level three). Isabella made additional statements in her post-interview and group's oral presentation that provides evidence for a more improved learning of science practices. For example, during her group's presentation, she stated "Our research question for the second phase was the constantly benefit or reduce the growth of algae? Our hypothesis was if we keep constant light on the algae than the algae will have a steady productive grow." This statement was coded as a level three for research question/hypothesis. When explaining the results of phase one, she stated "in the first phase everyone had a different concentration of nutrients because we wanted to figure out so we could use that in all of our bioreactors…Ours was the blue line 100% nitrate I mean 100% ammonia and compared to the 50-50 ours grew not as well." This was coded as an accurate and complete analysis of the data (level three). She went on to offer a scientific explanation for the data, "We believe the rapid decrease in growth was because of the constant light the algae could go through its natural process of photosynthesis. Conclusion the experiment seemed to be successful but we realize we had to correct for the constant light because it was helping it to grow faster but it made a die off faster because it couldn't go through its natural process of photosynthesis." This was coded as a level three for both aspects of a scientific explanation. She iterated this ability in her post-interview with the statement:

> "I think we had a good idea, but the constant light made it grow really fast and then die off really fast. I think what we should have done was headed on for a certain period of time and turn it off, then turn it off and on again since algae is photosynthetic organism, it couldn't go through its photosynthesis with light on it constantly."

Her post-interviews show that she was collecting data, with the statement "we dried it weighed it and we did the same thing everyday." My classroom observations support this finding. Overall, Isabella shows strong gains in learning of the science practices.

Sophia

Sophia's phase one, phase two, and total science practices scores were nine, ten, and ten, respectively. This suggests her learning of science practices increased as demonstrated in her research summaries. In addition, her interview and presentation statements showed further understanding of science practices. Sophia's phase one summary was:

> "From the chart data, we can conclude that our group which was testing 100% NH_3, had a great amount of algae except *it started dying off after 7 days.* The best one was the 50/50 *because they grew a lot differing in that they stayed steady*."

The statement "our group which was testing 100% NH_3" was coded as a level two for research question/hypothesis. Underlined statements were coded as level two for analyzing data, as these were accurate but incomplete statements. Italicized statements were coded as level two for connecting the evidence to their research question/hypothesis and level one (no evidence) for connecting the evidence to scientific principles. Sophia's phase two research summary was:

> "Our group was testing for pH. Our bottles were the greenest from all other groups. When we were doing the original experiment our pH was different all the time ranging from 5.5-7.5 as we were using 100% nitrite. In the 2nd experiment we switched to 50% ammonia & 50% nitrite and added baking soda to alter the pH. *When doing so, our pH stayed steady at 8.5 from each bottle."*

The first sentence shows she is being specific, but not stating a research question or hypothesis. This statement was coded as a level two. The remainder of her summary (underlined) shows an accurate and complete analysis of the data from her group's experiment. This statement was coded as a level three. Her post-interview statements demonstrated that she collected data:

> "We extracted 20 mL of water and we took the light meter and measured the klux. Once we got back in here we used 10 mL to test the pH and 10 mL to put inside the drying oven so that it could evaporate and what was left over was the algae and we weighed the pans before and after."

Her interview statements support this finding - "I did mainly the whole getting the data I did the light meter, I extracted the algae from the bottle, things like that. Tested the pH. I put the things in the oven.". Overall, Sophia shows a slight increase in her learning of science practices.

Tyler

Tyler's phase one, phase two, and total science practices scores were six, 12, and 13, respectively. This suggests his learning of science practices increased as demonstrated in his research summaries. In addition, his interview and presentation statements showed further understanding of science practices. Tyler's phase one summary was "*Our experiment produced too much ammonia to properly grow algae.* We had the lowest concentration of algae in our experiment." His summary of phase one shows that he an accurate but partial analysis of the data and was coded as a level two. However, he mistakenly states that the algae produce too much ammonia. This italicized statement was coded as a level one for scientific explanation. His phase two summary is more thorough and accurate:

> "Our research question was how would the constant light effect the growth of algae. We found out that constant light does help it grow, but also kills it. *It kills it because the algae can't recover during the night (like in nature). So the constant photosynthesis tired out and killed the algae. Our conclusion was that we could have the light to imitate the sun in a shaded environment, but turn off the lamp at the end of the day."*

The first sentence demonstrates a specific, testable research question and was coded as level three. He offers an accurate but incomplete analysis of the data (underlined). The first part of his explanation is connects the evidence to the original claim and a scientific principle. However the remainder of his explanation is inaccurate with regard to his conclusion. Thus his scientific explanation was coded as a level two for connecting the evidence to the claim and a level three for connecting the evidence to the scientific principle of photosynthesis. Tyler made the following statement during his group's presentation:

> "We withdrew 20 mL samples from each reactor and brought those back to class. We would split the sample into 2 10 mL and put one in aluminum pan and a drying oven to see how much algae growth and the other 10 mL was to measure the pH value of each. And we measured the pH *because the acidity can tell you whether the algae are healthy or not or dying off."*

The first part of this statement supports the finding that he collected data and the remaining italicized statement show an ability to accurately connect the evidence to the research question. This last statement was coded as a level three. Overall, the data showed an increase in Tyler's learning of science practices.

Jared

Jared's phase one, phase two, and total science practices scores were 10, 12, and 14, respectively. This suggests his learning of science practices increased as demonstrated in his research summaries. In addition, his interview and presentation statements showed further understanding of science practices. Jared's phase one summary was "My group was the 100% NO_3. Our algae grew the most at first but then started to decrease. The 50% NH_3 and 50% NO_3 grew the most. *Apparently ours went down due to self-shading*."

The first sentence is an explanation of what his group was doing, but does not phrase it as a research question or hypothesis. This was coded as a level two. The underlined statement is an accurate but incomplete analysis of the data and was coded as a level two. The last italicized statement partially connects the evidence to the research question, and accurately connects the evidence to a scientific principle. This statement was coded as a level two for connecting evidence to the research question and a level two for connecting the evidence to a scientific principle.

Jared's phase two summary was "My group's research question was how pH affects algae growth. Our data shows that increasing the pH dramatically improves the growth rate of algae. The controls algae did not grow as much as ours." The first sentence is a specific and testable research question and was coded as level three. The underlined statement was coded a level three for data analysis as he explains their results and compares it to the control group. Jared does not offer any evidence of a scientific explanation in his research summary, but does in his group's presentation with the statement "It (the purpose of the baking soda) was to stabilize the pH. In the first experiment the pH moved around quite a bit and the baking soda was to stabilize it." This statement demonstrates his ability to connect the evidence to their research question and was coded as a level three. Jared made statements during his post-interview to support the finding that he collected data as he stated, "I collected data and analyzed. We all took turns with the light meter collecting algae and testing pH." This data supports my classroom observations. Overall, the data suggest an increased understanding of the science content.

Daniel

Daniel's phase one, phase two, and total science practices scores were two, 13, and 14, respectively. This suggests his learning of science practices increased as demonstrated in his research summaries. His interview and presentation statements support these findings. Daniel did not complete a phase one summary, which explains his phase one summary score of two. A score of two reflects evidence of collecting data. His phase two summary was:

> "Our research question for phase two was "How does the constant effect of light change the growth of microalgae specific algae being the Chlorella species." Once the algae grew to its peak it did not just flatline and become stable also it decreased rapidly over a short period of time. *Our conclusion for the experiment somewhat supported our hypothesis we did*

> *have a increased growth compared to the control group which would have been the best time to harvest. But our hypothesis for the decrease in algae was that it could not keep up with its normal photosynthesis pattern."*

The first sentence was coded as a level three for research question/hypothesis. The underlined statement shows an accurate but partial analysis of the data, while the last italicized statement makes a connection to the research question. This was coded as a level two. He also accurately connects their evidence to the scientific principle of photosynthesis. Daniel made the following statement during his group's presentation:

> "We decided to use light as the independent variable in our experiment because the environment it was in with constant shading so we thought constantly would make it grow better. We think some of the solution from the first phase might have stayed in the bottle and that probably may have had an effect on our new solution in the bioreactor. We had 100% ammonia (first phase) so we may have had more ammonia in our bioreactor. *In regular 24/7 it gets dark at night but with constant light it never gets a chance to cool down so when I got to its peak it couldn't grow anymore because it couldn't take it anymore and it started dying off."*

The underlined statement shows that he has analyzed the data and understands a possible source of contamination that may have affected the outcome of their phase two experiment. In addition, he iterates his ability to offer a scientific explanation (italicized). Thus, Daniel does show learning of science practices as it relates to the algal biofuel project.

Keith

Keith's phase one, phase two, and total science practices scores were nine, nine, and 10, respectively. Keith's phase one summary was:

> "Our experiment consisted of 50% NO_3 and 50% NH_3. We didn't have the fastest growth rate but we had the least amount of algae lost. *I think this occurred because the NO_3 helped algae grow while NH_3 keeps the algae from dying.*"

Like many other students, his first sentence reflects a level two statement with regard to his research question/hypothesis. The underlined statement reflects an accurate but partial analysis of the data and the italicized statement is a partial connection of the evidence to the research question/hypothesis. Both statements were coded as a level two. There is not any evidence showing that he connected the evidence to a scientific principle. Keith's phase two summary was:

> "Our purpose was to create a controlled experiment for the other experimental groups can compare to. We had the best mixture data wise. It was very productive and stood at a high rate at a constant pace. *Trial 1 & 2 had similar results but we should of spent more time on trial 2*."

The first sentence was coded as a level three for research question/hypothesis. The underlined statement is evidence of an incomplete analysis of the data. In addition, he offers a partial connection of the evidence to their research question (in this case purpose as they were the control group). Keith made statements during his group's presentation (shown below) that show a higher ability to analyze data, how the results were obtained, and connecting the pH readings being about the same with the observation that bottles were all about the same color. This was coded as an accurate and complete analysis (level three).

> "The pH in all the bioreactors was between six and seven…That was the average for all three bottles. All three were about the same readings. Not the same but we averaged it out. And all the bottles were nice and green and they were pretty much the same."

Overall, he shows gains in his learning of the science content related to the algal biofuel project.

Katie

Katie's phase one, phase two, and total science practices scores were two, two, and four, respectively. These low scores are because Katie did not complete either research summary, nor was she present for the presentation. Thus, data was limited to her post-interview and classroom observations. My classroom observations showed Katie to be actively collecting data with her research group. In addition, her statement "I would take the data they got from drying the algae in the pan weight and I would like read all that down in the pH. I was the pH person." supports this finding. She made an additional statement that demonstrates she collected data but also a partial analysis of the data. This statement "We gathered data daily and we compared it to the data from before to make sure nothing had contaminated it or anything spilled" was coded as a level two for data analysis. Thus, there is evidence to show Katie made a small gain in her learning of science practices.

Neal

Neal's phase one, phase two, and total science practices scores were seven, 10, and 11, respectively. His phase one summary was:

> "We had steady growth then it stayed at 1 amount then all of a sudden it just stopped growing. One of the other groups had rapid growth but declined quickly then increased slowly. Another increased fast, never declined but it stopped growing at a slower rate than the rest but declined just like all the others."

This summary shows an accurate but partial analysis of the data, and was coded as a level two. His phase two summary was stronger:

> "<u>My group had pretty good growth on both phases but 50/50 works the best.</u> The whole idea for the experiment was to see what the best growth method was for algae. *In the beginning there were 4 different groups w/ 4 different amounts of* NH_3 *&* NO_3*. In the end we found out that the best growing method was 50%* NH_3 *& 50%* NO_3*. Not only because it grew the best but also because it was cheaper and much more efficient than any biofuels being used today."*

The statement "The whole idea for the experiment was to see what the best growth method was for algae" was coded as a level two for research question/hypothesis because it lacks specific information. All statements in this summary were coded as level two, as they were accurate but incomplete. In addition, the statement "because it was cheaper and much more efficient than any biofuels being used today" is inaccurate. Overall, Neal showed an increase in his learning of science practices.

Teacher

Mrs. Bodin, the marine science teacher, made statements to support the finding that students were engaged in and learning science practices.

> Angela: What did you expect students to do in this project?
> Mrs. Bodin: To collect data, make some charts, improve their people skills by working together toward a common goal.
> Angela: Tell me what did your students did during the project?
> Mrs. Bodin: They did the entire project from start to finish. From building/setup of reactors to collecting data, analyzing, drawing conclusions, making new hypothesis and presenting their findings…. Design and set up of experiment, collecting data, making data tables, inputting into excel, noting abnormalities, interpreting, making connections to class room and real life.
> Angela: Tell me about a typical day for your students during the project.
> Mrs. Bodin: Weigh boats, collect samples of water and light, record into lab books.

While the last statement is partially incorrect (they were collecting samples from the algal cultures, not "water"), the statement does support the finding that students were collecting data through out the project. This supports my classroom observational findings that students were collecting data. In addition, she notes that students were engaged in science and engineering practices, such as collecting and analyzing data, building bioreactors, and making use of technology. This supports the findings from the students' research summaries and oral presentations regarding their learning of specific science practices.

Research Question 4 Summary

Findings from analysis of the pre/post open-ended questions show an increased ability to explain the role of algae in our environment, including their use as a biofuel and photosynthetic organism. In addition, qualitative analysis of the data from research summaries, post-interviews, and presentations provided strong evidence that students learned specific science practices as related to the algal biofuel project. Quantitative analysis of the scores generated from the qualitative analysis showed statistically significant increases in student learning of science practices. The median scores for the phase one summary, phase two summary, and total science practice were 9.0, 11.0, and 11.5 on a 14 point scale. Collectively, these findings suggest that authentic science experiences have the ability to improve student learning of science practices. Thus, the evidence suggest that the students' perspective about the authenticity of the experience is an indicator of the outcomes with regard to their learning of science practices.

Overall Summary

In summary, trends emerged regarding how students are affected by participation in an authentic science experience with regard to their perception of the authenticity of the experience, attitude toward science, and perceptions about who can do science, science identity, and learning of the science content.

One finding is that 10 of the 12 students perceived their experience as one of authentic science. Table 20 specifies which students perceived the project as one of authentic science, with a "+" indicating that they believed the experience to be authentic science and a "-" indicating they did not believe the experience to be authentic science. Students often made reference to their excitement that the university research group treated them as peers, and that the found the project to be more interesting and engaging because they felt they were participating in original research. This is important because students' perspectives are often overlooked when these experiences are designed. The contextually based authentic science model considers the student perspective and voice to be important when designing authentic science experiences (Buxton, 2006).

There was a significant decrease in the choice of the stereotypical White male scientist on the pre- and post-IAS after their participation in the algal biofuel project. Students not only selected individuals of their own gender and ethnicity more often after the project, but they also increased their selection of White female, African American male, and Eastern male. This finding suggests that student participation in authentic science experiences and interaction with a more diverse group of scientists has the ability to influence their perception about who can do science.

Two separate data sources, post interviews and pre-post-IAS, were used to examine science identities after the project. One analysis showed that seven of the twelve students demonstrated an increase in gender- and ethnicity-matching between the pre- and post-IAS. This means that seven of the students chose an individual or individuals they believed to be a scientist that reflected their own gender- and ethnicity- more often after they participated in the algal biofuel project.

Carlone & Johnson's (2007) science identity model was used to develop a rubric to determine if student participation in the project influenced their science identity. Briefly, the three domains of this model are performance (talking and doing), competence (understanding), and recognition (by self and others as a scientist). I analyzed interviews and journals for explicit references for explicit reference to each of these domains (i.e. – "I felt like a real scientist" suggests a strong science identity with regard to the recognition domain). All students exhibited an increase in at least one dimension of their science identity after participation in the algae biofuel project. Overall, nine of the twelve students showed a moderate or strong science identity at the end of the project, meaning there was evidence that their participation in the project positively influenced at least two domains of the science identity model and/or their selection of scientists in the IAS that reflected their own gender and ethnicity. These findings are summarized in Table 21, showing the score determined from the science identity model.

With regard to student attitude, there was minimal change, as demonstrated in the data from the science attitude survey. The minimal change is due to the high median pre-survey scores, suggesting that the students had a strong attitude going into the project. The decrease in attitude observed in some cases may be due to a limitation of the instrument itself, a 5-point Likert scale instrument that does not allow students to explain their choices. However, two students (Alex and Sophia) showed a negative attitude score after the project was over. Given these two students exhibit characteristics of highly marginalized students, it warrants further investigation as to how we can use this type of experience to not only improve their science identity and learning, but also their attitude toward science. As shown in table 21, ten of the twelve students demonstrate a more positive attitude toward science after participation in the project.

Finally, student learning was assessed through administration of a pre- and posttest that included open-ended questions as well as students' ability to summarize each phase of the algae biofuel project. Overall, ten of the twelve students showed an improvement in their learning of the science practices.

Table 21: Student Summary by Research Questions

Student	Authenticity of Experience (RQ 1)	Science Identity? (RQ2)	Positive Science Attitude? (RQ 3)	Evidence of Learning Science Practices? (RQ 4)
Simon	+	8	+	12
Jessie	+	7	+	14
James	+	6	+	11
Alex	+	7	-	8
Isabella	+	8	+	14
Sophia	+	7	-	9
Tyler	+	5	+	12
Jared	+	8	+	14
Daniel	-	7	+	14
Keith	+	9	+	10
Katie	-	4	+	4
Neal	+	6	+	11
Key	+ = Yes, - = No	7-9 =strong 5-6 = moderate <5 = weak	+ = Yes - = No	12-14 =strong 7-11 = moderate <7 = weak

Participation in the algal biofuel project had a positive effect with regard to all four areas investigated (authenticity of the experience, science identity, science attitude, and learning) on eight of the 12 students, while one student was positively affected with regard to three areas investigated, and three students were positively affected in two areas.

Ten students demonstrated either a moderate or strong science identity and believed the experience to be one of authentic science, while one student demonstrated a weak science identity and did not believe the experience to be one of authentic science. Therefore, the student's perspective about the authenticity of the experience may be an indicator of science identity. This was not necessarily the case for gender- and ethnicity-matched role models. There was also a connection between authenticity from the students' perspective and attitudes toward science as eight of twelve students demonstrated a positive attitude toward science and believed the experience to be one of authentic science. There was also a connection between authenticity and learning of science practices as nine of twelve students demonstrated either moderate or strong learning of science practices and found the experience to be one of authentic science. Thus, this study suggests that authenticity as seen by the students might be an indicator of the outcomes with regard to science identity, attitudes toward science, and learning of science practices but not gender- and ethnicity-matched role models. Table 22 compares the different variables (authenticity, science identity, science attitude, learning). Each cell shows the number of students for each comparison. For example, 10 of the 12 students demonstrated learning of science practices and believed the experience to be one of authentic science. One student did not demonstrate learning of science practices and did not believe her experience to be one of authentic science. Only one student did not show a connection between perception of authenticity and learning of science practices. This suggests authenticity is an indicator of learning science practices.

Authenticity was also compared to science attitudes (SA) and science identity (SI). With regard to authenticity and science identity, 10 of the 12 students perceived their experience to be one of authentic science and showed a moderate or strong science identity while one student did not believe their experience to be authentic and showed a weak science identity. In contrast, one student showed a moderate or strong science identity but did not perceive their experience to be authentic science. Therefore, 11 of the 12 students showed a relationship between authenticity from the student's perspective and science identity. With respect to authenticity and attitudes, eight of the 12 students showed a positive attitude toward science and perceived their experience to be one of authentic science. In contrast, two of the 12 students believed their experience to be authentic but demonstrated a negative attitude toward science while two of the 12 students demonstrated a positive attitude toward science but did not believe their experience to be one of authentic science. This relationship was the weakest of all comparisons.

Another comparison was between science identity and learning of science practices. This comparison showed that 11 of the 12 students showed a moderate or strong science identity and moderate or strong learning of science practices. One student showed a weak science identity and weak learning of science practices. Therefore, there appears to be a relationship between science identity and learning of science practices for all 12 students involved in this project.

Attitudes toward science were also compared to science identity and learning of science practices. As seen in table 21, nine of 12 students showed a moderate or strong science identity and a positive attitude toward science, while three did not show this relationship. With regard to attitudes and learning, nine students showed evidence of a positive attitude toward science and learning of science practices while one student showed a negative attitude toward science and did not show evidence of moderate or strong learning. Therefore, 10 of the 12 students show a relationship between attitudes toward science and learning of science practices.

These findings taken collectively provide empirical evidence that the algal biofuel project as an authentic science experience improved student's science identities, change their perceptions about who can do science, their attitude toward science, and learning of science practices. In addition, the evidence suggests that science identity, authenticity, attitude toward science, and learning are related to one another.

Table 22: Relationship between authenticity (auth.) and outcomes

	Auth. (Yes)	Auth. (No)	SI (Mod. or strong)	SI (weak)	Learning (Yes)	Learning (No)
SA (+)	8	2	9	1	9	0
SA (-)	2	0	2	0	2	1
SI (Mod. or strong)	10	1			11	0
SI (weak)	0	1			0	1
Learning (Yes)	10	1	11	0		
Learning (No)	0	1	0	1		

CHAPTER 5: CONCLUSIONS AND IMPLICATIONS

Introduction

This study assumed an interpretivist perspective in order to make meaning of the students' experiences in an authentic science project. In the previous chapter, the data were presented and analyzed. In this chapter, a discussion of the findings within the context of the literature is presented. This chapter begins with an overview of interpretivism as a framework, followed by a summary of findings, and conclusions. Lastly, I describe recommendations and implications for future research in this field of science education.

Interpretivism

Interpretivism tries to better understand events, by asking what is the meaning of the event and what is the significance of the event. From this perspective, I sought to better understand the meaning of students' participation in a contextually based authentic science experience. Specifically, how the experience influenced the students' learning of science practices, attitude toward science, science identity, and perceptions about who can do science. In other words, I sought to make sense of their experience in order to reveal their meaning and significance. While making sense of the meaning from my perspective is important, I also wanted to better understand the meaning of the experience from the student's perspective as I considered their perception about the authenticity of the experience. In doing so, I was able to not only make sense of what participating in the project meant to them, but what they considered to be significant. The meaning and significance regarding students' perception about the authenticity of the project, learning of science practices, attitudes toward science, science identity, and perceptions about who can do science are discussed.

Authenticity of the Experience from the Student Perspective

An authentic science experience is one in which students are engaged in science activities that resemble the daily activities of scientists as closely as possible (Hsu et al, 2009). One model of authentic science allows for students to engage in science practices that reflect what scientists do, but is more student-centered as it gives students a voice in what they are investigating (Buxton, 2006). This model allows students to participate in authentic science activities, have a voice in what they are investigating and ensures the state mandated standards are being taught.

The findings in this study are significant and provide evidence to support arguments for authentic science experiences as one way of providing high quality science experiences (Buxton & Lee, 2010; Hsu et al, 2009, Lee & Songer, 2003). The contextually based authentic science model is a compromise, it allows the teacher to cover the curriculum and provides students with a voice in what they are investigating. However, the research interests of the engineering group that was willing to collaborate with high school students and their teacher limit the implementation of the model. Thus, when students are expected to investigate a specific topic such as algal biofuel, it makes it more challenging to give them a voice in what they are doing. The intervention design minimized this concern by giving students a say in what they investigated in the second phase of the project, as they collaborated with the engineering researchers to come up with their own research question for investigation.

What is missing from the literature is an examination of the student perspective with regard to the authenticity of the experience, specifically how students view the experience in retrospect. Do students view their participation in a project that is grounded in a contextually based authentic science model as one of authentic science?

From an interpretivist position, I sought to understand the meaning and significance of the students' experience as it relates to their perspective about the authenticity of the project. In that regard, two common themes emerged from the study that can be attributed to the authenticity of the experience from the students' perspective include:

- The students were engaged in original research, rather than traditional labs that have predetermined outcomes. Students expressed excitement at the idea that they did not know what the outcome was supposed to be, and there was not a right or wrong answer.
- Students felt like genuine collaborators with the engineering research group. Rather than being told what to do, they made their own decision on how to develop the second phase of the research project. Additionally, they felt valued because their data would be analyzed and useful to the engineering research group.

Data from the research skills survey and interviews support the conclusion that students believed their experience to be one of authentic science. These findings are significant as we consider how to implement authentic science experiences for students. It is not enough to assume the students' perception mirrors the perceptions of those designing the authentic science experience. A previous study at a middle school shows that the presence of scientists, and a project that has the elements of authentic science are not enough to ensure that the students will consider the experience to be authentic science as well (Feldman et al, 2012).

Perceptions About Who Can Do Science and Student Science Identity

Several findings emerge with regard to student perceptions about who can do science. In other words, understanding student perceptions about who can do science can help to make sense of the meaning of their experience as well as their identity.

While the Identify-a-Scientist is a new instrument that is different from the Draw-a-Scientist Test, it does allow students to make choices about who they perceive to be a scientist and to elaborate on those choices. This instrument, used in conjunction with analysis of data from interviews, allowed for the examination of individual science identities as well as how participating in the algae biofuel project influenced these identities. First, there was a significant increase in the choice of the non-White male scientist. This increase corresponds with an increase in White female, African American male, Asian female, and Eastern male. One explanation for finding that students developed a more diverse view of who can do science is that they were exposed to a diverse group of scientists ranging from graduate students to tenured faculty, and administrators during a field trip to the university. This field trip included a tour of the laboratory of the environmental engineering faculty as well as attending a graduate student poster presentation. The students interacted with several graduate students who were of various ages, ethnicities, and both genders. This finding provides a unique perspective that supports the literature in that exposure to role models has the ability to influence student perceptions and identities of who can do science (Karunanayake & Nauta, 2004; Zirkel, 2002).

Another explanation is connected with the students' own science identities and that engagement in authentic science led them to believe that people like them, that is someone with their own gender and ethnicity, can do science. This is evidenced by the fact that 11 of the students showed a moderate or strong science identity but only six of the students showed an increase in their gender- and ethnicity-matched score. This increase in gender- and ethnicity matching suggests a stronger science identity as students choose an individual that has physical similarities to themselves. I conclude that students were improving their science identity and becoming more diverse in their perceptions about who can do science. This study provides empirical evidence to support the argument that students should be encouraged to recognize more diverse role models, but not at the expense of same gender- and ethnicity role models (Karunanayake & Nauta, 2004).

This finding merits additional research to explore the relationship between science identity, gender- and ethnicity-matching and how these experiences are influenced by different educational experiences. The disparity between the results from the IAS findings and science identity model suggests that science identity is complex and multifarious in nature, and warrants further investigation.

The influence of the algal biofuel project on science identities was also examined by analysis of data obtained from interviews with students after the project. Carlone & Johnson (2007) have proposed a model of science identity that is multi-faceted, being comprised of performance, recognition, and competence. This model was developed from the investigation of adult women of color that are pursuing science careers. I used this model in a novel manner to develop a rubric and analyze science identities of high school students after their participation in the algal biofuel project. By using the science identity model to analyze interview and journal data within this investigation, findings revealed eleven of the twelve students showed a moderate or strong science identity related to their participation in an authentic science experience. If students demonstrate a science identity based on the rubric developed from Carlone & Johnson's model, then it can be argued that students are more likely to self-identify as scientists. The findings from this study suggest that engaging in authentic science activities led to students demonstrating a science identity as well as self-identifying as scientists. However, this study does not show that students with a strong science identity are more likely to self-identify as scientists. While it was predicted that students would choose a scientist on the IAS of their own gender- and ethnicity more often after the project, only six students did so. Findings of the IAS show that students developed a broader perception about who can do science. Thus, the qualitative data from the science identity model allowed for a better examination of student's science identity. Further research is warranted.

The findings from the interview data support the conclusion that students became more competent in their understanding of the science content as it relates to the algal biofuel project, were recognized by professionals and themselves as persons of science, and became more proficient in their ability do science (collect data, ask research questions, etc.). Also, the IAS data showed there was an increase in gender- and ethnicity-matched selections after the project was completed for 50% of the students. The evidence suggests this authentic science experience had the ability to improve students' science identities.

An important aspect of the authentic science experience is that the students, in addition to become authentic scientists, went on a field trip to the university in which students interacted with a diverse group of graduate students and faculty from the college of Engineering. Thus, an unintended aspect of the intervention was exposure to a heterogeneous group of varying ages, genders, and ethnicities. The extent to which the IAS findings were influenced by participation in the project and/or exposure to engineers and scientists from diverse backgrounds cannot be ascertained. Interview and journal statements indicate both aspects of the project (the investigation and field trip) influenced their perceptions about who can do science. Regardless, additional research is warranted to better understand how each aspect of the project affected the IAS findings and students perceptions about who can do science. For example, repeating the study with more in-depth interviews might help to answer these questions.

Science Attitudes

Overall, the survey showed that students had a positive attitude toward science going into the project, and this attitude improved slightly. Thus, data from the science attitudes survey provided limited information. In contrast, the data from the interviews indicate that most students found the algae biofuel project interesting, engaging, and one that they would consider continuing to participate in as part of a class project. The findings from interviews suggest that attitudes improved greater than indicated on the attitudes survey. This disparity might be attributed to 1) the ceiling effect and 2) a limitation of the survey as a 5-point Likert scale that does not allow students to elaborate on their choices and gives an incomplete picture of students' beliefs and attitudes.

The ceiling effect was observed as students reported high science attitudes at the onset of the project. The limitation of the survey design itself has been found to not necessarily provide a complete picture of participants' perceptions. For example, this limitation was what led to the development of the VNOS, which allows students the opportunity to elaborate on their selections (Abd-El-Khalik & Lederman) as well as the Identify-a-Scientist instrument (Walls, 2012). Because of this limitation with the science attitude survey as a Likert scale instrument, I chose to supplement this data with qualitative data from student journals and post-interviews. The findings from these different sources show disparities suggest caution when using pure Likert scale instruments in research.

Learning

The recently released next generation science standards (Achieve, 2013) state "learning about science and engineering involves integration of the knowledge of scientific explanations (i.e., content knowledge) and the practices needed to engage in scientific inquiry and engineering design." Thus, it is not enough for students to simply memorize scientific concepts and facts. Students need to understand scientific concepts within the context of application and real life relevance. The goal is for students to develop a deeper understanding of the content as well as an ability to practice science. Eight scientific and engineering practices that are considered necessary for all students have been included as part of the framework for the next generation science standards. Data were collected that provided evidence with respect to three of these science practices, specifically students were engaged in asking questions, analyzing and interpreting data, and constructing explanations. Thus, an authentic science experience such as the one utilized in this study provides students with an opportunity to learn science that reflects these standards.

Student understanding was assessed based on their responses to pre- and post- open-ended questions, journal summaries of both phases (one and two) of the project. A significant finding was that students demonstrated a shift not only in their research skills, but their way of thinking about science. Many factors that affect student achievement in science, and sustained interest in science have been previously described. One of these factors is the type of science instruction experienced by students. For example, students often experience science in a traditional format composed of lecturing, reading from their science text, and answering chapter questions. Sometimes, this type of instruction is supplemented with labs and/or experiments that are "cookbook" in nature in which students know there is an expected outcome. Moreover, they believe they have done something wrong if they do not achieve the expected outcome. Student interviews in this study support this idea as many students expressed traditional approaches as a typical science experience in the classroom. In addition, students found the algal biofuel project to be uniquely different from their typical science classroom learning experience. Again, the newly released Next Generation Science Standards call for science instruction that allows student to develop a deeper understanding of the content while developing science practices.

The findings in this study show that students developed a more sophisticated way of thinking about and doing science. For example, students demonstrated skills necessary to become competent scientists (asking a research question, creating a hypothesis, collecting and analyzing data), and also came to see scientific evidence as tentative in nature, and experiments lacking a right or wrong outcome. Overall, students showed improvement in their understanding of the content as it related to the algal biofuel project, and in their scientific practices. Thus, this type of experience has the ability to allow students to develop practices of a scientist while learning the content.

Equity in Science Education

Critical Theory

Critical theory in education aims for students to become aware of their oppression and challenge dominant structures that have led to the oppression with the goal of liberation. Thus, critical theory is socially transformative in nature. The design of the IAS implicitly challenges the stereotypical white Male scientist perception, which is arguably a dominant structure that has marginalized students in science education. Multiple lines of evidence support the finding that students were challenging this stereotype. First, there was a significant decrease in the stereotypical white Male scientist from the pre- to post-IAS. Second, students made specific statements in the post-interviews that support the finding that exposure to a diverse group of engineers and scientists during the field trip influenced their perceptual change about who can do science. Third, when students were asked why they chose an individual on the IAS, the most common choices before the IAS were those previously described (older, wearing glasses, beard). While these comments on the post-IAS were evident, students also referenced similarity to scientists and engineers they interacted with during the project. This includes Professor Berber, Grace, as well as faculty and graduate students at the research symposium they attended. In addition, students recognized the authentic science experience as a better form of instruction than their typical classroom experience. Again, this suggests a heightened level of consciousness about differences in types of learning in the science classroom. However, this study did not explicitly help students raise their level of consciousness about their situation, as might be expected from a critical theory perspective.

Culturally relevant pedagogy not only calls for high academic achievement, but also allows students the opportunity to develop critical consciousness, and develop cultural competence. Students were engaged in authentic science practices that reflect high academic achievement, involving the level of problem solving and critical thinking necessary to design and answer research questions related to algae as a biofuel. While a goal of critical consciousness is to bring individuals toward overcoming oppression, it does so by having a thorough understanding of the world that allows them to uncover social issues (Freire, 2000). To this end, students became more aware of environmental issues related to fossil fuels and how algae as a biofuel (including their research) can help address this problem. Finally, cultural competence refers to one's capacity to interact with many different people, including those from a variety of cultures. In this regard, students developed the competence to interact successfully within the culture of the scientific community.

Marginalization of students in science education

I have a commitment to not only helping all of my students become scientifically literate, but also challenging existing structures that have stood in the way of this goal and led to marginalization of students with regard to their science education. In other words, critical theory resonates with me as an educator. This resonance was the driving force behind the intervention as it was a novel experience for those students who participated in the project.

Marginalizing identifiers in science classrooms include gender, ethnicity, SES, ELL, and ESE. In addition, the type and quality of instruction and culture of power have been attributed to marginalization of students in science education (Buxton & Lee, 2010; Delpit, 1995). All students participating in this study can be considered marginalized based on these identifiers. In addition, all students described the authentic science experience as something new and very different from their typical classroom instruction.

This type of experience has the ability to improve student attitudes toward science, influence perceptions about who can do science, science identity, and learning of science. Indeed, some of the greatest effects were on the most marginalized students. Some of the disparities that emerged from this study suggest the need for additional research. For example, a case study analysis of mainstream and marginalized students might provide a more in-depth understanding of student attitudes before, during, and after participation in an authentic science experience.

Unexpected Findings

An unexpected and interesting finding emerged from this study. While student perceptions at the beginning of the project indicate that the stereotypical white male persists as the student choice, the percent was significantly less than that found with DAST studies. Early reports using the DAST showed that greater than 85% of students drew a male scientist, and greater than 98% drew a White scientist. More recent studies have shown that the stereotypical male scientist to be drawn with a frequency of approximately 57% (Steinke et al., 2007). One well-documented limitation of the DAST as an instrument is that it can be difficult to determine gender and ethnicity from student drawings. The pre-IAS findings in this study show that students' choice of the stereotypical white male is less than 50%. The decline in the choice of stereotypical white male, occurring since the 1980s, might also be explained by science education reforms that have focused attention to diversity in science. Therefore, the disparity between the DAST and IAS findings can be explained by the nature of the instruments themselves in how data is collected. Regardless, this disparity warrants further investigation and is discussed later in this chapter.

Implications, Recommendations, & Future Directions

Implications for current and future science teachers

While the success of this project is, in part, due to its interdisciplinary design it is important to keep in mind that most teachers are not prepared to teach science in this manner. While the teacher involved in the final project has considerable experience in the biology classroom and is highly regarded in her district, she expressed concern that she had never engaged her students in this type of project. I served as liaison between the teacher and the environmental engineering faculty and the graduate students. Thus, the engineering research group was able to bring their research into a high school classroom, but in a way that was meaningful, met the curriculum requirements, and was developmentally appropriate for the students. Furthermore, this is a replicable model (Figure 4) that can be applied to many scientific and engineering disciplines and grade levels. This model calls for learning science in an interdisciplinary manner that allows students and teachers to collaborate with scientists and perform original research.

The role of science education faculty is to facilitate the development of a project that allows students to learn course content but also develop scientific practices while engaging in collaborative, original research. This supports and adds to the findings from the STEMRAYS program in which elementary teachers were able to gain science practices necessary to help their students become genuine researchers in authentic science practices because the teachers had the subject matter knowledge for teaching and were treated like apprentices in a research group (Feldman & Pirog, 2011). The teacher involved in the pilot study has an elementary education degree, and very little experience teaching science, while the marine science teacher in the final study is a veteran science teacher with a science background. The success of the final can, in part, be attributed to the marine science teacher, as she is an experienced science educator who took great interest in the project and ownership with regard to students' success.

When examining existing teacher education programs, this model should be considered as a means of helping preservice teachers develop the research skills and scientific processes needed to effectively carry out this type of instruction in their classrooms. In addition, professional development programs for inservice teachers would benefit from considering this type of model to help teachers develop the content knowledge and scientific practices needed to help their students.

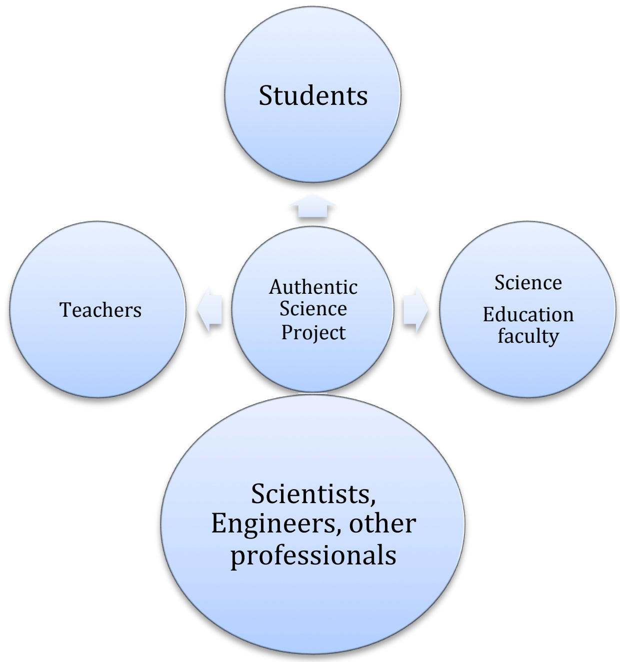

FIGURE 4: Collaborative nature of the authentic science experience

Currently, there is a national push for STEM based initiatives in K-12 classrooms. This model has the each of the elements of a STEM project, as summarized in the figure 5. With regard to science, students were learning about photosynthesis and renewable energy while learning scientific practices such as those described in the Next Generation Science Standards (Achieve, 2013). In addition, technology and mathematics were incorporated as students learned how to use Microsoft Excel to analyze data. This included creating formulas to calculate biomass production, averaging total solid and pH data, and graphing their data to examine relationships between dependent and independent variables. Additionally, students learned engineering principles as they helped to design and build bioreactors, as well as operating parameters such as gas flow rates.

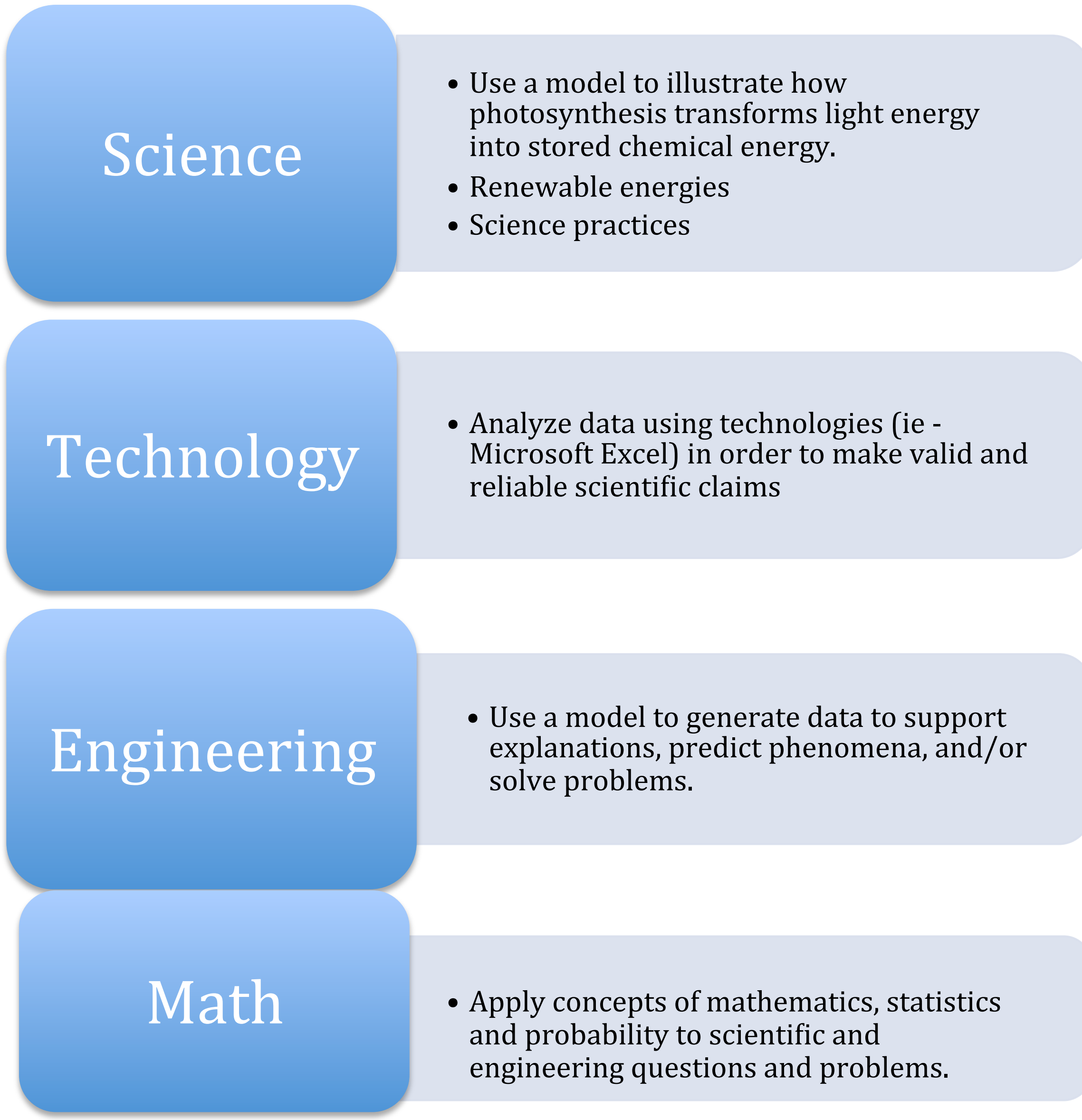

FIGURE 5: The algae biofuel project as a model of STEM education.

Recommendations

Creating an authentic science program requires active buy-in and participation by all stakeholders, including students, teachers, and researchers. One disadvantage is that researcher participation can sometimes get in the way of carrying out other research interests (Feldman & Pirog, 2011). While altruism and a personal desire to work with the community on the part of researchers is important, funding the project is one way in which to create a mutually beneficial partnership. In addition, this is an opportunity for engineering or science graduate students to perform pilot work that will further their dissertation research. It is also important to consider the interest and motivation of the teacher (Feldman & Pirog, 2011). As shown in this study, the teachers commitment to the project will make a difference for the students.

Exposure to Scientists and Engineers

The intervention was designed for students to experience authentic science by participating in an algal biofuel project, and to interact with practicing scientists and engineers during a field trip to the university. Part of the field trip included students talking with graduate students from the college of Engineering during a poster symposium. The individuals the students interacted with were very diverse based on age, gender, and ethnicity, but were also international graduate students. For example, high school student participants were not necessarily interacting with African-American students, or Hispanic students that were American citizens. Future studies are merited to examine whether this factor influences student perceptions.

Limitations

All of the researchers (education and engineering) had a stake in this project, due to personal reasons and drives that led us to choosing to be involved in this type of study. For me, as an education researcher, my passion was and still is creating positive science education experiences for all students and sharing my love of science and the thrill of self-discovery with my students. For the engineering researchers, I believe their commitment to environmental engineering was coupled to their desire to create positive environmental stewardship among our citizens. I considered their willingness to be involved in this type of project admirable and altruistic in nature as it did not necessarily advance their research careers.

I recognize that I was the sole observer in this study, and that my personal beliefs, thoughts, and biases were inherently part of the process. In order to address this limitation, I used several strategies. First, I utilized member checking through out the study to make certain that I accurately captured their perceptions, thoughts, and beliefs.

This took place during face to face and email communications with the teacher. Second, I used peer review with other educational researchers to discuss findings and interpretations during weekly group meetings. While it was not possible for me as he researcher to completely eliminate biases and beliefs it did help me to keep them in check.

One limitation of this study was the selection process for study participants. It became necessary to choose a school and a teacher that was willing to collaborate with the university. For this reason, we were able to work at an urban high school in the southeastern United States. Currently, this school is a science magnet that enrolls regular and magnet students and has a very diverse student population. Also, in order to minimize disruption of covering the required curriculum, we worked with an honors Marine Science class that included AP, honors, and regular students. Thus, the students studied were purposefully selected and may not necessarily reflect the general student population. As a result, the findings may be replicable or applicable to a more limited subset of our student population. Additional studies at different types of schools in different areas are necessary before generalizations can be made about the reproducibility of the intervention.

Another limitation was the IAS instrument. The IAS was chosen as an instrument because of the limitations about gender and ethnicity identification with the DAST. However, presenting students with a photo eliciting activity and asking them to choose from a finite group of photos introduces its own limitations as we are restricting their choice to the finite number of photos they are shown. To minimize this limitation, interview and journal data were triangulated with the IAS data.

Delimitations

The purpose of this study was to investigate how students were affected by participation in an authentic science experience. Thus, the parameters of this study were designed so that my primary focus was on the learning, attitudes, perceptions, and behaviors of students involved in the project. While I am interested in the thoughts, beliefs, and experiences of the teachers and researchers involved in the project, it was to the extent that it can provide insight into student experiences and how their behaviors may influence student attitudes, perceptions, and learning of science.

In addition, the aspects of the project reflected laboratory-based science. This is an important delimitation as research shows that the laboratory based scientist is one of the typical stereotypes that students possess and expect (Finson, 2002; Walls, 2012). However, this is a limited view of science, as other areas of scientific research may be field-based, laboratory-based, computer modeling-based, as well as observational or theoretical in nature.

APPENDIX A: INTERVIEW PROTOCOLS

Student Interview questions

Background questions

1) Why are you taking this class?
2) Why are you in the magnet program?
3) What are your dreams for the future? What are you interested in doing after high school?
4) What are your favorite subjects in school?

I'm now going to ask you some questions about this class and the project.

5) What are you studying in this class now (besides the algae project)?
6) How well do you understand these concepts?
7) What helps you to understand them? What gets in the way?

I'm now going to ask you questions about how you responded to the survey and test.

8) Tell me more about your response about your ability to do science on the pre-survey.
9) When you hear the word scientist, tell me what comes to mind.
10) What do you think you would need to do in order to become a scientist when you grow up?
11) Tell me more about why you chose that individual on the Identify A Scientist survey.
12) Is what you did in this project similar to/different from what you think scientists do day to day? How is it same/different?
13) How does what you did in this project compare to classroom science before this project?

Interview questions for professors:

Intentions:

1) Why do you work with schools and communities?
2) What outcomes do you expect from this project?
3) Is this pure outreach or does it contribute to your research?

4) Why are your graduate students involved in the project?
5) How do your graduate students benefit from being involved in this project?
6) What effect does this work have on your career?
7) What did you think your role would be in this project?
8) What did you think the teacher's role would be in this project?
9) What did you think your graduate students' roles would be in this project?
10) What did you expect the students to do in this project?

What happened:

1) What did you do during this project?
2) What did the teacher do during this project?
3) What did your graduate students do during this project?
4) What did the students do during this project?
5) Tell me about the actual science activities the students performed.

Reflective:

1) How did it go?
2) Tell me about the highlights of the project?
3) Did anything not go as planned? If so, tell me about that.
4) What would you do differently or will you do differently as you move forward?
5) Why is this type of outreach important to you?

Interview questions for graduate students:

Intentions:

1) Why did you become involved in this project?
2) What outcomes do you expect from this project?
3) What did you think your role would be in this project?
4) What did you think your professor's role would be in this project?
5) What did you think the teacher's role would be in this project?
6) What did you expect the students to do in this project?

What happened:

1) What did you do during this project?
2) What did your professor do during this project?
3) What did the teacher do during this project?

4) What did the students do during this project?
5) Tell me about the actual science activities the students performed.

Reflective:

1) How did it go?
2) Tell me about the highlights of the project.
3) Did anything not go as planned? If so, tell me about that.
4) What would you do differently or will you do differently as you move forward?

Interview questions for teacher:

Intentions:

1) Why did you become involved in this project?
2) What outcomes do you expect from this project?
3) What did you think your role would be in this project?
4) What did you expect students to do in this project?

What happened:

1) What did you do during this project?
2) What did the professor do during this project?
3) What did the graduate students do during this project?
4) What did your students do during this project?
5) Tell me about the actual science activities your students performed.
6) Tell me about a typical day for your students during the project.

Reflective:

1) How did it go?
2) Tell me about the highlights of the project.
3) Did anything not go as planned? If so, tell me about that.
4) What would you do differently or will you do differently as you move forward?
5) How were your students affected by this project?

APPENDIX B: IDENTIFY-A-SCIENTIST

After viewing the photographs, students will be asked three questions:

(1) Who in this group of photographs do you believe is the scientist?

(2) On a scale of 1 to 5, how sure are you of your selection?

(3) Why did you choose that particular individual?

APPENDIX C: PRE/POST ASSESSMENT & SURVEY

I. Place an ☑ in the box indicating how much do you agree or disagree with the following statements.

SD = Strongly Disagree D = Disagree U = Unsure A = Agree SA = Strongly Agree

	SD	D	U	A	SA
1. The Algae Biofuel Project will help me to understand how scientists do research.	❒	❒	❒	❒	❒
2. I will participate in the Algae Biofuel Project like a real scientist.	❒	❒	❒	❒	❒
3. Participating in the Algae Biofuel Project will make me want to do research like a scientist.	❒	❒	❒	❒	❒
4. I will feel like a real scientist when I participate in the Algae Biofuel Project.	❒	❒	❒	❒	❒
5. I can ask a scientific research question.	❒	❒	❒	❒	❒
6. I can create a research hypothesis.	❒	❒	❒	❒	❒
7. I can design a scientific experiment.	❒	❒	❒	❒	❒
8. I can make observations and collect data.	❒	❒	❒	❒	❒
9. I can figure out what the data means.	❒	❒	❒	❒	❒
10. I can explain to others the results of the research.	❒	❒	❒	❒	❒

11. Explain the difference between renewable and nonrenewable resources.

12. What benefits are obtained from growing algae?

APPENDIX D: HOW DO YOU FEEL ABOUT SCIENCE?

There are some statements about science in this survey. You may agree with some of the statements and you may disagree with others. That is exactly what you are asked to do. By doing this, you will show how you feel about science.

After you have carefully read a statement, decide whether or not you agree with it. If you agree, decide whether you agree a little or a lot. If you disagree, decide whether you disagree a little or a lot. You may decide that you are unsure or cannot decide. Then, find the number of that statement on the answer sheet, and **CIRCLE** the:

1 if you **DISAGREE strongly** or a lot
2 if you **DISAGREE** a little
3 if you are **unsure**
4 if you **AGREE** a little
5 if you **AGREE strongly** or a lot

Please respond to each statement and **circle** only ONE letter for each statement.

	Strongly disagree	**Disagree**	**Unsure**	**Agree**	**Strongly agree**
1. Science is useful for the problems of everyday life.	1	2	3	4	5
2. I don't do very well in science.	1	2	3	4	5
3. I would like to do some outside reading in science.	1	2	3	4	5
4. Science is easy for me.	1	2	3	4	5
5. Most people should study some science.	1	2	3	4	5
6. Sometimes I read ahead in my science book.	1	2	3	4	5
7. I usually understand what we are talking about in science.	1	2	3	4	5
8. I feel uneasy when someone talks to me about science.	1	2	3	4	5

9. Science is of great importance to a country's development.	1	2	3	4	5
10. I would like a job which doesn't use any science.	1	2	3	4	5
11. I am good at doing science problems.	1	2	3	4	5
12. You can get along perfectly well in everyday life without science.	1	2	3	4	5
13. It makes me nervous to even think about doing science.	1	2	3	4	5
14. It scares me to have to take science.	1	2	3	4	5
15. I have a good feeling toward science.	1	2	3	4	5
16. If I don't see how to do a science problem right away, I never get it.	1	2	3	4	5
17. I would rather be given the right answer to a science problem than to work it out myself.	1	2	3	4	5
18. It is important to me to understand the work I do in science.	1	2	3	4	5
19. I have a real desire to learn science.	1	2	3	4	5
20. If I don't see how to do a science problem right away, I never get it.	1	2	3	4	5
21. No matter how hard I try, I cannot understand science.	1	2	3	4	5
22. I often think, "I can't do it," when a science problem seems hard.	1	2	3	4	5
23. It is important to know science in order to get a good job.	1	2	3	4	5
24. I enjoy talking to other people about science.	1	2	3	4	5
25. Sometimes I do more science problems than are given in class.	1	2	3	4	5
26. I remember most of the things I learn in science.	1	2	3	4	5
27. Science is something which I enjoy very much.	1	2	3	4	5

28. Solving science problems is fun.	1	2	3	4	5
29. There is little need for science in most jobs.	1	2	3	4	5
30. When I hear the word science, I have a feeling of dislike.	1	2	3	4	5
31. I would like to spend less time in school doing science.	1	2	3	4	5
32. Science is helpful in understanding today's world.	1	2	3	4	5

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